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Periprosthetic Fractures after Total Knee Arthroplasties

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The management of periprosthetic fracture around the knee remains a challenging problem. The objective of this article was to review the general concepts, treatment algorithms, and the overall treatment outcomes of femoral and tibial periprosthetic fractures after total knee arthroplasty. This article aimed to highlight the deficiencies of the current classification systems that fail to provide a guideline for selection of appropriate treatment options. We proposed a new classification system for periprosthetic femoral fractures that takes into account the status of the prosthesis, the quality of distal bone stock, and the reducibility of the fracture. Type I fractures are those occurring in patients with good bone stock with the prosthesis being fixed and well positioned. Type IA fractures are either nondisplaced or easily reducible and can be treated conservatively. Type IB fractures are irreducible and require reduction and internal fixation. Type II fractures are defined as those occurring also in patients with good bone stock and being reducible, but either the components are loose or malpositioned. These fractures are treated by revision arthroplasty. Type III fractures are reducible or irreducible fractures that occur in patients with poor bone stock and in the vicinity of loose or malpositioned components. These fractures are treated by distal femoral replacement.

Level of Evidence: Therapeutic study, level V (expert opinion). See Guidelines for Authors for a complete description of levels of evidence.

There are more than 400,000 total knee arthroplasty (TKA) procedures performed in the United States annually. This number is expected to double over the next decade (National Hospital Discharge Survey 2002, Data obtained from U.S. Department of Health and Human Services). More periprosthetic fractures around the knee are expected to occur because of the increase in TKAs, the increased survivorship of the elderly with TKAs, and the increased activity of patients after TKA.[3,9,11,12,38] Periprosthetic fractures after TKA can involve the femur, tibia, or patella. The majority of the periprosthetic fractures after TKA are in the supracondylar region of the femur.[3] Periprosthetic fractures can also occur intraoperatively. Based on the fracture morphology, various host factors, and the timing of fracture, a number of treatment options are available to treat this rare, yet complex problem.[4,11–13,16–20,37,38]

The treatment of periprosthetic fractures around the knee can be challenging for a number of reasons: (1) these fractures occur in patients with poor bone stock that can compromise potential fixation; (2) the majority of these patients are elderly and by virtue of their age may have retarded fracture healing; and (3) the attachment of the ligamentous structures to the fracture fragment may predispose these knees to potential instability and necessitate the use of constrained prostheses with all their potential problems.[1,4,7,11,16,34] Despite these complications, the ultimate goal of a painless, well aligned knee with functional range of motion may be attained in a large number of these.

Our aim was to discuss various treatment options, propose a new classification and treatment algorithm for management of periprosthetic fracture of tibia and femur around total knee arthroplasty. All pertinent published studies relevant to the subject were reviewed and a synopsis of relevant articles were cited. Patellar fractures after TKAs will be discussed elsewhere in this symposium.

Incidence

The overall incidence of periprosthetic fractures after TKA is not well known. The majority of the reports pertain to supracondylar fracture of the femur, the most common type of periprosthetic fracture around the knee.[16,18,27,31,35] The overall incidence of periprosthetic fracture of the dis-

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tal femur ranges from 0.3–2.5% after primary surgery and 1.6–38% after revision surgery.[16,18,27,31,35] Berry reported an approximate 2% incidence for periprosthetic fractures after TKA using data from the Mayo Clinic Joint Registry.[3] Of these fractures, 0.1% involved the femur and occurred intraoperatively during primary surgery, and 0.9% of femoral fractures occurred during revision arthroplasty. The incidence of intraoperative periprosthetic fracture is likely to be underestimated as some of these fractures may go undetected, and others with minimal displacement may not require further intervention.[11] Felix et al[12] reported on the incidence of tibial fracture around knee prosthesis in 17,727 TKAs performed at the Mayo Clinic. They reported a 0.1% occurrence of intraoperative and 0.4% postoperative tibial periprosthetic fractures.[12] The incidence of tibial periprosthetic fracture was higher after revision TKA.[12]

