Interprosthetic Fractures of the Femur

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abstract

As the rate of hip and knee arthroplasty procedures increases, so will the rate of interprosthetic fractures. Several factors, including bone quality, bone quantity, and stability of the prosthetic components, play a role in determining the appropriate operative treatment. Patients with stable components should undergo reduction and internal fixation, while patients with loose components should undergo either revision arthroplasty, with or without additional fixation, or conversion to total femur replacement. Despite implant and technique advances, complications remain frequent. [Orthopedics. 201x; xx(x):xx-xx.]

Interprosthetic (IP) femur fractures—those occurring between a total hip arthroplasty (THA) and a total knee arthroplasty (TKA)—have been shown to complicate approximately 1.25% to 8.8% of ipsilateral hip and knee arthroplasties (Figure 1).1,2 As the rate of total joint arthroplasty increases, these fractures are likely to increase in incidence. Interprosthetic fractures pose a number of challenges for the treating surgeon, including poor bone quality and quantity and potential lack of total joint arthroplasty component stability, leading to complication rates of up to 57%.3

Multiple treatment options exist, including various forms of fixation and revision arthroplasty. Early studies4,5 first noted the difficulty in treating these fractures, as indicated by low union rates and poor outcomes. Despite implant and technique advances leading to improved results, no proven algorithm exists, and these fractures remain challenging to treat. In addition to the difficulty in treating these injuries, patients with periprosthetic femur fractures are at risk for requiring further surgery and have a 1-year mortality rate of approximately 17.5%.6-8

RISK FACTORS

Multiple risk factors play a role in the development of periprosthetic fractures. These factors may be patient specific, implant specific, or technique related.9 Patient-specific factors include osteoporosis, osteomalacia, and other conditions of bone that may weaken its structural integrity.9-11 Implant-related factors include implant design, loosening, infection, and prior revision surgery.9-11 Technique-related factors include malalignment, inappropriate implant size, stress shielding, osteolysis, and distal femur notching.9-11 Certain factors are specific to the development of IP fractures of the femur, such as the presence of 2 implants and the spacing between them. Biomechanical studies have shown that the presence of a proximal femoral stem reduces the strength of the femur approximately 32%.12 Additionally, when an ipsilateral retrograde rod is placed, this risk doubles.13 Lehmann et al14 found that a constrained knee prosthesis that is not loose does not increase the risk of an IP fracture in patients with an existing THA hip stem.

Conflicting evidence exists in the literature to determine if a smaller distance between intramedullary implants increases fracture risk. Using a finite element analysis model, Soenen et al15 determined an IP distance of less than 110 mm increases femur fracture risk in osteoporotic bone.

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femoral component has been well studied and validated, acting as a guide for treatment. The Lewis and Rorabeck classification and the Su classification of peri-prosthetic femur fractures about a TKA are also well-known to orthopedic surgeons and act as a guide for treatment. Several classification systems have been suggested for IP fractures but have yet to be validated.

Fink et al suggested an addition to the existing Vancouver classification. They classified IP fractures as either type IA, occurring between a stemmed prosthesis of the hip and surface replacement prosthesis of the knee, or type IB, occurring between 2 stemmed prosthetics. Type IA fractures are further subclassified according to implant stability: stable implants as type IA1 and loose implants as type IA2. Using this classification, Fink et al created an algorithm where type IA1 fractures are treated with osteosynthesis and type IA2 fractures are treated with revision of the prosthesis or possible total femur replacement. Type IB fractures are treated with either conversion to total femur or osteosynthesis. Fink et al reported successful treatment of these fractures using this approach.

Soenen et al modified the Vancouver classification by adding a type D. This type includes fractures that occur in between a total hip stem and a revision knee prosthesis with stem. They noted that all type D fractures in their series sustained at least 1 complication, believed to be due to the limited amount of bone stock present between these prosthetics and the subsequent stress concentration.

Pires et al created a classification system for IP fractures of the femur based on fracture site, viability of IP bone fragment, and prosthesis stability (Figure 2). In their algorithm, all type A fractures are treated with osteosynthesis, whereas types IB/C and IIB/C are treated with revision of the loose prosthetic component and osteosynthesis. Types ID and IID are treated with total femur replacement. Type IIIB fractures are treated with either total femur replacement or osteosynthesis. Types IIIC and IID are treated with total femur replacement or revision and osteosynthesis.

Hoffmann et al, in their retrospective series, found that neither the Soenen classification system nor the Pires classification system correlated with the development of a nonunion after open reduction and internal fixation.

Duncan and Haddad developed another classification system based on the Vancouver classification. Their classification, named the Unified Classification System, applies to periprosthetic fractures about any anatomical region. Types A, B, and C are consistent with the Vancouver classification. Type A fractures involve an apophysis or protuberance of bone to which soft tissue is attached. Type D fractures involve a bone that supports 2 joint replacements (ie, IP femur fracture). Type E fractures involve 2 bones that provide fixation for 1 joint replacement (ie, an ipsilateral distal femur and proximal tibia fracture in a patient with a TKA). Type F fractures involve a joint surface that is not resurfaced but is articulating with an implant (ie, glenoid fracture in a glenoid arthroplasty).

