Periarticular Fractures After Total Knee Arthroplasty: Principles of Management

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Abstract

Periarticular fractures about total knee replacements are sustained by 0.3% to 2% of patients who have undergone knee arthroplasty. The patient with such a fracture is usually a woman in her seventh decade who has osteoporosis and may also have rheumatoid arthritis that is being treated with corticosteroids. The treatment of such fractures is aimed at restoring the patient's functional status to the prefracture level. Accomplishing this requires healing of the fracture and retention of a mobile and painless prosthesis in correct alignment. These goals are often difficult to achieve because there is little experience with these uncommon fractures, the healing environment is suboptimal, and knee arthroplasties have a low tolerance for any resulting alteration in alignment. In general, nondisplaced fractures are treated nonoperatively, and displaced fractures require open reduction, rigid internal fixation, and bone grafting. If the prosthesis is loose, or if rigid fixation cannot be obtained, component revision is the treatment of choice.

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Fracture about a total knee arthroplasty occurs in a small percentage of patients who have undergone knee replacement surgery. Because of the dearth of cases, compilation and analysis of series of these injuries is difficult. As the number of patients with knee arthroplasties increases and the population ages, however, most orthopaedic surgeons will eventually encounter this difficult problem. In this article, we will discuss predisposing conditions, review the literature regarding management, and present recommendations for evaluation and treatment.

Definition, Incidence, and Etiology

Periarticular fractures about a total knee arthroplasty have been defined by various authors as occurring 9 to 15 cm from the knee joint line.[1,2] These fractures occur in regions of stress concentration adjacent to a prosthetic component, and the presence of the prosthesis has a significant effect on fracture treatment.

Fractures about total knee replacements are uncommon. Reported incidences of supracondylar femoral fractures range from 0.3% to 2%.[2-5] These values were derived in different patient populations with various risk factors for fracture. Tibial periprosthetic fractures are even less frequent. The only published series was reported by Rand and Coventry,[6] who described 15 cases of medial tibial plateau stress fractures, which occurred an average of 45 months after geometric or polycentric knee arthroplasty. These fractures were most frequent in knees with axial malalignment (varus) and tibial-component malposition (anterior tilt). Successful treatment required revision.

The timing of such fractures has been reported to range from early in the postoperative period to more than a decade after surgery, with a mean of 2 to 4 years.[3,4,7-10] Most patients who sustain fractures about a total knee arthroplasty are women, usually in their seventh decade.[1,4,5] As with other supracondylar femoral fractures in the elderly, periprosthetic fractures tend to occur after low-energy trauma, such as a fall. Osteoporosis is often present as well and may be due to a number of factors, including stress shielding due to a rigid implant, pharmacologic causes, hormonal influences, and senility. An association with rheumatoid arthritis, especially when the patient is receiving oral corticosteroid treatment, has been noted.[3,4,8]

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Neurologic disorders have also been implicated in the occurrence of these fractures, due to either medication-induced osteoporosis or unsteady gait.[8] In addition, revision arthroplasty has been associated with an increased incidence of periprosthetic fractures.[5,9] This is more common when constrained implants are used, as they transfer applied torque more directly to bone that is potentially already deficient.

Numerous reports document an association between notching of the anterior femoral cortex and periprosthetic fractures. Aaron and Scott[3] and Figgie et al[4] each reported series in which fractures occurred in 40% of notched femurs. In a series of 61 periprosthetic supracondylar femoral fractures, Culp et al[1] found that 27 were associated with a notched anterior femoral cortex. Theoretical calculations presented in their report demonstrated that a 3-mm breech of the anterior femoral cortex created a 29.2% decrease in polar moment of inertia, thereby decreasing torsional stiffness of the femur. Ritter et al[7] disputed this association in a description of 670 knees, 138 (20.6%) of which had notching of 3 mm or greater; a periprosthetic fracture had occurred in only 1 of the latter at the 2- to 10-year follow-up. It is likely that fracture about a total knee arthroplasty is multifactorial in etiology and that in patient populations with other risk factors, notching of the femoral cortex adds to this risk. In any case, it is best avoided.

