The Treatment of Periprosthetic Fractures

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Abstract

The management of periprosthetic fractures is an issue of increasing importance for orthopaedic surgeons. Because of the expanding indications for total joint arthroplasty (TJA) and an aging population with increasingly active lifestyles, the incidence of primary and revision TJA is increasing, and there is a corresponding increase in the prevalence of periprosthetic fractures about a TJA. The management of these fractures is often complex because of issues with obtaining fixation around implants, dealing with osteopenic bone or compromised bone stock, and the potential need for revising loose TJA components. In addition, these injuries frequently occur in frail, elderly patients, and the literature has demonstrated that both morbidity and mortality in these patients is similar to that of the geriatric hip fracture population. As such, the early restoration of function and ambulation is critical in patients with these injuries, and effective surgical strategies to achieve these goals are essential.

This chapter reviews the current evidence regarding the management of periprosthetic fractures of the upper and lower extremities. Fracture fixation and revision arthroplasty techniques are discussed.

Lower Extremity

Proximal Femur

Periprosthetic fractures of the femur represent an important potential complication of total hip arthroplasty (THA). Although these are relatively rare injuries, with an incidence of approximately 1% after primary THA and 4% after revision THA, the consequences of these fractures are substantial. The 1-year mortality rate after surgical fixation of these injuries is as high as 11%, which parallels that of the hip fracture population.

Classification

The most commonly used classification system for periprosthetic proximal femoral fractures is the Vancouver classification, which stratifies these injuries based on the location of the fracture and the stability of the implant (Table 1). This classification system is
Table 1
Vancouver Classification of Periprosthetic Femoral Fractures in Total Hip Arthroplasty

<table>
<thead>
<tr>
<th>Type</th>
<th>Fracture Description</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Fracture around the trochanters</td>
<td>Mainly conservative. ORIF for displaced greater trochanter fractures or loose stems</td>
</tr>
<tr>
<td>A₁</td>
<td>Greater trochanter</td>
<td>ORIF (cable/locking plate, strut allograft)</td>
</tr>
<tr>
<td>A₂</td>
<td>Lesser trochanter</td>
<td>Diaphyseal engaging implant</td>
</tr>
<tr>
<td>B</td>
<td>Fracture about the stem or just distal</td>
<td>Diaphyseal engaging implant; consider allograft supplementation</td>
</tr>
<tr>
<td>B₁</td>
<td>Stable implant</td>
<td>ORIF</td>
</tr>
<tr>
<td>B₂</td>
<td>Loose implant with good bone stock</td>
<td>ORIF</td>
</tr>
<tr>
<td>B₃</td>
<td>Loose implant with poor bone stock</td>
<td>ORIF</td>
</tr>
<tr>
<td>C</td>
<td>Well below the implant</td>
<td>ORIF</td>
</tr>
</tbody>
</table>

ORIF = open reduction and internal fixation.

relatively simple, is reliable, and serves to guide treatment.

Imaging

Diagnosis, classification, and subsequent surgical management rely on the careful evaluation of AP and lateral radiographs of the entire femur and hip. Location, displacement, comminution, and the surrounding bone stock should be carefully assessed. Radiographs also should be critically assessed for signs of implant loosening to distinguish between type B₁ and B₂ fractures. Whenever possible, preinjury radiographs should be obtained for comparison. The implant-bone, cement-implant, and cement-bone interfaces should be carefully evaluated. Radiographic signs of definite loosening include progressive periprosthetic or cement mantle lucency, a change in the position of the stem, and component or cement fracture. Radiographic signs of probable loosening include greater than 2 mm of periprosthetic or cement mantle lucency around the entire prosthesis, bead shedding, endosteal scalloping, and endosteal bone bridging at the tip of the stem. Occasionally, this chapter's authors find CT useful for evaluating stem loosening if radiographic findings are inconclusive. To differentiate between type B₁ and B₂ fractures, an assessment of bone stock is necessary and is based on the appearance of the cortices and the generalized density of the bone on radiographs.

Management

The management of periprosthetic fractures of the femur about a THA is based on the Vancouver classification. Type A₁ fractures involving the lesser trochanter are generally treated nonsurgically, unless they extend substantially into the calcar and affect prosthesis stability. (In this setting they are best classified as type B₂.) Type A₂ fractures involving the greater trochanter are managed nonsurgically if nondisplaced or only minimally displaced. Displaced fractures are treated with open reduction and internal fixation (ORIF) with or without bone grafting and liner exchange if associated with eccentric wear of the polyethylene liner and substantial osteolysis. Type B₁ fractures are treated with isolated ORIF. Type B₂ fractures are treated with femoral component revision and fracture fixation. The stem should bypass the fracture by at least two cortical diameters. Type B₂ fractures require revision, ORIF, and, oftentimes, allograft to restore bone stock. Type C fractures occur well below the stem and can generally be treated with isolated ORIF.

