TRAUMA

A review of periprosthetic fractures around total knee arthroplasties

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Summary
Escalating incidence of periprosthetic fractures around the knee is attributable to ever-increasing indications of total knee arthroplasties (TKAs), the growing elderly population with knee prostheses, and the increased activity of patients with TKA. Periprosthetic fractures around TKA can involve the femur, tibia, or patella. Successful treatment of periprosthetic fractures about TKA is defined as the absence of knee pain, fracture union in less than 6 months, return to functional range of motion and a normal ambulatory status. Treatment options include conservative and operative methods.

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Introduction
Periprosthetic fractures of the knee are relatively uncommon (0.3–2.5%). The management is however often challenging. Moreover, the ageing population with total knee arthroplasty (TKA) in conjunction with increased activity levels following TKA may further amplify the incidence of this complex problem. The failure of TKA often contributes to bone loss, consequently increasing the risk of intraoperative and postoperative periprosthetic fractures. They can occur in the femur, tibia, or patella. The prevention of periprosthetic fractures depends on the identification and management of predisposing risk factors, meticulous preoperative planning, the availability of appropriate surgical expertise and resources and a sound knowledge of incipient complications.

The treatment of periprosthetic fractures around the knee is directed at fracture union and prosthetic stability. The two main goals of treatment are a painless knee with a range of motion of over 0–90° and fracture union within 6 months. In 1977, Rinecker and Haibock reviewed periprosthetic fractures around TKAs in a small number of patients and recommended either open reduction and internal fixation (ORIF) or revision arthroplasty as the treatment option. It was Hirsh et al. who first reported in the English literature with their series of 4 patients in 1981; they proposed a nonoperative treatment option if the fracture could be reduced in a stable fashion. This was supported by Oni who suggested management using skeletal traction.

A comprehensive review of periprosthetic fractures of the knee in 1984 by Merkel and Johnson, advocated conservative measures. Failure of nonoperative treatment was documented by Short et al. More recently, operative treatment...
has been recommended to allow early mobilisation, to improve the range of motion of the knee and to avoid nonunion and malunion. The complication rates reported in the literature, following the treatment of periprosthetic fractures of the knee vary from 25% to 75%, even in the most experienced hands. Operative or nonoperative management seem to have comparable complication rates. This review paper outlines the epidemiology, risk factors, classification and current treatment options for femoral (supracondylar), patellar and tibial periprosthetic fractures in TKA.

Supracondylar femoral fractures

Supracondylar periprosthetic fractures are those within 15 cm of the knee joint line or within 5 cm of the proximal end of the implant (Figs. 1 and 2). They account for the majority of periprosthetic fractures around the knee. Their overall incidence ranges from 0.3% to 2.5% after primary knee arthroplasty, increasing to 1.6–38% after revision surgery. They are more common in patients older than 60 years old with osteoporosis. The Mayo clinic registry showed a 2% incidence of periprosthetic femoral fractures after TKA, of which 0.1% were seen in a primary arthroplasty and 0.9% in a revision arthroplasty. In the series reported by Hirsch et al., the fractures were supracondylar. These fractures result from a combination of axial and torsional loads. The most frequent mechanism for a supracondylar periprosthetic knee fracture is a low velocity fall. This is followed by motor vehicle accidents, manipulation of a stiff knee after TKA and seizures. The most important risk factor is osteopenia. The predisposing factors to osteopenia include advancing age, rheumatoid arthritis and chronic steroid use. The other risk factors include stress risers like screw holes, local osteolysis due to polyethylene wear debris, female gender, neurological disorders, previous revision TKA and a rotationally constrained prosthesis. Although, biomechanical studies have shown that anterior femoral notching more than 3 mm with sharp corners at the proximal end and closer proximity to the prosthesis produce the highest stress concentration and need cautious treatment, Ritter et al. in their retrospective analysis demonstrated no difference in knees with or without notching. Their observations were attributed to osseous remodelling and stress redistribution.