Risk Factors

Periprosthetic fracture after TKA can occur in any patient. However, several predisposing factors have been identified, the most important of which relates to osteopenia.[11,17] A number of conditions may lead to poor bone stock including old age, chronic use of corticosteroids, and rheumatoid arthritis (RA).[3,6,8,11,16,17,27] Other conditions include the presence of stress risers such as screw holes around the knee, local osteolysis, stiff knee, and anterior femoral notching.[2,5–8,11,13,17,22,27] Patients with neurological abnormalities such as epilepsy, Parkinson's disease, cerebellar ataxia, myasthenia gravis, poliomyelitis, cerebral palsy, or undefined neuropathic joints are also at risk of periprosthetic fractures around the knee.[8] No clear relationship between postoperative component malalignment and subsequent periprosthetic femoral fracture has been identified.[27] However, marked varus malalignment of the tibia is thought to be a potential etiological factor in tibial periprosthetic fractures.[24,30] More tibial periprosthetic fractures than supracondylar femoral fractures are likely to occur in the presence of component loosening.[24,30]

Types of Periprosthetic Fractures

Intraoperative femoral fracture can be divided into two groups: diaphyseal and metaphyseal fractures. Diaphyseal femoral fractures (usually anterior or anterolateral cortical penetration) occur because of malpositioning of the intramedullary (IM) guide. The majority of these fractures may go undetected intraoperatively and are only noted during postoperative radiographic surveillance.[11,23] The metaphyseal region of the femur may also experience fractures intraoperatively. These fractures are intercondylar splits or complete fracture of one or two condyles. These fractures can occur with some frequency in patients with preexistent osteopenia. Technical factors such as improper bone cuts, aggressive impaction of boxed posterior stabilized femoral component, and eccentric insertion of the trial component (particularly during revision surgery) are likely to contribute to this problem.[23]

Because of the strong, dense nature of the proximal tibia, intraoperative periprosthetic tibial fracture is rare.[12] However, intraoperative tibial fractures do occur and are more common in revision surgery than in primary surgery.[12] Some factors resulting in tibial periprosthetic fracture include forceful retraction of well fixed tibial component, eccentric cement removal, aggressive impaction of tibial component, and performing tibial tubercle osteotomy.[12] Theoretically, posterior stabilized knees are more vulnerable to intraoperative tibial fracture than cruciate retaining knee system. These fractures usually occur during impaction of posteriorly oriented tibial component with stem, are vertical in pattern, and are often undisplaced.[11] Cortical penetration around the tibia can also occur because of eccentric preparation of the canal.[11]

The most common and challenging periprosthetic fracture after TKA is supracondylar femoral fracture, which usually occurs in the distal ⅓ (15 cm) of the femur. These fractures are generally the result of low energy trauma.[16] The fracture may be more proximal in patients with a stemmed femoral component when the forces are transmitted to the tip of the stem or a region proximal.[34] Rorabeck and Taylor[34] proposed a classification for supracondylar femoral periprosthetic fracture that considered fracture displacement and fixation status of the femoral component. Three types of fracture were defined: Type I fracture was undisplaced; Type II fracture had displacement of greater than 5 mm or greater than 5° of angulation without component loosening; and Type III fracture was a supracondylar fracture with loosened component regardless of fracture displacement.[34] We proposed a new classification system for femoral periprosthetic fractures. The most important factors include the amount of bone (volume and density) in the distal fracture fragment, the position and the fixation status of the component, and the fracture reducibility (Table 1). Based on this classification there are three types of fractures. Type I fractures occur in patients with good bone stock with the prosthesis being fixed and well positioned. Type IA fractures are either non-displaced or easily reducible and can be treated conservatively. Type IB fractures are irreducible and require reduction and internal fixation(Fig 1). Type II fractures are reducible fractures with adequate distal bone, but with a malpositioned or a loose component. These fractures are treated by revision of the component to a long stem component (Fig 2). Type III fractures are severely comminuted fractures with inadequate distal bone for fixation or support of a conventional component (Fig 3). These fractures