Anterior defects may be present without notching, such as in cases of cystic lesions of degenerative or rheumatoid origin near the proximal aspect of the anterior femoral flange.[11] Adequate remodeling may not be possible when cysts are filled with cement at the time of arthroplasty. These defects remain as permanent stress risers, which may predispose to fracture. Large anterior defects might be better managed during primary knee arthroplasty with bone grafting and protection of the distal femur with an intramedullary stem. Another recently recognized factor leading to late supracondylar femoral fracture is the presence of a massive debris-related osteolytic defect in the distal femur.[12] Such defects have been reported in association with asymptomatic well-fixed cementless femoral components.[13] Ankylosis of a total knee arthroplasty may also predispose to fracture by producing increased stress in the distal femoral metaphysis.

Treatment Goals

The major goal of treatment of periprosthetic fractures should be the restoration of the prefracture functional status of the patient. To accomplish this requires achievement of the following objectives: fracture union; preservation of prosthetic components without loosening, infection, and other complications; maintenance of appropriate prosthetic alignment; and restoration of joint range of motion. If fracture union can be achieved while maintaining proper alignment and ensuring component integrity, a 5- to 10-degree loss of motion may be accepted and in general should be expected. It is the need to meet all of these objectives that makes these fractures difficult to treat; if even a single goal is not achieved, the results of treatment will be suboptimal and may lead to failure of the prosthesis.

Fracture Evaluation

Appropriate treatment of periprosthetic fractures begins with a thorough evaluation, including a careful physical examination, a review of the patient's medical history, and adequate radiographic studies. The injured limb should be assessed for soft-tissue integrity and neurovascular status. The location of previous skin incisions must also be noted. In general, when multiple skin incisions are present, the lateralmost incision should be used in subsequent procedures to avoid problems with skin-flap necrosis. As patients with periprosthetic fractures are generally older and have associated health problems, a detailed medical evaluation may also be necessary, particularly if surgical treatment is planned.

A complete radiographic examination of a fracture about a total knee arthroplasty includes standard anteroposterior and lateral radiographs as well as long-leg views of the involved limb. Oblique images and tomography are also often useful. The surgeon's assessment of these radiographs should focus on fracture displacement and comminution, axial limb alignment, the quality of bone stock, the location of the fracture relative to the prosthesis, and the stability of the prosthesis. The presence of a total hip arthroplasty or other implant should be noted. A review of prefracture radiographs can provide important data regarding baseline limb alignment, implant fixation, and the presence of regions of osteolysis or polyethylene wear. Such factors are important considerations in the choice of treatment and may indicate revision rather than fracture fixation. The type and technical specifications of the implant and templates in place will influence the selection of a fixation device if open reduction is necessary.

Treatment Methods

Because fractures about knee arthroplasties are so uncommon, there are insufficient data from which to develop a definitive treatment algo-

rithm. However, the following general principles can be outlined.