The focus of this section is the management of type B₁ fractures that require fixation around a well-fixed implant. It is of critical importance to confirm the stability of the implant in this setting because the most commonly cited reason for the failure of fixation when treating these fractures is implant loosening, presumably caused by unrecognized loosening associated with the fracture. A careful assessment of preoperative imaging to evaluate for any signs of implant loosening is critical; if any doubt remains, implant stability should be confirmed intraoperatively by either examining the bone-implant interface through the fracture site or with an arthrotomy of the hip and stressing the implant. Corten et al. reported that 20% of implants judged as stable based on preoperative radiographs were found to be loose at the time of surgery. The optimal fixation strategy for type B₁ fractures continues to be an issue of substantial controversy, with some authors advocating for cable plating combined with an anterior allograft strut (Figure 1) and others advocating for isolated lateral locked plating (Figure 2). Regardless of the fixation strategy used, several biomechanical and surgical principles must be adhered to when treating these fractures. First, proximal fixation around the stem is best achieved with a combination of wires or cables and screws, and it is critical that sufficient overlap of the femoral prosthesis be obtained to avoid...
mechanical failure⁹ (Figure 3). Second, it is imperative that the fracture is fixed without the stem in varus because increased rates of fixation failure have been reported with varus positioning of the stem.¹⁰ On rare occasions, this can require revision of a well-fixed implant if it has been implanted in substantial varus. It is important to adhere to the principles of absolute versus relative stability, which depend on the type of fracture healing desired. In the setting of a simple transverse or spiral fracture, absolute stability and compression at the fracture site should be achieved using compression plating or lag screw fixation. This is in contrast to comminuted fractures, which require relative stability and spaced fixation to allow for fracture healing indirectly by callus formation.

This chapter’s authors prefer to use a cable plate with an anterior allograft strut in a 90-90 configuration, particularly in the setting of fracture comminution, impaired fracture biology (for example, diphosphonate-associated fractures, diabetes, and smoking), or osteopenic bone. The biomechanical literature supports this construct as being the most stable and further suggests that there is no advantage to locked versus nonlocked plating when combined with an allograft strut.¹¹ Advocates of isolated lateral locked plating have reported good results and suggest that this technique has the advantages of minimally invasive application and the preservation of fracture biology.⁷,⁸ Comparative literature between the two techniques is lacking, and there is insufficient evidence to provide a strong recommendation for one strategy over the other.

Distal Femur and Stable Total Knee Arthroplasties

The published incidence of periprosthetic fractures of the distal femur above a total knee arthroplasty (TKA) is between 0.2% and 2.5% for primary TKAs and up to 30% for revision TKAs.¹² These fractures present a unique set of management challenges. The goals of treatment of a periprosthetic fracture around a well-fixed TKA include (1) a healed fracture; (2) appropriate length, alignment, and rotation of the limb; (3) a painless, stable TKA; and (4) functional range of motion of the knee.

Imaging and Investigations

High-quality radiographs of the affected knee and femur should be carefully reviewed to determine the location and the displacement of the fracture lines, identify any comminution, assess the stability of the femoral component of the TKA, and quantify the bone stock available for distal fixation. CT scans are valuable in evaluating these fractures, particularly in regard to assessing the distal bone stock and determining if the femoral box is open and large enough to accommodate a retrograde nail. Whenever possible, previous surgical notes should be obtained to identify the existing prosthesis, confirm that the femoral
Figure 2  Preoperative AP radiograph of the hip (A) and lateral view of the femur (B) showing a periprosthetic fracture of the femur below a well-fixed total hip arthroplasty (Vancouver type B1) in an elderly woman. Postoperative AP radiographs of the hip (C) and femur (D) demonstrating fixation with an isolated lateral locking plate.

Figure 3  Six-week postoperative AP (A) and lateral (B) radiographs of the hip and femur showing a periprosthetic femoral fracture treated with a lateral plate, anterior allograft strut, and cables. Inadequate overlap of the femoral component was obtained proximally and the fixation failed into varus. Postoperative AP (C) and lateral (D) radiographs of the hip and femur demonstrate revision fixation with a lateral plate, anterior allograft strut, and cables with adequate overlap of the femoral prosthesis.
box is open and replacement is possible, and verify that trial polyethylene liners are available if a retrograde nailing technique is chosen for management.