TABLE 1. New Classification for Postoperative Periprosthetic Femoral Fractures

Type	Fracture Reducible	Bone Stock in Distal Fragment	Component Well Positioned and Well Fixed	Treatment
IA	Yes	Good	Yes	Conservative
IB	No	Good	Yes	Surgical fixation
II	Yes/No	Good	No	Revision with long stem component
III	Yes/No	Poor	No	Prosthetic replacement

are best treated with prosthetic replacement (distal femoral replacement).

Although periprosthetic tibial fractures occurred relatively frequently with the earlier total knee systems,[24,30] these fractures are now quite rare because of the use of keeled or short stem tibial components.[24] Theoretically the standard use of keeled stem and presence of an intact fibula allow the tibia to withstand torque and shear forces, conferring a mechanical advantage for these fractures over the femoral fractures. Felix et al[12] reviewed 102 tibial periprosthetic fractures and classified them based on the anatomical location and component fixation. Four types of fractures were defined (Table 2).[12] Type I fractures were most common and occurred at the tibial plateau.[12] They were thought to be stress fractures resulting from varus malalignment or loosening of the tibial component.[12] This type of fracture occurred more commonly with the early design of total knee systems without a tibial keel or stem.[12] Type II fractures occurred around the prosthetic stem as a result of trauma and were the second most common.[12] The presence of extensive osteolysis was thought to be critical to induce this type of fracture.[12] Type III fractures occurred distal to the component and did not result in component loosening.[12] Type IV fractures were defined as those involving the tibial tuberosity and were noted to be extremely rare.[12]

Treatments Options

If cortical disruption of the femoral shaft is identified during surgery, then a stemmed prosthesis with or without bone graft is the best option for treatment.[11] The stem should bypass the cortical penetration by at least two femoral canal diameters. If the fracture is detected following fixation of the component or recognized on postoperative radiographs, then protected weightbearing for 6–8 weeks may be all that is required until the cortical disruption heals.[11] Femoral metaphyseal fractures are usually vertically oriented, and are nondisplaced with an intact periosteum.[23] These fractures can also be treated with protected weightbearing without additional intervention. The rare but displaced intercondylar fractures, or single condyle fracture with displacement, should be treated by the addition of an IM stem to the femoral component and transcondylar screw fixation.[11,23,27] Engh and Ammeen[11] reported the use of a single screw fixation for these fractures with good results. Screw usage may occasionally be precluded because of poor bone quality when the screw fails to obtain sufficient bone purchase. During these circumstances, a nonabsorbable strong suture material such as Dacron tape (Genzyme, Rivercity, ME) may circumferentially support the fracture. When necessary, stemmed components should be inserted press fit across the fracture site to prevent extrusion of the cement into the fracture and disruption of healing. All patients with periprosthetic fracture should be given instruction for protected weightbearing on the operated extremity until the fracture heals.

The majority of the intraoperative tibial periprosthetic fractures involve the plateau region and are usually nondisplaced.[11,12] These fractures can be managed by protected postoperative weightbearing.[11,12] In patients with a displaced fracture, additional fixation such as cancellous screws may be required to stabilize the fracture. Tibial cortical disruption or fractures distal to a well fixed component may be managed by cast immobilization with protected weightbearing.[12]

Postoperative periprosthetic femoral fractures are most common in incidence but their severity differs. The exact location of the fracture, the fixation status of the component, host bone quality, and the degree of fracture displacement are some of the most important factors that determine the treatment strategy.[13,20,24,25,27,36,42]

A stable fracture with minimal displacement with good host bone stock and a well fixed and well aligned component (Type IA) can be treated nonoperatively in cast or brace immobilization with protected weightbearing.[5,13,17,27,39] Close radiographic surveillance is mandatory to ensure satisfactory progression. In the event of fracture displacement or loss of alignment then surgical intervention may be necessary.

