Periprosthetic fractures associated with total knee arthroplasty

AN UPDATE

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Fractures around total knee arthroplasties pose a significant surgical challenge. Most can be managed with osteosynthesis and salvage of the replacement. The techniques of fixation of these fractures and revision surgery have evolved and so has the assessment of outcome. This specialty update summarises the current evidence for the classification, methods of fixation, revision surgery and outcomes of the management of periprosthetic fractures associated with total knee arthroplasty.

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The incidence of periprosthetic fractures after total knee arthroplasty (TKA) is approximately 2.5%.1-6 While most can be managed by fixation,7-9 revision surgery10 is indicated when fixation fails and in patients in whom osteosynthesis is not possible due to insufficient bone stock. We present a concise update of the literature on periprosthetic fractures after TKA and their management.

Several systems have been devised to classify periprosthetic fractures around a TKA. They have attempted to describe the biomechanics of the fracture and the stability of the components and in doing so to provide a framework for deciding how the fracture should be managed. As they tend to describe a fracture around only one of the components, a single injury may require three separate classifications for the relevant components.

The AO classification system uses alphabetic and numeric notation to denote the location and characteristics of the fracture with codes 33, 34 and 41 denoting distal femur, patella and proximal tibia, respectively. This is a detailed and reproducible system11 which addresses the displacement of the fragments and the stability of the component but does not deal with the quality of the bone stock, loosening prior to injury, or whether there is an ipsilateral arthroplasty of the hip in situ.

Many systems are available for classifying periprosthetic patellar fractures, focusing on the pattern of the fracture and the integrity of the cement mantle and extensor mechanism.18-21 Ortiguera and Berry18 further included the quality of bone stock in their evaluation and proposed a treatment algorithm.

Felix, Stuart and Hanssen’s22 Mayo classification for fractures relating to the tibial component is commonly used and describes the location of the fracture relative to the component, its fixation and whether the tibial tuberosity has been avulsed.

The principles of managing these injuries involve the restoration of axial alignment and length, stable fixation, the maintenance of a supportive biological environment and early mobilisation. The application of these principles can be confounded by poor bone stock, the presence of other arthroplasties in the same limb, the pattern of the fracture, a previously failed or failing arthroplasty and the intricacies of the design of the components.12
Patellar fractures are uncommon and complicated in only 0.68% of the 12,000 primary TKAs recorded over 13 years in the Mayo Clinic Joint Registry. Factors associated with these injuries include trauma, axial malalignment, whether a lateral release was undertaken, damage to the blood supply of the patella, the design of the patellar component, excessive resection and factors such as comorbidities relating to the patient. In the presence of an intact component and a functional extensor mechanism, conservative treatment yields better results than surgery. Operative treatment offers poor results with complications including re-operation, infection, pain, patellar or extensor instability, weakness and nonunion.

Tibial fractures after TKA are rare (0.4% to 1.7%) and can occur peri- or post-operatively. Contributing factors may include malalignment and instability. Undisplaced or minimally displaced fractures in the presence of a well-fixed component can be treated non-operatively. Displaced fractures distal to the component and which do not affect its stability may be treated by internal fixation, while those associated with loosening require revision arthroplasty, augmented by bone grafting where required. Periprosthetic femoral fractures after TKA usually occur in the supracondylar region (0.3% to 2.5%). Risk factors include trauma, anterior femoral notching, constrained components, vascular compromise, infection, ankylosis of the knee, previous revision TKA, the prolonged use of steroids, osteoporosis, rheumatoid arthritis, advanced age, female gender and neurological conditions.

The results of closed treatment of non-displaced supracondylar periprosthetic fractures vary in the literature, with 56% (four out of seven) of patients in the series reported by McLaren, Dupont and Schroeder deemed to have satisfactory results versus 83% (25 of 30) in the series reported by Chen, Mont and Bachner.

Displaced supracondylar periprosthetic femoral fractures with a stable component have traditionally been treated with open reduction and internal fixation. This approach has some inherent limitations and is best employed for simple, proximal fractures in strong bone using fixed-angle devices. The physiological, condylar buttress plates do not require as much bone distally but offer less stable fixation, risking nonunion or malunion with varus collapse (Fig. 2).

