The Open Orthopaedics Journal, 2012, *6*, (Suppl 2: M7) 301-304

Open Access

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

Mukai Chimutengwende-Gordon*,[1], Wasim Khan[1] and David Johnstone[2]

[1]*University College London Institute of Orthopaedic and Musculoskeletal Sciences, Royal National Orthopaedic Hospital, Stanmore, Middlesex, HA7 4LP, UK*

[2]*Department of Trauma and Orthopaedics, Stoke Manderville Hospital, Aylesbury, Buckinghamshire, HP21 8AL, UK*

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-

*Address correspondence to this author at the Mukai Chimutengwende-Gordon, University College London Institute of Orthopaedic and Musculoskeletal Sciences, Royal National Orthopaedic Hospital, Stanmore, Middlesex, HA7 4LP, UK; Tel: 02089540268, Ext. 5304;
Fax: 02084207392; E-mail: mukai.cg@mac.com

1874-3250/12 2012 Bentham Open

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 prosthetic 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 communition. 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 recommended [15]. The aim of open reduction and internal fixation is to provide anatomical reconstruction and early rehabilitation of the patient. It may be considered in healthy or active patients regardless of the fracture pattern to promote early mobilisation. A wide variety of implants are available for open reduction and internal fixation of the fracture, including angle blade plates (ABP), dynamic condylar screws (DCS), buttress plates, flexible or rigid intramedullary nails and locking periparticular plates. Locking plates such as the Less Invasive Stabilization System (LISS) plate may be implanted with minimal soft tissue dissection and periosteal stripping and allowing preservation of blood supply as well as potentially reducing intraoperative blood loss and the risk of infection. The LISS plate has virtually replaced the use of DCS and ABP plates in recent years. Locked plates have been shown in cadaver studies to be biomechanically more stable than non-locking plates such as the DCS and ABP. An advantage of the LISS plate is the ability to place multiple fixed-angled locked screws to avoid existing hardware or to capture specific fracture fragments and improve stability [1, 16]. Clinical studies have reported good outcomes with the use of LISS plates. For example, Althausen reported that LISS plates were superior to flexible intramedullary nails, plate fixation and retrograde intramedullary nails and allowed immediate postoperative mobilisation whilst being associated with low infection rates and no requirement for acute bone grafting [17].

Flexible intramedullary nails have been used as a less invasive treatment option to treat supracondylar periprosthetic knee fractures. However, this technique is associated with reduced axial and rotational stability and as a result is generally not used [18, 19]. Ritter *et al.* reported 100% union in a review of twenty-two cases treated with Rush rods. The average postoperative alignment was 10 degrees (compared to 7 degrees preoperatively). Two fractures healed in 15 degrees of valgus alignment [20]. This technique may be considered to treat mildly displaced fractures in patients with significant comorbidities [8]. Flexible intramedullary nails are now rarely used. Rigid retrograde femoral nails can be used instead for fractures with distal fracture fragments large enough to allow insertion of a locking screw. It is relatively minimally invasive and generally provides good axial, angular and rotational stability. However, it is limited as it cannot be used for very distal fractures, in severe comminution with loose total knee components and it should not be used in the presence of a pre-existing ipsilateral total hip replacement as it can lead to a stress riser below the femoral stem [1, 8].

External fixation is another treatment option but is rarely used due to problems with tethering of the quadriceps muscles, limitations imposed on knee range of motion of the knee and the risk of propagation of pin tract infections into the knee joint space [1, 8, 21]. Other techniques that have been used include fibula strut grafting, use of femoral allograft in combination with a prosthesis and arthrodesis. As these treatment modalities have been used much less frequently, there are limited reports on them in the literature [6].

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 periprosthetic 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.

ACKNOWLEDGEMENT

None declared.