Displaced and irreducible supracondylar fractures with adequate distal bone stock (Type IB) almost always require operative intervention as nonoperative management is likely to fail.[5,7,8,27] The action of the muscles around the knee usually forces the distal fracture fragment into a

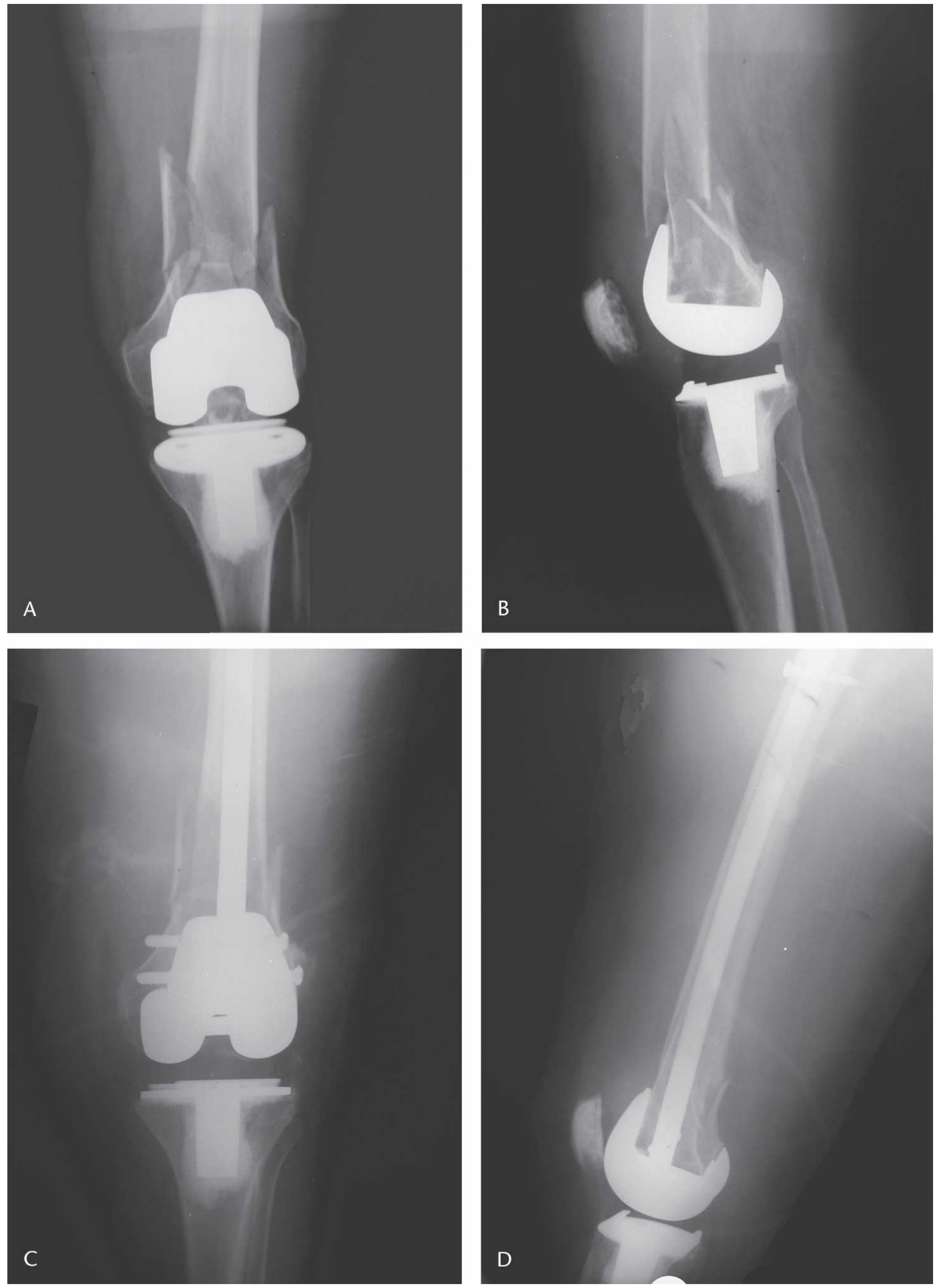

Fig 1A–B. (A) Anteroposterior and (B) lateral radiographs show a patient with supracondylar femoral fracture. (C, D) Closed reduction and fixation using a retrograde intramedullary nail was performed because there was adequate bone in the distal fragment, along with good component positioning and fixation.

varus adduction and internal rotation displacement.[13] The objective of the surgical intervention is restoration of limb length, anatomical alignment, and allow early mobilization of the knee. There are a wide variety of orthopaedic devices that may be utilized for fixation of these fractures including angled blade plates (ABP), dynamic condylar screws (DCS), cobra plates, and flexible or rigid retrograde IM nails.[1,13,15–17,25–29,32,36,38,42] In recent years locking periarticular plates such as Less Invasive Surgical Stabilization® (LISS, Synthes Corporation, Paoli, PA) system have become a popular treatment option.[1,10,21] Multiple fixed angle screws facilitate optimal fixation around the fracture site and the component.[21] Kregor et al[21] described the advantages of these plates including maintenance of distal fixation, low incidence of infection, and low need for bone grafting with favorable results in 11 supracondylar fractures treated with LISS system. The major advantage of the locking devices relate to the ability to implant these devices with minimal soft tissue dissection and periosteal stripping. Rigid retrograde IM nails are also

