

Current Reconstruction Options in Periprosthetic Fractures Around the Knee

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Giorgio Cacciola, MD¹ , Fabio Mancino, MD², Federico De Meo, MD¹,
Antongiulio Bruschetta, MD¹, Ivan De Martino, MD²,
and Pietro Cavaliere, MD¹

Abstract

Background: Periprosthetic fractures are a rare complication after total knee arthroplasty (TKA). However, the incidence of these fractures is growing after the increasing number of TKAs performed every year and the progressive aging of the population. In addition, the surgical treatment and peri-operative management of these complications are demanding, representing a challenge for the orthopedic surgeon. **Significance:** A thorough understanding of these fractures and a correct classification are necessary in order to select the most suitable surgical treatment. The aim of this review was to analyze the epidemiology, classification, diagnosis, surgical treatment, and outcomes of periprosthetic knee fractures in order to give an exhaustive overview. **Results:** Reduction and internal fixation with locking plates or intramedullary nails represents the preferred option in case of a stable prosthetic implant. Conversely, in case of loose tibial and/or femoral component, implant revision is mandatory. Conservative treatment is rarely indicated. **Conclusion:** A deep understanding of the characteristics and patterns of periprosthetic knee fractures, and the determination of the stability of the prosthetic implant are necessary in order to establish the correct treatment.

Keywords

periprosthetic fracture, knee fracture, knee revision, review

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Introduction

Total knee arthroplasty (TKA) is a safe and common procedure for the treatment of end-stage osteoarthritis of the knee. Currently, more than 300.000 TKAs are performed each year in the United States (US)^{1,2} with favorable outcomes reporting survivorship at 10 and 15 years up to 94.8% and 92.7%, respectively.^{2,3} Periprosthetic fractures in TKA are a growing problem facing today's Orthopaedic surgeon, and according to the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR) represent the fourth cause of revision TKA (3.6% of cases), after implant loosening (24.7%), periprosthetic joint infection (PJI, 23.7%), and patellofemoral pain (9.1%).³ Periprosthetic fractures of the knee can involve the distal femur, the proximal tibia, and the patella.⁴ Multiple classifications and different treatments have been described according to the pattern of the fracture.⁵⁻⁹ The aim of this review is to describe the epidemiology, classification, treatment options, outcomes and complications of periprosthetic fractures around TKA.

Distal Femur Periprosthetic Fractures

Distal femur periprosthetic fracture is the most common pattern of periprosthetic fractures in TKA (60% to 80%).¹⁰ It is defined as a fracture that occurs within 15 cm from the joint line, or within 5 cm from the proximal end of the femoral stem.⁵ In elderly and female-osteoporotic patients is frequently related to low-velocity trauma (fall from standard height), while in younger patients with good bone quality is usually secondary

¹ Orthopaedic Institute of Southern Italy "Franco Scalabrino," Messina, Italy

² Division of Orthopaedics and Traumatology, Department of Aging, Neurological, Orthopaedic and Head-Neck Studies, Fondazione Policlinico Universitario Agostino Gemelli IRCCS, Rome, Italy

Corresponding Author:

Pietro Cavaliere, Orthopaedic Institute of Southern Italy "Franco Scalabrino," Messina, Italy.

Email: cavalierepietro@gmail.com.



