Recent Advances and Developments in Knee Surgery: Principles of Periprosthetic Knee Fracture Management

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Abstract: The management of distal femoral, tibial and patellar fractures after total knee arthroplasty can be complex. The incidence of these fractures is increasing as the number of total knee arthroplasties being performed and patient longevity is increasing. There is a wide range of treatment options including revision arthroplasty for loose implants. This review article discusses the epidemiology, risk factors, classification and treatment of these fractures.

Keywords: Femur, knee arthroplasty, patella, periprosthetic fractures, supracondylar, tibia.

INTRODUCTION

Periprosthetic fractures following total knee arthroplasty may occur at the supracondylar region of the distal femur, proximal tibia or the patella. They may be difficult to treat and are associated with significant morbidity. The existing implant may obstruct attempts at reduction and fixation. If the existing implant is loose, revision arthroplasty may be required. The incidence of periprosthetic fracture is increasing as patients are living longer, have greater activity levels and have a higher rate of revision arthroplasty which is associated with increased risk of periprosthetic fracture as a result of bone loss from the revision procedure. This article reviews the basic concepts of periprosthetic factors following total knee arthroplasty and discusses the literature on management of these fractures [1, 2].

Epidemiology

More than 300,000 total knee arthroplasties are carried out annually in the United States [1]. The incidence of periprosthetic fractures following total knee arthroplasty is up to 5.5 % [1, 3, 4]. Supracondylar femur fractures are the most common type of periprosthetic fracture following total knee arthroplasty. The Mayo Clinic Joint Registry reported an approximately 2 % incidence of periprosthetic knee fractures, of which 0.1 % of femoral fractures occurred intraoperatively during primary surgery and 0.9 % of femoral fractures occurred during revision arthroplasty [1]. Intraoperative fractures may occur and may be undetected if only minimally displaced and may not be reported if they do not require intervention. The incidence of periprosthetic supracondylar femur fractures has been reported as ranging from 0.3 to 2.5 % following primary total knee arthroplasty and from 1.6 to 38 % after revision surgery. Periprosthetic proximal tibial fractures are less common. A series of over 17,000 total knee arthroplasties reported by the Mayo Clinic showed an incidence of periprosthetic tibial fracture following total knee arthroplasty of 0.1 % intraoperatively and 0.4 % postoperatively. The incidence of patella fracture following total knee arthroplasty has been reported as being between 0.2 and 21 % in resurfaced patellae and 0.05 % in unresurfaced patellae [1,2]. A review of 12,462 consecutive total knee arthroplasties at the Mayo Clinic reported a prevalence of patellar fracture following total knee arthroplasty as 0.68 %. 44% of the fractures were asymptomatic or minimally symptomatic. Most of these were identified on routine follow-up radiographs. 82% of patellar periprosthetic fractures were discovered within three years [5].

Risk Factors

Many periprosthetic fractures following total knee arthroplasty occur after traumatic events. Numerous patient and surgical factors predispose patients to developing these fractures. A significant patient factor that is associated with an increased risk of periprosthetic knee fracture is osteopenia [6]. Osteopenia is associated with advanced age, chronic corticosteroid use, rheumatoid arthritis and female sex. Poor bone stock may also occur secondary to stress shielding. Other patient factors include neurological disorders such as epilepsy, Parkinson’s disease, cerebellar ataxia, myasthenia gravis, poliomyelitis, cerebral palsy and other undefined neuropathic joints [1, 6, 7]. Patients with knee flexion greater than 95 degrees generate increased patellofemoral compression forces and frequently have higher activity levels, potentially predisposing to fracture [8]. Conversely, a stiff knee may be associated with mechanical stress-risers at the knee [1].

Meticulous surgical technique is essential to avoid periprosthetic fracture [7]. Intraoperative fracturing is more likely to occur during component removal, bone retraction, trial reduction or preparation for insertion of stemmed components. Screw holes or anterior notching of the distal femur increase fracture risk by creating mechanical stress-
risers at or around the knee. 40 to 52% of reported fractures of the distal femur are associated with an anterior notch [8]. If an anterior notch of the distal femur is created intraoperatively, the surgeon should consider implantation of the femoral component with an attached diaphysis-engaging system to support the weakened distal femur. Axial malalignment and component malposition has been shown to be associated with an increased risk of tibial fracture. Component loosening and knee instability also increase the risk of fracture [8].