Intramedullary nails are load-sharing and offer maximal respect of the soft-tissue environment. Retrograde nailing is effective in both displaced and undisplaced supracondylar periprosthetic fractures, and may offer more stability in the presence of comminution of the medial cortex. The technique requires the femoral component to permit intramedullary access through it and a single metaphyseal block distally. There must be no proximal intramedullary implant and the intramedullary diameter must be sufficient to allow passage of the nail (Fig. 3).

In osteoporotic bone, a blade-like device which interlocks with a nail has been shown in cadaveric models to confer benefits in both stiffness and strength over conventional locking bolts. Mechanical studies have also suggested that fixed-angled locking may have increased time to failure than non-locking nails, potentially important in fractures which are slow to heal.

More recent designs of locking plate (Fig. 4) offer more rigid fixation than traditional plates for peri-articular, comminuted and osteoporotic fractures and variable-angle plates allow fixation around implants.

Good results have been described and the retrospective study by Streubel et al suggested that extremely distal periprosthetic supracondylar fractures extending distal to the proximal border of the femoral component could still be managed in this way. Unicortical and polyaxial screws are now being used, but have yet to be proven efficacious. While locking plate systems offer many solutions, including a minimally invasive deployment in the hands of an experienced surgeon, they remain load bearing rather
than load sharing, and it can be challenging to reconstruct a
distal femur missing many of its landmarks after resection.
Augmentation with polymethylmethacrylate,\textsuperscript{41} intramedullary fibular autograft or allograft\textsuperscript{32,43} and medial
allograft struts\textsuperscript{44} have all been described as adjuvant measures to internal fixation. Bone grafting should be used to
address bone deficiency, rather than to contribute to the
stability of fixation.
Revision TKA should be considered when osteosynthesis is unlikely to be successful. Absolute and relative indications are summarised in Table II. Primary reconstruction with osteosynthesis allows the preservation of bone stock, but primary endoprosthetic replacement may be preferred to further reconstruction after failed osteosynthesis.45

Patients should be positioned to permit an extensile surgical approach and a sterile tourniquet should be considered to maximise the proximal extent of the sterile field. The use of tranexamic acid should be considered. Previous surgical scars may limit the choice of incision; if more than one is present, the most lateral should usually be used. Osteotomy of the tibial tubercle enhances exposure of the proximal tibia, whereas extensile manoeuvres are rarely needed for a distal femoral resection because the collateral ligaments are excised.

Revision for simple (UCS type A) fractures may be approached by the same principles as those used for metaphyseal bone defects.46 Collateral instability can be addressed by repair or, more commonly, the use of a hinged prosthesis.
Metaphyseal defects can be managed using porous-coated metal cones or allograft. Stemmed components may then be used to bypass this region.

In more complex cases (UCS types B, D and E) extensive bone loss must be addressed and augments alone are insufficient to support the use of stemmed devices. In this context, excision of deficient segments and massive endoprosthetic replacements are indicated. In proximal tibial replacements, the extensor mechanism is re-attached directly to the implant and may be augmented with a medial gastrocnemius flap. Hydroxyapatite collars at the bone-implant junction improve the osseointegration to bone and silver coating is now being investigated as a means of reducing the incidence of infection.

Interprosthetic (UCS type D) fractures present a complex challenge. When both components are fixed, bridge plating with augmentation with a strut graft offers reasonable fixation, but if one component is loose, this is not viable. In this scenario, custom-made implants such as femoral sleeves or couplers can be designed to link the well-fixed component to the revision component. When both components fail, total femoral replacement is the sole reconstructive option (Fig. 5), with an ‘internal replacement’ technique describing the strategy of reconstructing some bone stock around the components (Fig. 6).

Results of treatment

In the current literature, locking plates have better results than more traditional plates. Retrograde intramedullary nails offer higher rates of union and reduced rates of reoperation when compared with other techniques, but may be prone to higher rates of malunion, the implications of which are not fully understood.

There are no level 1 or 2 studies to inform the outcomes of these procedures. Herrera et al reviewed 29 case series comprising 415 fractures and reported a rate of nonunion of 9%, a rate of failure of fixation of 4%, a rate of infection of 3%, and a rate of revision surgery of 13%.