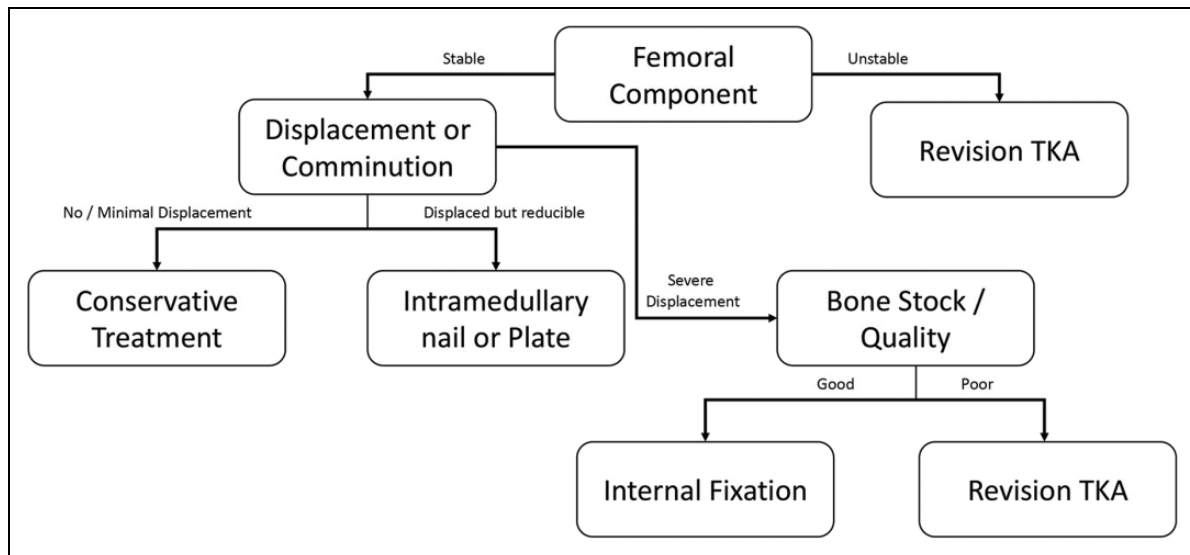


Figure 1. Flowchart—treatment for periprosthetic fractures of the distal femur.

to a high-energy trauma.¹⁰ The risk of distal femur periprosthetic fractures is increased in case of frequent falls, neurologic disorders and notching of the anterior flange.^{4,5,10} Key elements that drive the treatment options are the stability of the implant, the degree of displacement, the bone stock and bone quality, and finally the clinical condition of the patient.⁵ The final goal of the surgical treatment is a stable fixation with <2 cm of leg shortening, <5° of coronal deviation, <10° of sagittal deviation, and a range of motion (ROM) free of pain of 0-90°, as defined by Lewis and Rorabeck.⁵

Distal femur periprosthetic fractures classification. Neer et al firstly classified in 3 types distal femoral periprosthetic fractures in 1967¹¹ based on displacement and comminution of the bone fragments. Type I was not displaced, type II involved a displacement >1 cm (IIA with the condyles displaced medially, IIB laterally), type III involved both condyles or the femoral shaft. Su et al,¹² classified supracondylar periprosthetic femoral fractures into 3 groups based on the location of the fracture to the femoral component. In type I, the fracture was above the femoral component, in type II, it started from the apex of the femoral component extending proximally, and in type III, the fracture started distally or anteriorly to the superior margin of the femoral component. The most frequently used classification is the one described by Lewis and Rorabeck.⁵ It is based on 2 criteria, the presence of displacement and the stability of the implant. In type I, the fracture is undisplaced (<5 mm or <5° of displacement) and the implant is stable. In type II the fracture is displaced (>5 mm or >5° of displacement) and the implant is stable, and in type III the fracture is either displaced or not, but the implant is loose.⁵ Implant stability is crucial in driving the treatment. In Type I, either nonoperative treatment or internal fixation represent a valuable option.^{4,5,10} In Type II, open reduction and internal fixation (ORIF), with either retrograde intramedullary nail or locking plate can be effectively

considered.^{4,10} In case of implant loosening (Type III), a tailored surgical treatment with revision of the implant is necessary. In case of severe displacement, poor bone stock and bone quality, some authors suggested a distal femur replacement (DFR) with tumor-type prosthesis^{4,10} (Figure 1).

Nonoperative treatment. Nonoperative treatment should be considered for type I fractures in elderly patients with a cast or brace immobilization for 4-6 weeks.^{4,10} Alignment and healing of the fracture should be checked every 2-weeks.^{4,10} In case of secondary displacement or non-union, a surgical procedure is recommended (open or closed reduction and internal fixation).^{13,14} The reported healing rate is between 60% and 80%,^{13,14} however, immobilization may reduce the functional outcomes and lead to medical complications in the elder population.^{4,13} Moreover, surgical treatment of type I fractures is associated with higher healing rate and functional outcomes, suggesting nonoperative treatment only in case of patients with severe clinical comorbidities.¹⁰ Chen et al,¹³ reported the outcomes of nonoperative treatment in case of type I and II fractures, with healing rate of 83% and 67%, respectively. In addition, Moran et al¹⁴ reported 100% of healing rate with nonoperative treatment in a small cohort of type I fractures, and a failure rate of 89% (8 out of 9) when nonoperative treatment was used for type II fracture.