Duncan and Haddad suggest that type D fractures be treated using a “block-out analysis.” That is, consider what would be done for a periprosthetic fracture about one component if it were in isolation first (ie, total hip stem). Next, consider the same for the other component (ie, total knee femoral component). A plan is then created based on the combination of these individual analyses.

Platzer et al created a classification system based on fracture location and prosthetic stability. Type I fractures are those distal to the tip of the shaft and proximal to the knee component. Type II fractures are adjacent to either the hip shaft or the knee component. Type III fractures are adjacent to both prosthetic components. The classification is then di-
vided into A (both components are stable), B (one is stable and one is loose), or C (both components are loose). Type B fractures are then subclassified into type B1 (the hip component is loose) and type B2 (the knee component is loose). Platzer et al\textsuperscript{25} found, in their series of 23 patients with IP femur fractures, that the 2 delayed unions and 1 nonunion that occurred were in patients with type IIA fractures.

**TREATMENT AND RESULTS**

As with other periprosthetic femur fractures, patients should first be evaluated by a medical team to ensure that they are stable for surgical intervention. After medical optimization, the treatment plan should be tailored specifically to each patient. Fracture location, prosthetic stability, prosthetic design, and remaining bone quantity and quality should all be considered. Open reduction and internal fixation should be performed for patients who have a stable prosthetic component and sufficient bone suitable for internal fixation. The most common methods for stabilization of IP femur fractures include various plating techniques and intramedullary nailing. Whenever treatment is pursued, the same goals should be kept in mind: preservation of blood supply, restoration of length, alignment, rotation, and sufficient stabilization to allow for early mobilization.

**Plate Fixation**

Plate fixation comes in many forms, and significant heterogeneity exists both within and between studies on its outcomes. During preoperative planning for plate fixation, the surgeon should consider techniques that preserve vascular supply to bone. Additionally, during reduction and fixation, the surgeon should practice atraumatic soft tissue techniques. Further, the surgeon should plan for plate lengths that will provide sufficient stabilization and stress distribution. Farouk et al\textsuperscript{26} compared minimally invasive plate osteosynthesis with conventional open plating in a native distal femur model. They found that the minimally invasive plate osteosynthesis group had better periosteal perfusion in all cadavers and improved medullary perfusion in 70%, concluding that minimally invasive plate osteosynthesis disrupts the blood supply less.\textsuperscript{26} Regarding plate length, Kubiak et al\textsuperscript{27} used a cadaver model to assess prosthetic gap and overlap when a THA femoral stem is in place and a distal lateral locking plate is applied for a supracondylar femur fracture. They recommended either overlapping the plate with the THA component or leaving an IP distance of greater than 8 cm, in the absence of regional osteopenia. A gap of 2 cm was found to be the most biomechanically disadvantageous when compared with both an overlapping plate and an 8-cm gap model.\textsuperscript{27} Using a similar model, Walcher et al\textsuperscript{28} recommended that, from a biomechanical standpoint in osteoporotic bone, the optimum gap or overlap between the stem and the plate be at least 6 cm.

Results of conventional non-locking open plating have been unfavorable. Kenny et al\textsuperscript{1} described 2 patients who underwent conventional plating; both had nonunion after the index procedure. Among 5 patients with IP fractures who underwent conventional open plating, 3 went on to nonunion in the study by Soenen et al.\textsuperscript{3} Michla et al\textsuperscript{29} and Della Valle et al\textsuperscript{30} have shown successful use of the dynamic condylar screw for IP femur fractures in single patient series.

The use of locking plate technology has aided orthopedic surgeons in the treatment of patients with osteoporosis who...
sustain operative fractures (Figure 3). Fixed-angle locking compression plates, placed using a minimally invasive plate osteosynthesis technique, and the less invasive stabilization system (LISS; DePuy Synthes, Paoli, Pennsylvania) have been shown to have more favorable results compared with conventional open plating for the treatment of IP fractures of the femur; however, they are not without complications, including nonunion.3,22,23,31-36

In a retrospective review of 22 patients who received either locking compression plates or LISS plating for IP fractures of the femur, Sah et al11 noted a 100% union rate with no infections, nonunions, or malunions. Furthermore, 1 patient required removal of symptomatic hardware. All patients had primary TKA components in place. The authors emphasized the importance of avoiding soft tissue stripping.31 Chakravarthy et al32 described a fracture distal to the locking compression plate and proximal to the TKA component in a patient with a Vancouver type C fracture, emphasizing the importance of maximizing plate length. Fulkerson et al33 treated 3 patients with the LISS plate, with 1 patient going on to nonunion and the other 2 having union at 5 and 8 months. Platzer et al25 treated 19 of 23 IP fractures of the femur with an angular stable lateral plate, with 2 delayed unions and 1 nonunion. Only 73% of patients in that series achieved a satisfactory result.25

Pires et al22 described 6 patients with IP fractures of the femur; 2 were treated with LISS plating, 1 with a locking compression plate, 1 with a 95° blade plate, 1 with a retrograde rod, and 1 with an Ilizarov frame. All patients went on to union, with the patient treated with the Ilizarov frame developing a pin-site infection.22 Soenen et al13 treated 5 of their 14 IP fractures with locking compression plate bridge plating, with 1 patient later requiring formal open plating and the remaining 4 patients going on to uneventful union.