Intraoperative supracondylar fractures are usually neither displaced nor comminuted and are associated with little soft tissue trauma. They may be classified as diaphyseal or metaphyseal. Diaphyseal intraoperative supracondylar fractures are usually anterior and occur during insertion of the intramedullary alignment rod and may be missed intraoperatively. It happens more commonly in the transitional zone between the cancellous metaphyseal and the cortical diaphyseal bone of the distal femur. Despite several classification systems in vogue for postoperative periprosthetic femoral fractures, none have universal acceptance.

Figures 1 and 2  AP and lateral radiographs of a displaced supracondylar fracture.
(Table 1). The Neer classification system based on the displacement of the fracture and the stability of the implant was in wide use. However, it failed to convey the relationship of the fracture to the prosthesis. This led to modification of the classification initially by Digoia et al. and subsequently by Rorabeck et al. The latter is now the most popular system worldwide.

Rorabeck et al. described 3 types of periprosthetic femur fractures. A Type I fracture is undisplaced, and has a stable prosthesis. In Type II, the fracture is displaced but the prosthesis is stable. In Type III, a displaced or undisplaced fracture is associated with an unstable prosthesis. The limitation of this classification system is its inability to conjoin the type of fracture to its management. This was overcome by Kim et al. who proposed a more comprehensive classification system based on the amount of bone, the position and fixation status of the prosthesis and the reducibility of the fracture (Table 2). In this classification, supracondylar periprosthetic fractures around the knee are classified into three types. In Type I fractures, patients have good bone stock and the prosthesis is well fixed and well positioned. They may be subdivided into Type IA, where, the fractures are either undisplaced or are easily reducible and may be treated conservatively, or Type IB fractures which are irreducible and entail operative reduction and internal fixation (Fig. 3). The Type II fractures are reducible fractures with good bone stock, but the prosthesis is loose and malaligned. These fractures are treated by revision arthroplasty with long stem prostheses. The Type III fractures are severely comminuted with inadequate distal bone for fixation or support of a conventional prosthetic component and often necessitate a distal femoral replacement.

Management

The main goals of management of a supracondylar periprosthetic fracture are to achieve a painless knee with good range of motion, acceptable fracture alignment (flexion/extension malalignment less than 10° and varus/valgus malalignment less than 5°), fracture union (shortening less than 2 cm) and a stable prosthesis. The patient’s pre-morbid ambulatory status and general health have to be acknowledged, before management options are considered.

The nonoperative options available are skeletal traction, pins and plaster, and cast brace. Nonsurgical management is reserved for patients too unfit for surgery and for undisplaced fractures without intercondylar extension. The disadvantages of nonoperative treatment are (1) high risks associated with prolonged bed rest in the elderly patients, (2) higher rates of nonunion and malunion, and (3) marked loss of knee motion. A review of 12 studies by Chen et al. showed no significant difference in results between operative and nonoperative management following supracondylar periprosthetic femur fractures. However, currently there is robust evidence to support surgical management where feasible. The various operative options available are condylar plates, intramedullary fixation with flexible or rigid nails, revision arthroplasty, external fixators, cerclage wiring with or without strut grafts and arthrodesis.

If an intraoperative fracture is noticed on table, a stemmed prosthesis which bypasses the cortical penetration by at least two femoral canal diameters with or without graft is indicated. Ideally, the stem has to be fluted and cylindrical to provide rotational stability and it should not be cemented at the level of the fracture or proximal to it as union can be hindered by cement by reducing axial loads. If the fracture is also displaced, the stemmed prosthesis may be augmented with transcondylar screws to maintain bony alignment. If the supracondylar femur fracture is not recognised on table or a long-stemmed prosthesis is unavailable, protected weight bearing for a minimum of