Intramedullary nailing. It is common opinion that in case of type II fractures a retrograde intramedullary nail is the most effective option.¹⁵ It provides stable fixation, enables early rehabilitation, and preserves the soft tissue coverage. Intramedullary nailing is contraindicated if the fracture is located <20 mm from the intercondylar notch, in case of presence of a long-stem hip arthroplasty, or in case of a small box of the femoral component. In case of a stemmed femoral component retrograde nailing is impossible. In these cases, a different fixation technique should

be considered.^{15,16} Chettiar et al,¹⁷ reported the outcomes of 16 periprosthetic supracondylar fractures treated with an intramedullary nailing with a healing rate of 100% at mean 16-weeks follow-up. Radiological alignment was obtained in 11 patients (69%) according to the Lewis and Rorabeck criteria.⁵ Similarly, Shin et al,¹⁸ reported radiographic union of 100% at mean 13-weeks follow-up in case of type II fracture treated with intramedullary nailing (10 knees) with mean 0.1° of valgus in coronal plane, 1.9° of extension, and mean flexion of 103°.¹⁸ In addition, Lee et al¹⁹ reported the outcomes of 25 type II fractures treated with a long retrograde intramedullary nail. The authors reported 100% healing rate at mean 12-weeks follow-up, mean flexion was 111°, and mean post-operative Knee Society Score (KSS) was 81.5. Malalignment was documented in 4 cases. Finally, Toro-Ibarguen et al²⁰ reported the outcomes of 26 type II fractures. Non-union was reported in one case, and after mean follow-up of 81 months 7 patients underwent revision TKA.

Locking plates. Locking plate fixation is currently considered the main option in case of type II fractures, together with intramedullary nailing. Locking plates are particularly effective in osteoporotic bone working through a fixed-angle construct.^{4,10,15,16} In addition, this fixation system has increased stability at varus stress, it allows the use of polyaxial screws and enables a better reduction compared with intramedullary nailing.^{4,10,15,16} Contraindications to this technique are implant loosening, in which a component revision is necessary, and elderly patients with multiple comorbidities.^{4,10,15,16,21} Song et al²² compared the outcomes of distal femur locking plates in patients with periprosthetic fractures and patients with non-periprosthetic fractures of the distal femur. The authors reported no difference in healing rate, time of union, clinical outcomes, radiological outcomes and re-operation rate among the 2 groups.

Intramedullary nailing versus locking plate. No consensus has been reached regarding the best treatment for Lewis and Rorabeck type II fractures.¹⁵ According to the current literature there are no high-quality randomized controlled trials comparing the outcomes of the 2 techniques. Intramedullary nailing requires a less aggressive approach, enables earlier weight bearing and achieves healing with bone (callus) formation, however, it has some contraindications (fractures within 20 mm from the femoral component, or small open box).^{10,15} Locking plates have no relative contraindications except the comorbidities of the patient.^{10,15,22} When comparing the 2 techniques, Shah et al,¹⁵ reported similar union rates (1.188 patients). Despite that, locking plates were associated with significant lower complication and reoperation rates, while intramedullary nailing was associated with faster recovery to full weight bearing (100% at 7.6 weeks VS 94% at 15.8).¹⁵ Ebraheim et al⁴ reported the outcomes of 448 distal femur periprosthetic fractures reporting that plating and intramedullary nailing are valuable and effective options in Lewis and Rorabeck type II fractures with healing rate of 87% and 84%, respectively.