Mamczak et al34 described 26 patients who underwent locked plating via a “tissue-preserving exposure.” All 20 patients available for final follow-up went on to union. Complications included 3 patients with malunion, 2 patients with painful hardware, 1 patient with thigh pain due to a loose prosthesis that required revision,
and 1 patient with superficial infection.\textsuperscript{34} Hou et al\textsuperscript{35} treated 7 patients with locked bridge plating; 2 patients died prior to final follow-up. The remaining 5 patients had union, with 1 requiring revision of a loose prosthesis 3 years later.\textsuperscript{35}

Polyaxial locked plating may be advantageous for patients with IP fractures of the femur, as it provides a fixed-angle construct while allowing for variability in screw placement. This may allow placement of screws into superior-quality bone and around the existing prosthesis. Ruchholtz et al\textsuperscript{36} reported on the use of a polyaxial plate in 41 periprosthetic femur fractures, 3 of which were IP fractures. Twelve percent of patients required reoperation for a major complication. The outcomes of the patients with IP fractures were not commented on, specifically.\textsuperscript{36} Hoffmann et al\textsuperscript{23} used a polyaxial plating system with submuscular insertion in 27 patients with IP fractures of the femur. Twenty-four of the patients went on to union after the index procedure.\textsuperscript{23}

\textbf{Intramedullary Nailing}

Retrograde nailing of the femur remains an option for patients with IP fractures of the femur who have a TKA prosthesis that is able to accommodate retrograde nail placement (Figure 4). As noted previously, when a retrograde nail is inserted with a THA femoral stem in place, this does increase stress concentration and fracture risk at the intervening bone site.\textsuperscript{13} Placement of a retrograde nail for an IP fracture of the femur is not without complications. Valle Cruz et al\textsuperscript{2} treated 2 of 5 IP fractures of the femur with retrograde nailing; 1 failed to unite and required revision to a hinged knee arthroplasty. Two of the 14 cases reported by Soenen et al\textsuperscript{3} were treated by retrograde nailing, with 1 of these patients developing a nonunion and later a surgical-site infection.

\textbf{Revision Arthroplasty}

If there is nonunion about the prosthesis or minimal IP bone between prostheses, revision arthroplasty or total femur arthroplasty may be a valuable option. Additionally, any patient with a loose component should undergo revision arthroplasty or total femur replacement. If both components are loose with little remaining bone stock, strong consideration should be given to total femur replacement.

Total femur arthroplasty has been shown to have mixed results, with favorable results reported for select patients but poor functional outcomes reported for the elderly.\textsuperscript{37,38} Limb salvage is more beneficial for these patients than amputation, but total femur replacement remains a demanding operation, with a complication rate of 32\% and infection rates ranging from 8.6\% to 13.5\% reported.\textsuperscript{39-45} An interpositional device may be used for select situations in place of total femur replacement, as it requires less extensive soft tissue dissection and stripping.\textsuperscript{38} Walker et al\textsuperscript{5} suggested matched THA and TKA components for revision cases using an interpositional sleeve. They reported favorable results for a series of 3 patients for whom previous attempts at fixation using this technique failed. A THA stem was inserted into a TKA sleeve that was filled with polymethylmethacrylate.\textsuperscript{5} Patel et al\textsuperscript{26} used a similar design for the treatment of 15 patients with IP fractures of the femur who required revision of one component. They used a hollow cylindrical component that was cemented in place over the retained stem of the remaining component.

There was a 93.3\% survival rate, with 1 revision at an average follow-up of 5.3 years (range, 0.5-19.3 years). The authors noted that this technique provides diaphyseal reconstruction, allowing for immediate weight bearing. Additionally, the technique maintains soft tissue attachments and subsequent hip and knee stability, permitting improved rehabilitation.\textsuperscript{26}

\textbf{Complications}

As noted previously, these fractures are not benign, having complication rates of up to 57\% and a 1-year mortality rate of approximately 17.5\%.\textsuperscript{3,8} Despite advances in implants and techniques, nonunion remains a concern when using osteosynthesis. Additionally, patients are at risk for malunion, infection, hardware failure, need for further surgery, and other complications.\textsuperscript{2,5,7-9,23,25,32-36}

\textbf{Conclusion}

Treatment of an IP fracture must be tailored to the patient. Although no validated classification system or treatment algorithm exists, orthopedic surgeons who have a thorough understanding of these
injuries and potential complications can achieve successful outcomes for patients. Stability of THA and TKA components and the quality and quantity of remaining bone stock should be used to guide treatment. For patients with stable prosthetic components and sufficient IP bone, preference should be given to reduction and stabilization with soft tissue–preserving techniques and the use of locked plating with sufficient length to prevent stress concentration. For patients with unstable prosthetic components, revision arthroplasty should be pursued with consideration of total femur replacement or interpositional arthroplasty. If both THA and TKA components are loose, total femur replacement should be considered.

References

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