**Classification**
The Rorabeck and Taylor classification system is the most commonly used classification system for periprosthetic fractures of the distal femur above a TKA13 (Table 2). Although it remains useful, this classification lacks some important information that pertains to management, including distal bone stock and the location of the fracture.

**Treatment**
In nondisplaced fractures, nonsurgical treatment in the form of a cast or a hinged brace with protected weight bearing may be considered. Close radiographic surveillance is required to ensure that fracture displacement does not occur. As a result of high rates of nonunion, malunion, and knee stiffness after the nonsurgical management of displaced periprosthetic fractures of the distal femur, nonsurgical treatment is reserved for nonambulatory patients or those who cannot tolerate anesthesia.14

Surgical treatment is indicated for most patients. Modern options for the surgical treatment of fractures with a stable implant (type 1 or 2) include locked plating or retrograde intramedullary nailing. Two separate systematic reviews have shown that both locked plating and retrograde intramedullary nailing have important advantages over nonlocked plating in regard to improved union rates and decreased rates of malunion and secondary surgical procedures.15,16 As such, it is generally agreed that these fractures are best treated with one of these two constructs. However, there is substantial controversy in the literature regarding locked plating versus retrograde intramedullary nailing. In general, the literature has shown good outcomes with either technique, but comparative literature between the two is lacking.17-25 A recent systematic review by Ristevski et al16 compared locked plating with retrograde intramedullary nailing for the treatment of distal femoral fractures above a TKA. The authors reported that retrograde intramedullary nailing had a statistically significant higher rate of malunion compared with locked plating (Figure 4); however, there was a nonsignificant trend toward increased nonunion rates with locked plating. The authors concluded that locked plating may offer some advantages over retrograde intramedullary nailing, but further research is needed.

There are several important situations in which retrograde intramedullary nailing cannot be used, including the presence of a closed femoral box or a stemmed femoral component (Figure 5), an ipsilateral THA, or an extremely distal fracture where sufficient fixation cannot be obtained with distal locking screws.19 In these situations, the fracture is best treated with locked plating. When using a locking plate, it is

<table>
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<tr>
<th>Table 2</th>
<th>Rorabeck and Taylor Classification of Periprosthetic Distal Femoral Fractures in Total Knee Arthroplasty</th>
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<tbody>
<tr>
<td>Type</td>
<td>Fracture Description</td>
</tr>
<tr>
<td>Type 1</td>
<td>Nondisplaced fracture with no loosening of components</td>
</tr>
<tr>
<td>Type 2</td>
<td>Displaced fracture (&gt;5 mm of displacement or 5° of angulation) with no loosening of components</td>
</tr>
<tr>
<td>Type 3</td>
<td>Any supracondylar fracture associated with loosening of components</td>
</tr>
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Figure 4  A, Preoperative AP radiograph of the left knee and femur of an elderly man showing an open periprosthetic distal femoral fracture above a well-fixed total knee arthroplasty. Postoperative AP (B) and lateral (C) radiographs of the left knee and femur demonstrate fixation with retrograde intramedullary nailing. Extension deformity on the lateral radiograph demonstrates the typical malunion deformity that occurs with retrograde intramedullary nailing.
important to adhere to the principles of absolute versus relative stability. Simple fracture patterns should be treated with a construct that provides absolute stability to promote primary bone healing. Multifragmentary fractures should be treated with a construct that provides relative stability (such as bridge plating) so as to lead to secondary bone healing.

The management of distal femoral fractures above a stable TKA requires careful consideration of the issues described earlier because there is substantial controversy regarding the ideal fixation construct. Further research is needed to clarify these issues and guide management.

**Proximal Tibial Fractures and TKAs**

Periprosthetic tibial fractures around knee prostheses are relatively uncommon, and there is very limited literature available.