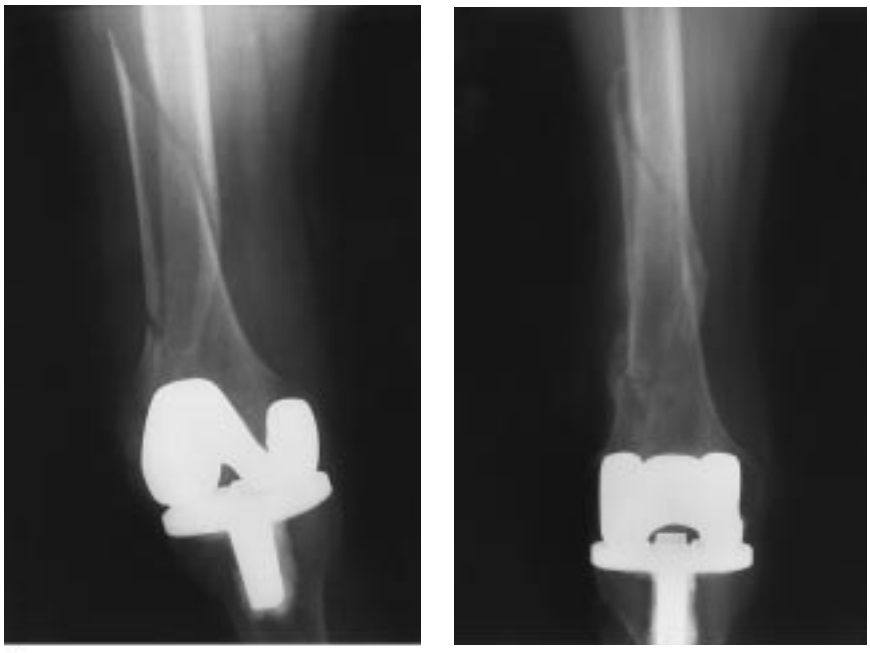
The first step in treatment is to establish whether the implant is loose. If so, even if the fracture is well aligned and heals, treatment that does not include revision will lead to a poor result. The determination of prosthetic stability may require, in addition to standard radiographs, tomography and comparison with prefracture radiographs. Prefracture malalignment, osteolysis, and polyethylene wear are important factors in the decision-making process. Treatment of a periprosthetic fracture may necessitate the exchange of a worn modular tibial polyethylene insert or a severely worn nonmodular tibial component.

The second step in treatment is identifying fracture displacement and deciding whether reduction is needed. Various recommendations have been given as to what constitutes acceptable fracture alignment about a knee prosthesis. The criteria described by Schatzker and Lambert[14] for supracondylar femoral fractures without prostheses are often cited. These include the following: less than 5 mm of translation, less than 5 to 10 degrees of angulation, less than 10 mm of shortening, and less than 10 degrees of rotational displacement.[1,14] Although these values provide a convenient general guide to the care of periprosthetic fractures, they should not be considered absolute. Any alteration in limb axis resulting from a fracture can result in altered loading of the prosthesis, which may, in turn, lead to enhanced wear and/or accelerated implant loosening. In three studies,[2,4,9] the early appearance of radiolucent areas, with progression to pain necessitating revision, was noted in more than 50% of cases in which periprosthetic fractures healed with varus angulation, compared with no such radiolucent areas when healing occurred with maintenance of limb alignment.

Nondisplaced fractures can be treated nonoperatively in a functional brace, with non-weight-bearing until fracture union, provided close attention is paid to alignment. Such a treatment regimen is often difficult due to the typical patient's advanced age and medical status, as well as the frequent multiple-joint involvement. If appropriate alignment can be preserved through fracture healing, however, such treatment can be expected to result in restoration of the prefracture status of the knee.[1,5] If an initially well-aligned fracture is comminuted, it may have an inherent tendency to fall into varus angulation, analogous to the progressive collapse of a casted distal radial fracture in osteopenic bone.

Periprosthetic fractures have a higher rate of nonunion than other supracondylar femoral fractures in the elderly. This has been attributed to premorbid alterations in vascularity at the fracture site due to previous surgery, the presence of a metal implant and intramedullary polymethylmethacrylate (PMMA), or long-term oral corticosteroid administration.[1] Therefore, these patients must be followed up closely, and further intervention should be undertaken if proper healing does not ensue.

The next step in decision making is determination of the appropriate treatment for a displaced fracture. In infrequent cases, such a fracture can be treated by closed reduction followed by functional bracing with close monitoring (Fig. 1). Even if reducible, however, these fractures are



A B

Fig. 1 **A,** Anteroposterior radiograph of the knee of a 63-year-old woman with corticosteroid-dependent rheumatoid arthritis who sustained a supracondylar femoral fracture 7 years after total knee replacement. **B,** The fracture was reduced by closed means and treated in a cast brace. Patient's ambulatory status and range of motion were maintained at their prefracture level.

generally not stable enough to allow motion. Cast treatment has often led to unacceptable outcomes, generally due to loss of motion, which Culp et al[1] reported to average 26 degrees.