Biomechanical studies have demonstrated that contact forces substantially increase the patellofemoral malalignment. The eccentricity and magnitude of patellofemoral loads increase with patellar subluxation increasing the risk of patellar fracture. Excessive insufficient or asymmetric patellar resection, disruption of the patellar blood supply resulting in avascular necrosis increase the risk of patellar fracture. Thermal necrosis of bone due to the heat of polymerisation of cement predisposes to fracture. Additionally, an increased risk of patellar fractures has been associated with certain patellar component designs such as metal-backed uncemented patellae or components with large central pegs [1, 7, 8].

**Classification**

A number of classifications for periprosthetic fractures following total knee arthroplasty exist. The classification of periprosthetic supracondylar fractures by Rorabeck is commonly used and takes into account the displacement of the fracture and the stability of the prosthesis. A Type I fracture refers to an undisplaced fracture with an intact bone-prosthesis interface. A Type II fracture refers to a displaced fracture with an intact bone-prosthesis interface. A Type III fracture refers to either a displaced or undisplaced fracture with a loose or failing prosthesis [6, 8, 9].

Felix et al. classified periprosthetic tibial fractures into four types based on the anatomic location and proximity to the prosthesis as well as the status of the prosthetic fixation. Type I fractures occur at the tibial plateau. Type II fractures occur adjacent to the prosthesis stem. Type III fractures occur distal to the stem. Type IV fractures involve the tibial tubercle. The fracture types are further classified according to whether the prosthesis was well fixed (A) or loose (B) based on radiographic appearances and whether the fracture occurred intraoperatively (C) [8, 10].

The Goldberg classification of patellar fractures following total knee arthroplasty consists of four types and takes into account the stability of the implant fixation, the status of the extensor mechanism, the location of the fracture and the presence of dislocation. Type I refers to fractures through the mid-body or superior pole of the patella not involving the implant, cement or quadriceps mechanism. Type II fractures involve the implant/bone/cement composite and/or the quadriceps mechanism. Type III refers to the inferior pole fractures and is subdivided into Type IIIA, which occurs with patellar ligament rupture and Type IIIB which occurs without patellar ligament rupture. Type IV refers to fracture-dislocations [11].

**TREATMENT OF SUPRACONDYLAR PERIPROSTHETIC FRACTURES OF THE FEMUR**

**Nonoperative Treatment**

Nonoperative options include skeletal traction, application of a cast, pins and plaster and cast bracing followed by protective weight bearing and range of motion exercises. The advantages of nonoperative treatment are that it is noninvasive and the infection rate is negligible. Nonoperative management is generally recommended for stable, minimally displaced fractures with good bone stock and a well-fixed and well-aligned component (Type IA). Non-operative treatment is best reserved for nondisplaced fractures that do not demonstrate intercondylar extension. Disadvantages of non-operative treatment are the relatively high rate of malunion and functional loss particularly in patients with displaced fractures. Maintenance of reduction of displaced fractures is particularly difficult when there is associated osteopenia and comminution. Non-operative treatment often requires immobilization which leads to loss of motion and reduced walking capacity. Radiographs must be monitored closely and frequently [7, 8].

Several studies have looked at outcomes of nonoperative treatment of supracondylar periprosthetic fractures and have shown varying results. Chen et al. reviewed the literature and reported on 195 periprosthetic supracondylar fractures in twelve published studies. They revealed satisfactory results in 83% of patients with type I fractures that were treated nonoperatively. They found satisfactory results in 64% of patients with Type II fractures treated nonoperatively [12]. A literature review by Harlow and Hoffman of 142 supracondylar periprosthetic fractures treated nonoperatively found that 29% of these fractures eventually required operatively treatment [8]. Culp et al. reviewed sixty-one supracondylar periprosthetic knee fractures. Of the thirty cases treated nonoperatively, 50% had increased pain levels or a change in ambulatory status, compared to only 13% of patients treated operatively [13]. A review by Merkel and Johnson showed that 35% of patients (9 out of 26) with supracondylar periprosthetic knee fractures treated nonoperatively required revision arthroplasty because of non-union, malunion, loosening of the components and extensor lag. Despite this, they recommend conservative management and concluded that patients who have a poor arthroplasty result after nonoperative treatment of the fracture can usually undergo a revision arthroplasty with the expectation of a satisfactory result [14].