Revision TKA and distal femur replacement. In case of Lewis and Rorabeck type III fractures, ORIF is not enough, and the loose component should be revised with an implant with a higher level of constraint.^{5,10,23} Implant revision is a valuable option in case of failed fixation, however, bone stock, fracture comminution, and bone quality are crucial elements.²⁴ Stem extensions are usually required to enhance fixation beyond the fracture line and can be cemented in case of thin cortex and wide medullary canal, or press-fit in case of good bone-quality.^{4,10} DFR is usually considered the last option in case of poor bone stock, multiple failed surgeries, or severe distal comminution for elderly patients in order to allow early weight bearing.^{4,10,25,26} Highly constrained rotating hinge implants (RHK) are not widely used despite the grade of bone loss and/or ligamentous instability.²⁷⁻²⁹ However, Joshi et al²⁷ and Efe et al,²⁸ reported acceptable outcomes with RHK in case of Lewis and Rorabeck type III fracture, despite the small cohorts of patients. When considering tumor-type prosthesis, restoring the joint line and balancing the extensor mechanism are complex steps of the procedure.^{4,10} According to the current literature, there is a lack of evidence on the outcomes of megaprotheses after periprosthetic distal femur fractures. Distal Femur Replacement (DFR) provides a stable diaphyseal fixation enabling early weight bearing and early mobilization, key elements in the treatment of elderly patients in order to avoid severe medical comorbidities due to immobilization. Despite that, it requires high costs for the hospital (>12.000\$/patient³⁰), and it is associated with mortality rate ranging from 6% to 35%, higher risk of reoperations, and PJI, which is a catastrophic complication.³¹ However, DFR can be considered a valuable and effective salvage procedure when less invasive options have failed, as reported in the current literature.^{31,32}

Proximal Tibial Periprosthetic Fractures

Proximal tibial periprosthetic fractures are rare complications after TKA, and they are usually associated with high-energy trauma, with a reported incidence ranging between 0.4 and 1.7% according to the AOANJRR.³ Multiple host-related risk factors have been described, including morbid obesity, osteoporosis, and long-term therapy with bisphosphonates.^{10,6,33-35} However, periprosthetic tibial fractures have been frequently described as intraoperative complications associated with the positioning of a stemmed tibial trial or definitive component, and during component's removal in revision TKA.³⁶

Periprosthetic tibial fractures classification. The most popular classification was described by Felix et al⁷ in 1997 on 101 proximal tibia periprosthetic fracture evaluated at the Mayo Clinic (Rochester, MN) between 1970 and 1995. This classification, also known as the Mayo Classification system, describes the fracture based on 2 characteristics: the position in relation to the tibial component, and the stability of the tibial component. There are 4 fracture types, and 3 subtypes per each category (A for stable implant, B for loose implant, C for intraoperative