Traction with range of motion, followed by functional bracing (once the fracture site has become adequately stable), has been reported to be successful in selected cases, with less loss of joint motion. For example, Merkel and Johnson[5] reported 92% satisfactory results in 26 fractures initially treated nonoperatively, with loss of less than 10 degrees of motion and an average change in tibiofemoral alignment from 6.8 to 1.3 degrees of valgus after treatment. However, 9 of these 26 fractures subsequently required operative intervention after initial treatment in traction. Other authors have reported significantly more problems with persistent pain, malunion, and nonunion after nonoperative treatment with traction than with surgical treatment. This has been attributed to the less than ideal environment for fracture healing and the low tolerance of prosthetic arthroplasties for the alterations in limb alignment that may result with such a treatment regimen.[1,2] The use of traction has also been associated with other complications, such as deep venous thrombosis and skin breakdown, which would be expected with any type of recumbent treatment in the elderly.[8]

In selected cases, an adequately reduced fracture can be stabilized with intramedullary fixation to avoid direct fracture exposure and additional soft-tissue traumatization. Hanks et al[15] reported good results without complications in three patients in whom a standard locked antegrade intramedullary nail had been used to stabilize fractures that were at least 8 cm proximal to the prosthetic joint line. Ritter et al[16,17] have reported on the use of flexible intramedullary nails inserted through a limited exposure. In a series of 22 fractures, followed for a mean of 7 years, 20 healed without complications in an average of 10 degrees of valgus angulation and achieved an average of 108 degrees of flexion.[17] Although this technique does not provide initial rigid fixation, it is attractive because it is minimally invasive and may therefore be of particular value in a significantly debilitated patient.

Retrograde insertion of reamed, closed-section stainless-steel intramedullary nails has been used for the treatment of supracondylar femoral fractures above total knee arthroplasties (Fig. 2). This technique allows fracture fixation through minimal incisions without direct fracture exposure. Fracture hematoma is not disturbed, soft-tissue stripping at the fracture site is avoided, and blood loss is reduced. Postoperative functional bracing is recommended to maintain correct axial alignment. A total of 15 cases in which this technique was used have been reported. All fractures healed without complications; however, there was no long-term follow-up in the three series.[18-20]

Fig. 2 Anteroposterior radiograph obtained after fixation of a supracondylar femoral fracture with an intramedullary supracondylar nail.

Antegrade intramedullary fixation requires preoperative assessment of the bone stock, which must be adequate distal to the fracture to allow fixation with two distal locking bolts. Retrograde intramedullary nailing requires similar planning, as well as the presence of a femoral component that will allow intramedullary access through the intercondylar notch. The overall excellent results noted to date suggest that retrograde nailing may be superior to plate fixation in properly selected cases. Further assessment of this technique with extended follow-up will be necessary to delineate the precise indications for its use, especially with regard to radiographic alignment.

Several early reports on the use of open reduction and internal fixation (ORIF) of periprosthetic fractures about total knee arthroplasties documented numerous cases of delayed union, nonunion, hardware failure, and union with deformity.[4,5,9] This paralleled initial attempts at ORIF of supracondylar femoral fractures that were not adjacent to prostheses, as in the report of Shatzker and Lambert,[14] which documented a satisfactory outcome in only 21% of patients in whom rigid fixation was not obtained. When rigid fixation is obtainable, however, ORIF provides the optimal treatment of displaced periprosthetic fractures in terms of returning patients to their prefracture functional status on a long-term basis (Fig. 3).[1,10,20]

Culp et al[1] reported an average of only 7 degrees of motion loss with a treatment regimen for periprosthetic fractures consisting of rigid fixation and early motion, which contrasted with their experience with nonoper-

Fig. 3 **Top,** Supracondylar femoral fracture in a 61-year-old woman with osteoarthritis 18 months after total knee arthroplasty. Uncomplicated healing followed ORIF with use of a dynamic condylar screw and side plate, autologous iliac crest bone grafting, and early motion. **Bottom,** Clinical and radiographic results were excellent at the 3-year follow-up examination.

ative treatment requiring immobilization. Healy et al[10] documented good results with ORIF of 20 periprosthetic supracondylar femoral fractures; alignment within 1 degree of prefracture alignment was maintained after healing. Zehntner and Ganz[21] treated eight fractures above total knee replacements with ORIF and achieved an average alignment of 5 degrees of valgus after union and an average knee flexion of 97 degrees. In a recent report limited to the treatment of fractures above posterior cruciate ligament–retaining condylar total knee replacements, Moran et al[11] found that ORIF of displaced fractures resulted in improved Knee Society scores, range of motion, and alignment compared with the results in cases treated nonoperatively.