<table>
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<tr>
<th>Table 1</th>
<th>Supracondylar periprosthetic fractures: classification systems.</th>
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<tbody>
<tr>
<td>Author</td>
<td>Type/group</td>
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<tr>
<td>Neer et al.</td>
<td>Type I</td>
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<tr>
<td></td>
<td>Type II</td>
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<td></td>
<td>Type IIA</td>
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<td>Type IIB</td>
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<td></td>
<td>Type III</td>
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<td>DiGioia and Rubash</td>
<td>Group I</td>
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<td></td>
<td>Group II</td>
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<td></td>
<td>Group III</td>
</tr>
<tr>
<td>Chen et al.</td>
<td>Type I</td>
</tr>
<tr>
<td></td>
<td>Type II</td>
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<tr>
<td>Lewis and Rorabeck</td>
<td>Type I</td>
</tr>
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<td></td>
<td>Type II</td>
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<td></td>
<td>Type III</td>
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<th>Table 2</th>
<th>Classification of postoperative supracondylar fractures of the knee by Kim et al.</th>
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<tbody>
<tr>
<td>Type</td>
<td>Fracture reducible</td>
</tr>
<tr>
<td>IA</td>
<td>Yes</td>
</tr>
<tr>
<td>IB</td>
<td>No</td>
</tr>
<tr>
<td>II</td>
<td>Yes/no</td>
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<tr>
<td>III</td>
<td>Yes/no</td>
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Figure 3  (A,B) Preoperative radiographs of Type 1B supracondylar fracture. (C) Postoperative radiograph of Type 1B treated with ORIF.
6–8 weeks may be the only option. Postoperative periprosthetic femur fractures are more common and the treatment strategy depends on the location of the fracture, the displacement of the fracture, the bone stock quality and the stability, and position of the prosthesis. Stable minimally displaced fractures with a well-aligned stable stem and good bone stock may be treated nonoperatively in a cast brace with protected nonweight bearing and radiographic follow-up.

Displaced, irreducible fractures with good bone stock quality warrant operative management and the options available are less invasive surgical stabilization (LISS) plating, angled blade plating (ABP), dynamic condylar screws and intramedullary nailing. ABP is the preferred method of holding the reduced fracture (Fig. 3), but maintenance of reduction in a patient with fracture comminution and osteopenia may be challenging, often requiring the additional use of polymethyl methacrylate, cortico-cancellous graft or fibular graft to aid osseosynthesis.

Condylar plates often work well in displaced fractures albeit with less comminution and a satisfactory bone stock. LISS plates have the advantage of minimal soft tissue dissection or periosteal stripping. The first published report on the use of LISS plates in periprosthetic supracondylar fractures was by Kregor et al. Recent series by Raab et al. and Althausen et al. claim excellent results with LISS plates when compared with other types of fixation. When dealing with open box prostheses with a good distal fracture fragment, a rigid IM nail may be ideal due to its load-sharing property. However, there is a potential risk of introducing intra-articular infection. The earliest report of the use of a supracondylar nail in a TKA was in 1994. In 2005, Glatis et al. published their satisfactory outcome in a series of 9 patients with a mean follow-up of 34.5 months.

Curral et al. studied intercondylar notch dimensions of 10 most commonly used TKAs and their compatibility with supracondylar nails. Contraindications to the use of intramedullary nails are poorly fixed TKRs, severe fracture comminution, and an extremely distal fracture. Flexible nails have been tried in the past, but may lead to shortening or malalignment. All reducible fractures with a loose prosthesis but good-quality bone stock may be treated by revision knee arthroplasty, using a diaphysis engaging intramedullary stem (uncemented) and ORIF of the fracture. This allows early weight bearing and better range of motion. Treatment is particularly arduous in fractures associated with poor bone stock in the vicinity of a loose and malaligned prosthesis. Viable options are distal femoral replacement in the elderly and APC (allograft-prosthetic composite) in younger patients. Poor prognostic factors for outcome following supracondylar periprosthetic femur fractures are noted in the presence of displacement, intercondylar extension, and comminution. Fig. 4 shows the management pathway.