CONFLICT OF INTEREST

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

REFERENCES

[1] Parvizi J, Jain N, Schmidt AH. Periprosthetic knee fractures. J Orthop Trauma 2008; 22: 663-71.
[2] Della Rocca GJ, Leung KS, Pape HC. Periprosthetic fractures: epidemiology and future projections. J Orthop Trauma 2011; 25(Suppl. 2): S66-70.
[3] Healy WL, Siliski JM, Incavo SJ. Operative treatment of distal femoral fractures proximal to total knee replacements. J Bone Joint Surg Am 1993; 75: 27-34.
[4] Schroder HM, Berthelsen A, Hassani G, Hansen EB, Solgaard S. Cementless porous-coated total knee arthroplasty: 10-year results in a consecutive series. J Arthroplasty 2001; 16: 559-67.
[5] Ortiguera CJ, Berry DJ. Patellar fracture after total knee arthroplasty. J Bone Joint Surg Am 2002; 84-A: 532-40.
[6] Johnston AT, Tsiridis E, Eyres KS, Toms AD. Periprosthetic fractures in the distal femur following total knee replacement: A review and guide to management. Knee 2012; 19(3): 156-62.
[7] Maestro A, Rodriguez L, Lopis JA. Periprosthetic knee fractures. Rev Ortop Traumatol Ed Lat Am 2008; 52: 179-87.
[8] Dennis DA. Periprosthetic fractures following total knee arthroplasty. Instr Course Lect 2001; 50: 379-89.
[9] Rorabeck CH, Taylor JW. Classification of periprosthetic fractures complicating total knee arthroplasty. Orthop Clin North Am 1999; 30: 209-14.
[10] Felix NA, Stuart MJ, Hanssen AD. Periprosthetic fractures of the tibia associated with total knee arthroplasty. Clin Orthop Relat Res 1997; 345: 113-24.
[11] Goldberg VM, Figgie HE III, Inglies AE, *et al*. Patellar fracture type and prognosis in condylar total knee arthroplasty. Clin Orthop Relat Res 1988; 236: 115-22.
[12] Chen F, Mont MA, Bachner RS. Management of ipsilateral supracondylar femur fractures following total knee arthroplasty. J Arthroplasty 1994; 9(5): 521-6.
[13] 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: 212-22.
[14] Merkel KD, Johnson EW, Jr. Supracondylar fracture of the femur after total knee arthroplasty. J Bone Joint Surg Am 1986; 68: 29-43.
[15] McGraw P, Kumar A. Periprosthetic fractures of the femur after total knee arthroplasty. J Orthop Traumatol 2010; 11: 135-41.
[16] Kregor PJ, Hughes JL, Cole PA. Fixation of distal femoral fractures above total knee arthroplasty utilizing the Less Invasive Stabilization System (L.I.S.S.). Injury 2001; 32: SC64-75.
[17] 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: 834-9.
[18] Cain PR, Rubash HE, Wissinger HA. Periprosthetic femoral fractures following total knee arthroplasty. Clin Orthop 1986; 208: 205-14.
[19] Tanaka Y, Kobayashi T, Ohashi M, Kaneko D, Nemoto K. A new operative procedure using a Kuntcher nail for a periprosthetic supracondylar femoral fracture after revision total knee arthroplasty: a case report. Knee 2007; 14: 59-62.
[20] Ritter MA, Keating EM, Faris PM, Meding JB. Rush rod fixation of supracondylar fractures above total knee arthroplasties. J Arthroplasty 1995; 10: 213-6.
[21] Figgie MP, Goldberg VM, Figgie HE III, Sobel M. The result of treatment of supracondylar fracture above total knee arthroplasty. J Arthroplasty 1990; 5: 267-70.
[22] Keenan J, Chakrabarty G, Newman JH. Treatment of supracondylar femoral fracture above total knee replacement by custom made hinged prosthesis. Knee 2000; 7: 165-70.
[23] Hanssen AD, Stuart MJ. Treatment of periprosthetic tibial fractures. Clin Orthop Relat Res 2000; 380: 91-8.
[24] Parvizi J, Seel MJ, Hanssen AD, Berry DJ, Morrey BF. Patellar component resection arthroplasty for the severely compromised patella. Clin Orthop Relat Res 2002; 396: 356-61.
[25] Pagnano MW, Scuderi GR, Insall JN. Patellar component resection in revision and reimplantation total knee arthroplasty. Clin Orthop Relat Res 1998; 356: 134-8.

Received: February 14, 2012 Revised: February 21, 2012 Accepted: March 9, 2012

© Chimutengwende-Gordon *et al.*; Licensee *Bentham Open*.

This is an open access article licensed under the terms of the Creative Commons Attribution Non-Commercial License (http://creativecommons.org/licenses/by-nc/3.0/) which permits unrestricted, non-commercial use, distribution and reproduction in any medium, provided the work is properly cited.