If ORIF is planned, one must first decide which implant will be used for fixation. This will generally be a condylar buttress plate, blade plate, or condylar screw with side plate, the choice of which is often determined on the basis of the surgeon's preference and experience. The blade plate and condylar screw plate provide more rigid stabilization, but they may not be implantable because of the prosthesis configuration or the condition of the distal femoral bone stock (Fig. 4). Although simpler to insert, the condylar screw removes bone from a distal femur that is already potentially deficient. The condylar buttress plate is more versatile in terms of screw placement for distal fixation, but is less rigid. The proposed surgical procedure should be templated out to ensure appropriate postoperative alignment, as well as the ability to incorporate fixation hardware around the existing prosthesis.

A lateral surgical approach may be used for the fixation of periprosthetic supracondylar femoral fractures.[10,21] This approach allows direct exposure of the lateral femoral cortex when hardware is placed under fluoroscopic control. It also allows fracture fixation without the need for exposure of the knee joint.

An anterior midline approach can provide other advantages in the surgical management of these fractures.[2] First, there is no risk of skin-bridge necrosis with an anterior approach through a preexisting scar. Second, the anterior approach provides direct visualization of varus/valgus fracture alignment, which is of prime importance in the treatment of these fractures. Third, if revision must be performed because of unexpected looseness of the implant or inability to obtain adequate fixation, this is more readily accomplished via an anterior approach. Fourth, if dual plating is required to

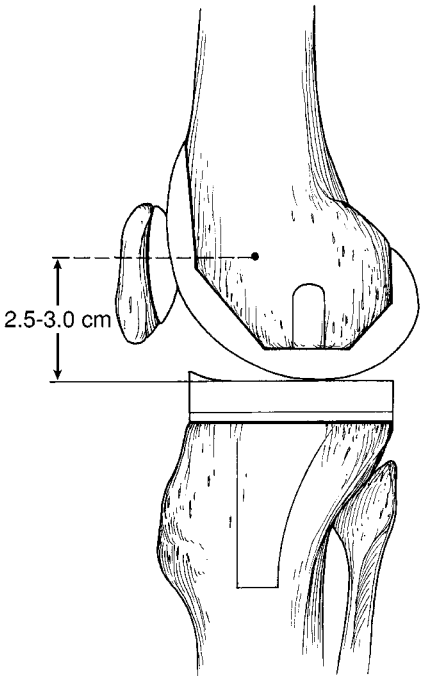


Fig. 4 Placement of a fixed-angle plate for ORIF of a periprosthetic supracondylar femoral fracture. The site of entry of the guide pin for the condylar screw or blade-plate chisel should be 2.5 to 3 cm proximal to the prosthetic joint line, centered in the anterior half of the lateral femoral condyle.

obtain stable fixation, this can also be readily accomplished via a single anterior incision.

During fracture fixation, PMMA may be used to enhance screw purchase in osteopenic bone without adverse effects on fracture healing.[14,21] Liquid cement is injected into screw holes after drilling and depth determination. The screw is inserted before cement polymerization to within a few millimeters of complete seating and is then fully tightened aften the cement has hardened. Alternatively, liquid PMMA can be placed in the bone and allowed to harden, after which drilling, tapping, and screw insertion can be carried out in routine fashion. Strong consideration should also be given to bone grafting in all cases in which ORIF is performed for periprosthetic fractures in an attempt to improve the healing environment (Fig. 5). If not otherwise contraindicated, autologous graft is preferred over allograft. Healy et al[10] have shown an average time to union of 11 weeks with autograft versus 17 weeks to union with allograft after ORIF of periprosthetic fractures. As rigid fixation is obtained, patients may be treated immediately with a program of range-of-motion exercise.