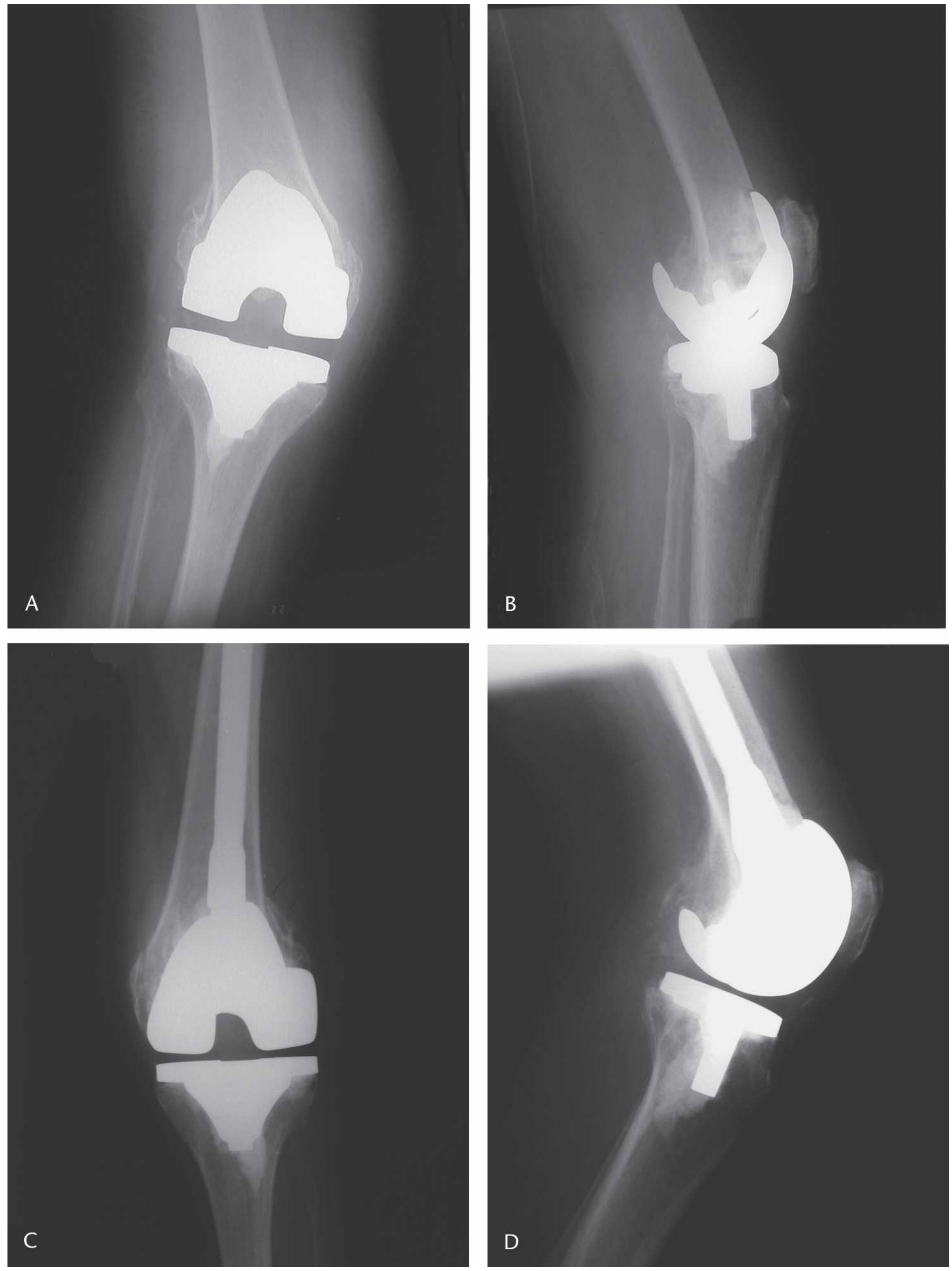

Fig 2A–B. (A) Anteroposterior and (B) lateral radiographs show a distal femoral fracture. The femoral component was found to be loose and was revised. (C, D) A long stem component was cemented to the metaphysis and press fit into the diaphysis.

invaluable devices for treatment of femoral periprosthetic fractures. These devices should be employed liberally for patients with adequate distal fracture fragment and an open box femoral component.

Although no single device offers universal superiority, the ABP is the preferred method of plate fixation.[16] Theoretically, the ABP plate provides more secure impaction of the blade in the distal femoral cancellous area than the DCS, which requires a larger volume of bone for positioning of the lag screw. Because of the presence of femoral prosthesis, proper positioning of the lag screw in the distal fracture fragment is often difficult. Further augmentation of the fixation may need to be performed.[16,42] Techniques for augmentation include the use of impacted cancellous bone graft, extramedullary strut allograft, methylmethacrylate bone cement, and supplemental fixation with an interfragmentary compression screw.[14,20,41,42]

An increasingly popular method for fixation of supracondylar uses load sharing IM nail devices. Flexible IM nails have mostly been abandoned because of their inability to provide adequate rotational stability.[5,32] Rigid retrograde femoral nails are the preferred method of fixation