Fig. 5
Total femoral replacement for failed osteosynthesis in a Unified Classification System type D fracture.
nailing was associated with relative risk reduction (RRR) of 87% (p = 0.01) for developing a nonunion and 70% (p = 0.03) for requiring revision, when compared with traditional, non-locking plating. Locking plates conferred some advantage over traditional plating with a RRR of 57% for nonunion (p = 0.2) and 43% for revision surgery (p = 0.23).31

The results of a review by Ristevski et al55 of 44 studies reported 719 fractures with similar findings and, crucially, also gave a more contemporaneous comparison of retrograde intramedullary nailing and locking plate fixation. This showed no significant differences in the rates of nonunion (odds ratio (OR) = 0.39, 95% confidence interval (CI) 0.13 to 1.15; p = 0.09) or further surgical procedures (OR = 0.65, 95% CI 0.31 to 1.35; p = 0.25). Retrograde nailing was, however, associated with a significantly higher rate of malunion (OR = 2.37, 95% CI 1.17 to 4.81; p = 0.02).

Lizaur-Utrilla, Miralles-Muñoz and Sanz-Reig56 performed a case-control study of 28 patients with periprosthetic fractures, matching them to 28 patients undergoing primary TKA. The study group received various forms of treatment, ranging from screw fixation to distal femoral replacement, and had a significant decrease in Knee Society Score (KSS)57 post-operatively (p = 0.001) at 6.7 years mean follow-up, compared with the control group in whom the scores improved. Their mean KSS scores (p = 0.001), range of movement (p = 0.005), health status and quality of life measured using Short-Form 1258 (p = 0.03 except pain), were also significantly lower.

Li et al’s59 recent meta-analysis compared the clinical results of locking plates and retrograde intramedullary nails. No statistically significant difference was found six months post-operatively in terms of rate of or time to union, operating time and rates of complication.

Revision TKA
Chen et al27 reviewed the outcomes of 195 fractures reported in 12 studies. A total of ten patients were treated with revision TKA and in 92% (ten out of 11), high patient satisfaction rates were reported. The use of structural allograft was reported in three studies, including that by Backstein, Safir and Gross60 who used allografts in 61 knees; 17 of which were for periprosthetic fractures. A high rate of re-intervention was reported, with 13 of 61 (21%) requiring revision at a mean of 5.5 years post-operatively. Other studies reported 75% (nine of 12) and 100% (seven of seven) rates of union respectively.61,62 There were two patients in the latter series who had knee instability (28.6%).

Springer et al63 reported the results of 11 distal femoral replacements, ten of which were for nonunion. A total of eight (81%) were satisfied with the outcome with a mean KSS of 75 (44 to 99) at a mean follow-up of 58.5 months. Nearly a third of the patients, however, had a complication, the most common being infection requiring washouts.

Mortazavi et al47 noted an improvement in mean KSS from 72 to 83 in 22 patients at a mean follow-up of 58.6 months, with five requiring further revision (one loose stem and four fractures above the stem).

Patellar fractures
Ortiguer and Berry18 reported the outcome of 78 patellar fractures in association with a TKA at a mean follow-up of 3.6 years. A total of 38 were stable with an intact extensor mechanism and all but one of these were treated non-operatively, with only one late failure. A total of 12 were associated with disruption of the extensor mechanism and 11 of these were treated operatively; six had complications, leading to further surgery in five. Loose components were seen in the remaining 28 patients, 20 of whom were treated.
operatively; nine developed complications and four had further surgery.

Keating, Haas and Meding\textsuperscript{21} reported a series of 177 patellar fractures, 13 of which required operative management. Patients treated non-operatively generally had no extensor lag and had encouraging pain and function scores. Those treated operatively had a high rate of complications. A total of four of nine patients treated with excision of an extruded patellar button developed a deep infection. Both patients treated with open reduction internal fixation developed nonunion.

There is a paucity of literature concerning periprosthetic tibial fractures. Felix et al\textsuperscript{22} reported 102 fractures, 19 of which occurred during surgery. Those involving the tibial plateau and adjacent to the stem were, when associated with a loose tibial component, treated most successfully with revision surgery. Intra-operative fractures were managed by fixation, bone grafting or external immobilisation and weight-bearing restrictions depending on the location and pattern.

In conclusion, these are challenging injuries. The surgeon is often faced with an elderly patient with compromised biological and physiological reserve. The goal should always be early mobilisation. There is a need to identify centres and surgeons with a special interest in the management of these complex injuries in order to optimise the outcomes.

Take home message:
This specialty update summarises the current evidence for the classification, methods of fixation, revision surgery and outcomes of the management of periprosthetic fractures associated with total knee arthroplasty.

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