Patellar fractures

The next most common periprosthetic fractures in a TKA are those involving the patella with an incidence of 0.2–21% in resurfaced and 0.05% in unresurfaced knees. The mean incidence of periprosthetic patellar fractures is 1.19% in primary TKAs and 0.15–12% in revision TKAs. It is more common in men which may be attributed to increased activity level and body weight. The etio-pathogenesis is often multifactorial and they commonly follow trauma or can be regarded as fatigue fractures. The risk factors may be classified as host-related such as osteoporosis, rheumatoid arthritis, bone loss, osteolysis, high-activity levels and hyperflexion of the knee or surgery-related factors such as malalignment of the limb, maltracking of the patella, malposition of the implant, lateral release, fat pad removal, excessive bone resection, patellar designs with central peg, uncemented implants, and revision surgeries. Patellar fracture may be an intraoperative complication of revision arthroplasty. Reimplantation of the patella in revision surgery is not routine as bone stock can militate against it. Failure to achieve a stable reduction of the fracture makes partial patellectomy imperative. The extensor mechanism may have to be augmented using a semitendinosus graft or an extensor mechanism allograft.

Various classification systems for periprosthetic patellar fractures have been described by authors, such as Tria et al., Goldberg et al., Hozack et al., Ortiguera and Berry, and Keating et al. All of them are based on the site of the fracture, displacement of the fracture and implant stability. The classification described by Ortiguera and Berry is currently in wide use. A comparison of classification systems is given in Table 3. Treatment for these fractures is fraught with difficulties due to high complication rates and poor outcomes. Most of these fractures are identified during routine follow-up as more than 88% are asymptomatic.

Treatment is guided by presence or absence of an intact extensor mechanism, implant stability, fracture pattern, and bone stock quality. Fractures with an intact extensor mechanism and a stable implant may be treated nonoperatively using a cylinder cast or functional brace for best functional outcome. The literature suggests that 69% of patellar periprosthetic fractures are treated nonoperatively while 31% are treated operatively. Loosening of the patellar component, maltracking of the patella and disruption of extensor mechanisms are all indications for surgical intervention. Owing to the modest outcome and high rates of nonunion (92%), infection, and failure of fixation simple ORIF is often not recommended. Partial patellectomy, with repair or advancement of the extensor mechanism is advocated for fractures with extensor mechanism disruption, although a 42% reoperation rate and 50% complication rate may be seen in these patients. Patellar fractures with implant loosening and adequate bone stock (thickness > 10 mm) may be treated by revision and patellectomy. In the presence of poor bone stock, excision arthroplasty and partial or total patellectomy is the only feasible option. Berry reported an 11% reoperation rate and 29% complication rate. More than 50% of the patients in his series stayed symptomatic after treatment. Fig. 5 is the treatment algorithm.

Periprosthetic fracture of the tibia

Periprosthetic fracture of the tibia is an extremely uncommon complication of TKA, with a reported intraoperative incidence...
of 0.1% and postoperative incidence of 0.4%. The incidence is higher in revision arthroplasty (0.36% in intraoperative and 0.48% postoperative). The introduction of modern condylar designs of arthroplasty have made periprosthetic fracture of the tibia exceptionally rare, although there is a re-emergence due to increased number of revisions with stems, osteolysis due to polyethylene wear, newer prosthetic designs and new surgical techniques.

Intraoperative fractures may occur at trial reduction, component or cement removal, preparation of the tibia,
overzealous cement impaction, or when osteotomising the tibial tubercle.\textsuperscript{57} Postoperative fractures are often a complication of trauma, malalignment, prosthetic loosening, or knee instability.\textsuperscript{7,57-62} Felix et al. in 1997 reported the largest series of periprosthetic tibial fractures to date from the Mayo clinic and defined a logical framework to classify these fractures and derive a treatment algorithm. Felix et al. classified the fractures based on the anatomic location of the fracture, the stability of the prosthesis and the timing of the fracture. Type I involves the tibial plateau, Type II occurs adjacent to the stem in the metaphyseal–diaphyseal region, Type III occurs distal to the stem (Fig. 6), and Type IV involves the tibial tubercle. They are then subtyped into A, B, and C. Subtype A has a well-fixed stems whereas subtype B has a loose prosthesis. All intraoperative fractures are grouped as subtype C (Fig. 7). Type IA fractures may be treated conservatively with protected weight bearing and cast bracing. Type IB fractures require revision arthroplasty with a long-stemmed tibial prosthesis, bone graft or modular augments. Some of these fractures may even require a custom prosthesis. Type IC