Fig 3A–B. (A) Anteroposterior and (B) lateral radiographs show a supracondylar periprosthetic fracture in an 82-year-old woman. (C, D) A distal femoral replacement was performed because of the high degree of comminution and poor bone quality.

for supracondylar fractures with large enough distal fracture fragment to allow insertion of a locking screw.[25,26,28,33,36,38] The advantages of IM fixation are the relative sparing of the fracture region, minimal soft tissue dissection, and periosteal stripping.[28,29,38] However, it does require an arthrotomy with the potential for introduction of infection to the joint, and can only be performed for cases with large distal fragment. A further limitation of this technique is that IM nail cannot be used in patients with a closed box femoral component in place.[11] Some authors have reported perforation techniques for the closed box utilizing a metal cutting burr to allow insertion of the

TABLE 2. Classification of Postoperative Periprosthetic Tibial Fractures

Major Anatomic Pattern	Subcategory
I. Tibial plateau	A. Well fixed prosthesis
II. Adjacent to stem	B. Loose prosthesis
III. Distal to prosthesis	C. Intraoperative
IV. Tibial tubercle	

Reproduced with permission from Felix NA, Stuart MJ, Hanssen AD. Periprosthetic fractures of the tibia associated total knee arthroplasty. *Clin Orthop Relat Res.* 1997;345:113–124.