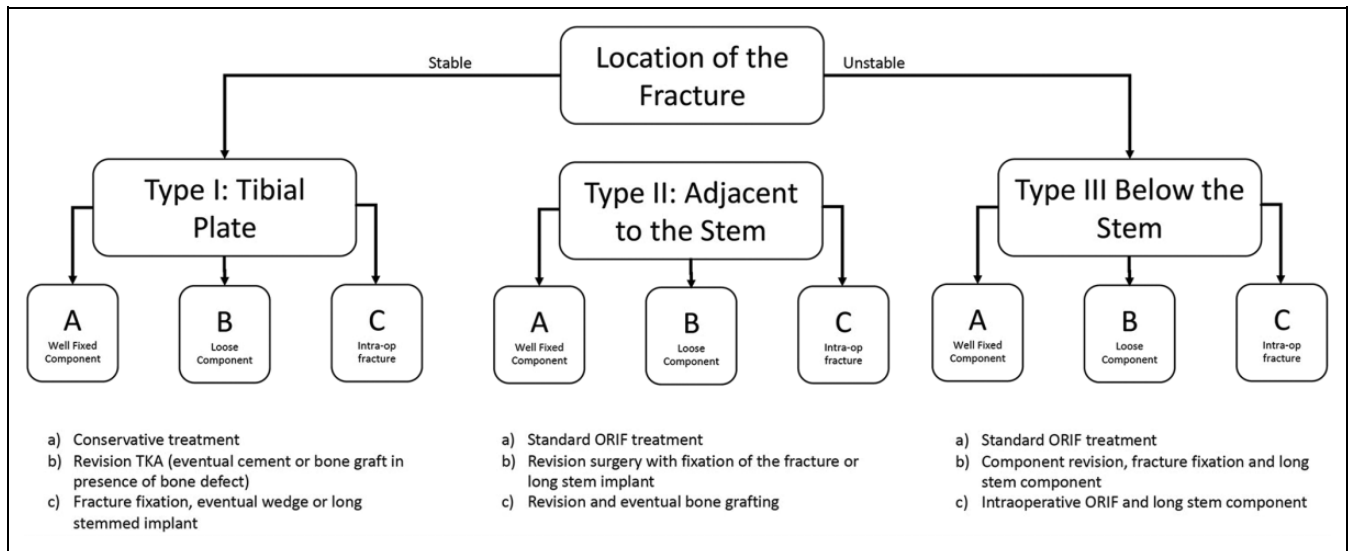


Figure 2. Flowchart—treatment for periprosthetic fractures of the proximal Tibia.

fracture). Type I fractures are at the level of the tibial plateau. Type II fractures are at the level of the metaphysis or the meta-diaphyseal junction (near the tibial stem/keel if presents). Type III fractures are distal to the tibial stem. Finally, type IV fractures are the avulsion of the tibial tubercle. In the original study⁷ type I was the most common pattern (61 of 101 cases, 60.3%), followed by Type II (22 cases, 21.8%).

Management of proximal tibial periprosthetic fractures with a stable component (Type IA, IIA, and IIIA). In case of proximal tibia periprosthetic fractures with a stable tibial component the ORIF should be the first option. However, some patterns of type IA and IIA can be treated nonoperatively with brace or cast immobilization for at least 6 weeks. The stability of the fractures needs to be checked regularly every 2 weeks with X-ray evaluation in antero-posterior (AP) and lateral views, considering ORIF in case of secondary displacement. Displaced type 2A fractures should be treated with a fixed-angle plate, and in case of a tibial stem or keel, unicortical screws should be used to obtain primary fixation. In case of type 3A fractures usually a long locking plate is necessary to by-pass the fracture and provide stable fixation.^{7,33} According to the current literature, only few studies have reported the outcomes of proximal tibia periprosthetic fractures with a stable tibial component.⁷ Kim et al,³⁷ reported the outcome of 16 cases treated with a minimally invasive locking plate where type 2A was reported in 6 cases (37.5%), and type 3A in 10 (62.5%). Fracture healing was reported in 87.5% of cases at a mean of 17.2 weeks, and non-union was reported in 2 cases. Morwood et al,³⁸ reported on 38 periprosthetic fractures (4 type IA, 7 type IIA, 27 type IIIA) caused by high-energy trauma (55.4% of cases) and low-energy trauma (44.7%). ORIF was performed in 31 cases (81.6%), and intramedullary nailing was performed in 4 (10.5%). Complete healing was reported in 76.5% of the cases after 6 months. When non-union was reported, it was usually in the proximal

third of the tibia. Overall reoperation rate was 31.6% (12 cases). The most frequent cause of reoperation was non-union (13.1%, 5 cases), followed by early infection and subsequent irrigation and debridement (10.5%, 4 cases) (Figure 2).

Management of proximal tibia periprosthetic fractures with a loose component (Type IB, IIB, and IIIB). In case of proximal tibia periprosthetic fractures with a loose tibial component (type IB, IIB, IIIB), the tibial component should be revised. Often, a total knee revision with a long-stemmed tibial component is necessary to obtain a stable fixation of the fracture and an adequate joint reconstruction. When tibial component fixation is obtained, further internal fixation may be necessary in case of unstable bone fragments. Bone defects of the proximal tibia should be reconstructed with metal augments in order to obtain implant stability. In case of small-to-medium bone defects (≤ 5 cm), metal augments with thicker polyethylene insert can be effectively used; however, severe bone defects or comminuted fractures requires more aggressive treatment using either strut allograft or tumor megaprosthesis.^{36,39}