<table>
<thead>
<tr>
<th>Classification and year</th>
<th>Type I</th>
<th>Type II</th>
<th>Type III A</th>
<th>Type III B</th>
<th>Type IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keating et al.\textsuperscript{51}</td>
<td>Vertical fractures intact extensor mechanism stable implant</td>
<td>Horizontal fractures disrupted extensor mechanism stable/ unstable implant</td>
<td>Any type of fracture with intact extensor mechanism with an unstable implant</td>
<td>Unstable implant intact extensor mechanism good bone stock</td>
<td>Unstable implant Intact extensor mechanism poor bone stock</td>
</tr>
<tr>
<td>Ortiguera and Berry\textsuperscript{52}</td>
<td>Stable implant intact extensor mechanism</td>
<td>Disrupted extensor mechanism stable/ unstable implant</td>
<td>Unstable implant intact extensor mechanism good bone stock</td>
<td>Unstable implant intact extensor mechanism poor bone stock</td>
<td>Unstable implant Intact extensor mechanism poor bone stock</td>
</tr>
<tr>
<td>Tria et al.\textsuperscript{46}</td>
<td>Undisplaced fracture stable implant intact/disrupted extensor mechanism</td>
<td>Undisplaced fracture unstable implant intact/disrupted extensor mechanism</td>
<td>Displaced Fracture Stable implant intact/disrupted extensor mechanism</td>
<td>Displaced fracture unstable implant intact/disrupted extensor mechanism</td>
<td>Displaced fracture unstable implant intact/disrupted extensor mechanism</td>
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<tr>
<td>Hozack et al.\textsuperscript{56}</td>
<td>Displaced fracture</td>
<td>Undisplaced fracture</td>
<td>Commuinted fracture</td>
<td>Transverse middle third</td>
<td>Pole</td>
</tr>
<tr>
<td>Goldberg et al.\textsuperscript{48}</td>
<td>Fracture not involving implant, cement, and quadriceps mechanism</td>
<td>Fractures involving implant, cement, and quadriceps mechanism</td>
<td>Inferior pole fracture with patellar ligament rupture</td>
<td>Inferior pole fracture without patellar ligament rupture</td>
<td>Fracture dislocation</td>
</tr>
</tbody>
</table>

Figure 5: Treatment pathway for patellar fracture.

Table 3: Classification of periprosthetic patellar fractures.
Fractures should be treated by ORIF of the fracture, prior to insertion of the prosthesis. Undisplaced Type IIA fractures may be treated by cast immobilisation. In Type IIA fractures, failure to achieve acceptable reduction and internal fixation makes revision arthroplasty imperative. Type II B fractures are treated by a revision with a long-stemmed prosthesis and bone graft. Additional fixation of the fracture may be indicated, when a fracture is discovered intraoperatively (Type II C) or if the fracture pattern requires postoperative immobilisation, which restricts the range of movement of the knee. Minimally displaced intraoperative fractures may be treated with a brace postoperatively. Type IIIA fractures are treated based on basic fracture fixation principles. Undisplaced fractures are treated conservatively and revision is indicated if there is axial misalignment. In Type IIIB fractures, revision with a long-stemmed prosthesis is ideal in proximal fractures whereas in the more distal ones, revision arthroplasty is performed only after achieving bony healing by means of internal fixation. The intraoperative III C fractures may be treated by cast immobilisation and protected weight bearing until the fracture heals.

Again the treatment has to be individualised and should address the fracture personality. Type IV fractures which involve the tibial tubercle, are treated by immobilisation, if the fracture is undisplaced and by accurate reduction and internal fixation if displaced. In conclusion, the management of periprosthetic knee fractures poses a major challenge. An understanding of risk factors and the prevention of these injuries through planning and careful surgery is important. Intraoperative fractures require immediate recognition and stabilisation where possible. Postoperative fractures should be managed by surgeons capable of undertaking both fixation and revision procedures. In some circumstances, nonoperative treatment may also have a role to play. Several algorithms are now available to guide management.

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