IM nail.[25,26] The latter carries the potential problem of introducing metal debris into the joint and the subsequent third body wear. There are a few reports on the use of external fixation for managing these fractures with variable results.[8,13,27,37] In general, external fixation for treatment of these fractures is not popular because of the problems with tethering of quadriceps muscles, limitation imposed for knee ROM, and the risk of propagation of pin track infections into the joint space.[8,13] The only exception is when extremely poor bone quality precludes the use of internal fixation.[37]

Type II fractures are defined as those occurring also in patients with good bone stock and being reducible, but either the components are loose or malpositioned. These fractures are treated by revision arthroplasty using an uncemented long stem component with fracture fixation; both performed under the same anesthesia. The result of revision TKA under these circumstances is variable.[7,8,19,26] This treatment option is for fixation of a highly comminuted fracture in patients with poor bone stock, and can be extremely challenging.

A supracondylar fracture that is a reducible or an irreducible fracture with poor distal bone stock and in the vicinity of loose or malpositioned components (Type III) is very difficult to treat. One of the treatment options for patients with a loose femoral component and poor bone stock is the use of distal femoral replacement. The distal femoral replacement can be performed with relative ease, expediency, and is best suited for elderly or sedentary patients.[20] Because of the potential problem with loosening of the constrained prosthesis, other treatment options may need to be considered in younger patients. The objective of treatment is preserving bone stock. Two options may be considered. The first is resection arthroplasty and an attempt for fracture fixation with delayed reimplantation. The major problem with this option is the need for prolonged immobilization of the knee, imposing functional limitations on the patient, and the potential for subsequent stiffness. Patients also require a delayed surgery. The second option is the use of allograft-prosthetic composite (APC).[41] The advantages of the latter option are single surgery, early mobilization, reduced morbidity, and lower incidence of postoperative stiffness.[13,14,20] Problems related to the use of APC include higher incidence of infection, graft resorption, loosening of the components, and the technical demands of the procedure. Occasionally custom made femoral components which incorporate the use of long-stems with transfixing screws for bicortical fixation may be employed.

There is no clear treatment protocol for the management of postoperative tibial fractures because of their relative rarity.[12,40] Fractures with a loose and/or malpositioned stem and displacement generally require surgical intervention.[11] For Type I fractures, revision TKA is generally recommended as tibial component is likely to be in varus malalignment.[30] The use of metal or bone augmentation of the (medial) tibial plateau defect is also usually necessary.[30] In Type II fractures with well fixed component and minimal displacement, nonoperative management is generally recommended.[12] Revision surgery utilizing long stem component is required for patients with displaced fracture or loose component.[30] On occasion, structural allograft or tumor prosthesis may be needed for patients with extensive bone loss.[14] In Type III fractures with a stable component, fracture reduction with or without internal fixation may be required.[12] The rare type IV fractures are treated with open reduction and internal fixation and treatment of the osteolytic defect, which may have led to the generation of the fracture, with appropriate bone grafting techniques.

Treatment Outcome

There is very little published on the outcome of treatment of intraoperative periprosthetic fractures. Lombardi et al[23] reported the treatment outcomes for intraoperative intercondylar fracture of the femur in 41 knees. The fracture was recognized at the time of surgery in six patients (15%) and detected on postoperative radiographs of the knee in 35 knees (85%).[23] The recognized intraoperative fractures were managed with screw fixation or the use of long stem prosthesis with no adverse consequence.[23] The fractures detected postoperatively were treated with protected weightbearing and routine physical therapy.[23] These fractures also healed without any problems.[23]