**Operative Treatment**

Surgical intervention has the advantage of facilitating early mobilisation and so may be considered in healthy or active patients regardless of the fracture pattern. Displaced fractures with adequate bone stock generally require operative treatment as there is a high prevalence of progressive displacement, nonunion and joint misalignment [8].

If the prosthesis is stable, open reduction with or without bone grafting is generally indicated. If the prosthesis is loose, revision arthroplasty to a stemmed component is
Revision Total Knee Arthroplasty

Revision total knee arthroplasty may be used for an extremely distal and comminuted fracture where secure fixation cannot be achieved or if the fracture is associated with a loose and unstable implant or poor bone stock in the distal femur. Revision total knee arthroplasty is frequently required in cases in which nonoperative or other methods of treatment have failed. An uncemented long-stemmed prosthesis with fracture fixation, typically with interfragmentary screws and/or small plates may be used. A long-stemmed prosthesis provides stable fixation and allows patients to start early movement and weightbearing. A custom implant may be required to enable distal femoral replacement to be undertaken in cases where a loose prosthesis is coupled with metaphyseal bone stock [1, 8].

Chen et al. reported that ten out of eleven supracondylar periosteal fractures treated with revision total knee arthroplasty had a satisfactory result [12]. Keenan et al. reported seven cases of displaced supracondylar fractures above a total knee arthroplasty with custom made implants and reported good implant alignment and fixation as well as rapid postoperative recovery, mobilisation and good functional outcomes [22].

TREATMENT OF TIBIAL PERIPROSTHETIC FRACTURES

Periprosthetic fractures of the tibia occur less frequently than supracondylar fractures. If the fractures are associated with stable, well-aligned knee components, standard methods of nonoperative or operative tibial fracture care may be undertaken. Fractures associated with loosening or instability of the prosthesis requires revision of the component. A diaphysis-engaging tibial intramedullary stem with open reduction and internal fixation of additional fracture fragments may be used. If there is extensive bone loss, structural allograft or tumour prosthesis may be necessary [1, 23].

TREATMENT OF PATELLAR PERIPROSTHETIC FRACTURES

Some patellar fractures may go undetected and require no treatment. Nondisplaced fractures of the patella and fractures associated with stable implants and an intact extensor mechanism should be treated nonoperatively. Operative management is indicated in cases of extensor mechanism disruption, loosening of the patellar component and patellar maltracking. Surgical treatment includes open reduction and internal fixation, component revision, partial patellectomy with tendon repair, total patellectomy or patellar resection arthroplasty and fixation. Patellectomy should only be performed in cases where bone stock is extremely poor or for grossly comminuted fractures as patellectomy can result in marked quadriceps weakness. Patellar resurfacing may be performed in patients with a loose patellar component and adequate bone stock [1, 8, 24, 25].

Ortiguera and Berry retrospectively reviewed eighty-five patellar fractures following 12,464 consecutive total knee arthroplasties. They found that nonoperative treatment was
generally successful. Thirty-eight of the patellae had Type I fractures. All but one were managed nonoperatively. There was one late failure of nonoperative treatment. Operative management was carried out for Type II and Type III fractures. Operative treatment was associated with a high rate of complications and reoperations [5].

**CONCLUSION**

Periprosthetic fractures after total knee arthroplasty is increasing in incidence as the number of total knee arthroplasties being performed is increasing. The effects of periprosthetic fractures can be devastating and the treatment of these fractures may be complicated. Patient factors such as osteoporosis play a significant role in increasing the risk of these fractures. Efforts should be made to reduce the risk of periprosthetic knee fracture at the time of performance of the total knee arthroplasty, by using meticulous surgical technique in order to ensure correct implant alignment and avoidance of notching or the development of stress risers. There is a wide range of treatment options. The most appropriate treatment to achieve a satisfactory outcome is dependent on a number of factors, including the degree of displacement, the adequacy of bone stock, the stability of the implant and the medical fitness of the patient.

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**CONFLICT OF INTEREST**

None of the authors have a conflict of interest to declare in relation to the production of this manuscript.

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