Management of Subtype C (Intraoperative) and Type IV Fractures. Intraoperative proximal tibia periprosthetic fractures are more frequent than femoral fractures. This type of fractures occurs during implant positioning in primary TKA, or during component removal in revision TKA. The choice of treatment is based on the status and type of fracture. The stability of the implant may not be compromised, and the fracture could be treated with screw fixation or by adding stem extensions. If the fracture is recognized and treated correctly intra-operatively, there is no difference in post-operative rehabilitation compared to a normal primary or revision knee replacement.^{6,33,40,41} In case of unstable type IC fractures, a secure option may be screw fixation and implant of a long-stemmed tibial component that bridges the fracture engaging the distal diaphysis and enhances

fixation. In case of type IIC, a long-stemmed tibial component can be used while bone grafting the fracture site. Finally, type IIIC fractures can be managed either with internal fixation or with nonoperative treatment based on the fracture site and pattern.³³

Type IV fractures, involving the tibial tubercle, should be treated with particular attention to avoid the disruption of the extensor mechanism. Felix et al⁷ reported bone healing in 2 cases of type IVA fractures (one conservative treatment and one screw fixation). In addition, polypropylene mesh tape or semitendinosus rerouting for fixation of tibial type IV fractures have been proposed by Hanssen et al.³⁹

Patellar Periprosthetic Fractures

Patellar periprosthetic fractures classification. Periprosthetic patellar fractures are a rare complication after TKA ranging between 0.2% and 21% in case of replaced patella and 0.05% in case of non-resurfaced ones.^{42,43} It occurs typically within the first 2 years after primary TKA, and it is usually caused by a traumatic event.^{44,45} Patellar resurfacing, morbid obesity, lateral release, and implant design have been associated with increased risk of fracture.³³ Implants with a large central peg cause greater anterior patellar strain resulting in increased fracture risk.⁴⁶ In addition, osteonecrosis should be prevented by preserving peripatellar soft tissue and by protecting the lateral superior genicular artery during lateral retinacular release.^{43,47}

The most widely used classification system was described by Goldberg et al.⁴² This classification is based on the integrity of the extensor mechanism and the stability of the patellar component. Type I fractures are considered the most frequent and are characterized by an intact extensor mechanism and stable patellar component. Type II fractures are characterized by either a compromised extensor mechanism or a loose component. In type III the fracture is at the patellar distal pole, and it is further classified in type A or B based on the extensor mechanism integrity. Type IV are classified in case of patellar fracture and dislocation.⁴² Recently, Ortiguera and Berry,⁴⁴ proposed a new classification system of periprosthetic patellar fractures where in type I the implant is stable and the extensor mechanism is intact, in type II the extensor mechanism is compromised with a loose patellar component, and in type III the implant is loose with an intact extensor mechanism. Type III fractures are classified in IIIA in case of good bone stock, and IIIB in case of poor bone stock (thickness < 10 mm or severe comminution).

Patellar periprosthetic fractures treatment. Ortiguera and Berry,⁴⁴ proposed a surgical approach based on their classification system. Type I fractures are treated conservatively with high success rate (1 failure out 38 cases). Type II fractures require a reconstruction of the extensor mechanism, or a partial or total patellectomy if reconstruction is not possible. In type IIIA a revision of the patellar component should be performed, while in type IIIB a complete patellectomy is often necessary. Some authors recommended in case of severe comminuted fractures nonoperative treatment or removal of bone fragments with

attachment of the patellar or quadriceps femoris tendon to the bone.^{45,48} In addition, extensor mechanism allograft can be considered as an option, however, this procedure is difficult, and it is characterized by a high grade of failure and postoperative complications.^{9,45} In case of stable implant, the treatment is based on the bone stock. With good bone stock, revision TKA or patellectomy can be performed, while in case of poor bone stock, partial or complete patellectomy are recommended.³⁶

Conclusions

Despite increasing technology have been progressively introduced in TKA to achieve better outcomes and reduce the incidence of complications, periprosthetic knee fractures remain a severe problem. The correct treatment should be based on a thorough understanding of the fracture pattern and its characteristics, while considering risk factors, patients' comorbidities, and local conditions. Nonoperative treatment, locking plate fixation, intramedullary nailing and revision TKA are valuable options when applied in the right circumstances. Satisfactory clinical and radiographic outcomes can be achieved when periprosthetic knee fractures are deeply understood and correctly approached. However, a considerably relevant complication rate remains an issue after treatment of periprosthetic knee fractures.


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ORCID iD

Giorgio Cacciola  <https://orcid.org/0000-0001-7739-4819>

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