There are several reports regarding the outcome of nonoperative treatment of nondisplaced supracondylar fractures with a union rate ranging from 65–100%.[6,17,27] Chen et al[6] reviewed 195 combined cases reported in the literature reported that nonoperative treatment showed a satisfactory result in 83% of Type I fractures and in 67% of Type II fractures. The results of using flexible IM nails (Rush and Enders nails) have been variable.[15,26,32] Although positive outcome has been reported by some,[32] nonunion and malunion of the fracture as well as malalignment of the tibiofemoral angle have been encountered in almost all series.[5,15,32] The outcome of supracondylar periprosthetic fractures using plate and screw fixation, though better than flexible nailing, has also been variable.[7,8,13,16,42] Some authors have reported excellent outcomes after such intervention,[8,16,42] while others have reported 30–100% failure rates after using plate and screw fixation.[7,13] Complications such as nonunion, malunion with varus angulation, implant migration, infection, and limb shortening have also been encountered after plate and screw fixation.[7,13] Bezwada et al[4] in a comparative study reported a superior outcome with the use of retrograde IM nails than plate and screw fixation for supracondylar periprosthetic fractures. Other reports have also reported excellent results after using retrograde IM nail for fixation of supracondylar periprosthetic fractures.[11,26,28,29,33] Some surgeons have reported the use of bone graft or bone cement to augment the fracture fixation.[11,26,28,33] Complications such as nonunion, rod migration into the knee joint, knee stiffness, infection, and limb shortening have also been observed after using IM nails.[29]

There are few reports on the results of external fixation for managing supracondylar fractures, and the results are variable.[8,13,27,37] Although successful outcome with the use of this fixation technique in three patients has been reported,[27,37] most studies show a high complication rate.[8,13] Various studies have reported on the outcome of simultaneous revision arthroplasty and fracture stabilization using a long stemmed prosthesis.[7,8,19,26] McLaren et al[26] found satisfactory outcomes in 24 of 25 patients undergoing revision arthroplasty for periprosthetic fractures using long stemmed prosthesis. In another study, the use of custom made prostheses resulted in an excellent outcome for all seven patients.[19] Revision arthroplasty for acute fractures allows early ambulation, faster recovery, and possibly better functional outcome and ROM.[8] There are a few reports evaluating the outcome of APC for management of periprosthetic fracture around the knee.[11,13,14,20] Kraay et al[20] reported seven patients who required large segment distal femoral allograft with a nonlinked total knee prosthesis. Although most patients' results were satisfactory, only two allografts incorporated with the host bone. Two patients required knee bracing at the time of last followup because of persistent instability.

Reconstructive and trauma surgeons are likely to encounter an increasing number of periprosthetic fractures after TKA. Although the management of these complex cases can be technically demanding, the majority of patients have an acceptable outcome.[4,5,7,14,16,19,20,26,38,41,42] The major challenge in the treatment pertains to the severely compromised bone quality that caused the fracture. A delicate balance between biology (fracture healing) and mechanics (fracture fixation) influences the outcome. Conventional fracture fixation techniques may need to be modified because of the severe osteopenia in most of these patients.[10,14,19,20,36,41,42]

Surgeons managing these fractures must be aware of their complexity, and should always have alternative treatment strategies available in the operating room if the initially planned treatment cannot be performed. The use of distal femoral replacement or proximal tibial replacement should be reserved for sedentary and elderly patients with limited demand on the prosthesis. These prostheses are likely to fail early in young, active patients. Even if the bone stock is poor in quality, preservation efforts should be exercised in young patients.

The main goals of functional restoration and a painless joint can be achieved in the majority of patients with a periprosthetic fracture after TKA. All efforts to prevent this undesirable complication should be made. Appropriate bone cuts, proper positioning, gentle impaction of the components, meticulous care during extraction of the components and cement, and avoiding stress risers should be exercised. Referring patients with poor bone stock for possible intervention should always be considered.

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