A loose implant is best treated with immediate revision. This will require the use of a long-stemmed component if the distal femur is to be preserved. During fixation of the new implant, care must be taken that cement is not introduced into the fracture site, which can present an impediment to union. The use of press-fit stems is recommended in such cases.

Replacement of the distal femur with an allograft is occasionally necessary. Kraay et al[22] reported satisfactory results in seven patients in whom distal femoral allografts and prosthetic revision were used to treat fractures that could not be rigidly fixed, whether because of bone deficiency, comminution, proximity to the prosthesis, or severity of osteoporosis. In all cases, follow-up revealed that alignment had been restored to 3 to 8 degrees of valgus, and the average range of motion was 96 degrees. Component revision, with use of allografts as necessary, may be the most prudent course of treatment in elderly patients, who often have multiple underlying medical or neurologic disorders and for whom recumbent treatment and multiple futile surgical procedures are to be avoided.

Fig. 5 **A,** Supracondylar femoral fracture sustained by a 63-year-old woman with corticosteroid-dependent rheumatoid arthritis after a minor fall approximately 10 years after total knee arthroplasty. **B,** Initial treatment consisted of ORIF with use of a dynamic compression plate and supplemental morselized femoral-head allograft. A cast brace was applied postoperatively, allowing early motion. **C,** Failure of fixation occurred 2 months postoperatively. **D,** Repeat ORIF was carried out with use of a dynamic condylar screw and side plate. Screw fixation was augmented with PMMA. Autologous iliac-crest bone graft was also placed at the original fracture site.

Complications

As with any fracture treatment, major early complications include nonunion and malunion, with the latter often leading to prosthetic loosening, pain, and revision. The rates of malunion and nonunion in three large series of patients available range from 20% to 70% for nonoperative treatment, and reasons for this have been reviewed.[1,4,5] With open treatment, acceptable healing depends on rigid fixation and the use of bone graft. Zehntner and Ganz[21] reported acceptable results and no complications in six typical patients with periprosthetic fractures in whom fixation was supplemented with PMMA when needed and bone grafting was utilized. With a similar approach, Healy et al[10] reported delayed union in 2 of 20 patients, in both of whom the fracture united after bone-grafting procedures. In contrast, Figgie et al[4] reported nonunions in 5 of 10 patients who underwent ORIF, two of which healed after bone grafting. Of the seven healed fractures in the series, five were in varus, and each developed a radiolucent area in the tibia at the bone-cement interface. Five failures of fixation occurred at the plate-bone interface, which might have been prevented by the use of cement and primary bone grafting. Adhering to the tenets of rigid fixation and the liberal use of bone grafting appear to be the keys to obtaining a successful result after ORIF of these injuries.

The treatment of delayed unions with bone grafting is possible, and is advocated if appropriate limb alignment and fracture fixation are maintained. In cases of deformity, early signs of prosthetic failure, or inability to secure rigid fixation, revision may be the most appropriate course of action.

The most devastating complication of operative care of these fractures is infection. In the series cited, deep infections developed in approximately 4% of patients who underwent operative fracture fixation, necessitating above-knee amputation in each case. It must be emphasized that the patients who sustain these fractures often have multiple medical problems and are taking corticosteroids, which decrease their immunocompetence. Therefore, a careful preoperative medical evaluation is necessary so that treatable risk factors for infection, such as remote sites of sepsis and nutritional deficiencies, can be identified. The diligence used in decision making and planning must also extend to meticulous surgical technique to maximize host resistance to infection.

Summary

Fractures about total knee arthroplasties, although uncommon, have the potential for disastrous results. Affected persons are generally elderly women with osteoporosis who often have other underlying medical, neurologic, or rheumatologic conditions. Treatment goals include maintaining a well-fixed, appropriately aligned, mobile, and painless arthroplasty and restoring the patient's prefracture functional status. To accomplish this, diligence is required throughout the evaluation and treatment of these injuries. If healing in appropriate alignment with maintenance of joint motion will not be possible, immediate revision should be considered.

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