**Classification**

The Mayo classification subdivides these fractures based on the anatomic location: (1) medial or lateral tibial plateau, (2) adjacent to stem/keel (metaphyseal), (3) distal to stem (diaphyseal), and (4) involving the tibial tubercle. Injuries are further subclassified based on whether the fracture is associated with a well-fixed prosthesis, is associated with a loose prosthesis, or occurs intraoperatively.26

**Treatment**

Revision arthroplasty is required for most type 1 fractures involving the tibial plateau because these usually occur in association with a loose TKA secondary to polyethylene wear and osteolysis. Metaphyseal (type 2) fractures occur around the keel/short stem of modern primary TKA designs. Revision arthroplasty is required if the prosthesis is loose or failing or if there is insufficient bone stock available for fracture fixation. Revision is typically performed with a stemmed revision prosthesis to bypass the defect, combined with a strategy for managing expected bone loss. For smaller defects, bone loss can be managed with metal augments; however, large defects may require bulk allografts or trabecular metal cones.

ORIF is preferred when the TKA is stable and there is sufficient bone for stable fixation. This situation is the norm for diaphyseal periprosthetic tibial fractures (type 3) and often the case for metaphyseal fractures (type 2). The main challenge to surgical treatment is...
the presence of the tibial component, which precludes the use of an intramedullary nail and complicates proximal fixation. Strategies to manage this situation include locking plate fixation (plus or minus variable angle-locking screws) as well as the use of multiple plates to stabilize the proximal segment (Figure 6). Infection is a serious complication in the setting of an arthroplasty. The soft tissue should be respected, and minimally invasive strategies can be attractive to possibly reduce infection rates and promote union.

Revision Arthroplasty for Periprosthetic Fractures and TKAs

With a stable prosthesis, fixation is usually preferable to revision arthroplasty to avoid the creation of very large bone defects. There is some controversy in the literature regarding the necessary amount of distal bone for fracture fixation.25 This determination is most often made based on a thorough radiographic review, typically including CT scans if the quality of the distal bone stock is in question (Figure 7). In the absence of a universally agreed-on threshold with regard to distal bone stock, a tailored approach is required, with the treating surgeon understanding the available fracture implants and whether they will have sufficient purchase in the available distal bone.

After determining that a revision is required, two major scenarios are possible. The first scenario is that there will be insufficient bone for distal fixation alone but enough salvageable bone that, after healing, some support for the prosthesis and supporting ligaments will be present (Figure 8). In this situation, limited ORIF of the condyles can maintain bone stock and the ligamentous attachments, thus reducing the amount of constraint required in the prosthesis while preserving anatomy.
for potential future revisions. The revision construct will require stems that bypass the metaphyseal region as well as a partially constrained prosthesis (varus-valgus constrained) to protect the repaired ligamentous origins. However, a fully constrained hinge is usually not required.

The second scenario occurs when there is essentially no functional distal bone to support the revision prosthesis. This is the more common scenario, usually occurring in elderly patients with very poor bone quality. Revision arthroplasty with management of the massive bone defect is required. Options include using either a distal femoral allograft (Figure 7) or a tumor-type distal femoral replacing prosthesis (Figure 9).

For younger patients with expected longevity to require future revision, the retention of bone stock or the replacement of bone stock with bulk allograft is an attractive but more technically demanding option. Arthroplasty using a distal femoral replacement is a technically easier and quicker procedure, but it is associated with high prosthesis cost and difficulties with later revision. However, distal femoral replacement offers the advantage of immediate stability and weight bearing in a patient population that is typically elderly and prone to complications from prolonged immobilization. A carefully considered and individualized approach is required to optimize the outcomes in these situations, taking into account patient factors and institutional expertise.

**Upper Extremity**

Periprosthetic fractures in the upper extremity are relatively uncommon compared with those of the lower extremity. However, with increasing numbers of upper extremity joint arthroplasties being performed each year, these fractures will likely be seen more commonly. Risk factors for such fractures include advanced age, female sex, a prior history of fracture, osteoporosis, rheumatoid or inflammatory arthritis, and revision surgery. Periprosthetic fractures in the upper extremity may occur intraoperatively or postoperatively. In general, intraoperative fractures most frequently occur during the insertion of trial or definitive components or the removal of components during revision surgery. Fractures also may occur during reduction or dislocation maneuvers, positioning of retractors, retraction against resistant soft tissues, overzealous reaming or broaching, or during procedures for joints with substantial deformity. Postoperative fractures may be a late presentation of an unrecognized intraoperative event, occur as the result of a low-energy fall or (less frequently) high-energy trauma, or present in association with a loose component.
The incidence of periprosthetic fractures about a shoulder arthroplasty has been reported to range from 0.6% to 3%, with most fractures occurring either intraoperatively or postoperatively as a result of low-energy trauma. Glenoid Fractures

There is a paucity of literature pertaining to periprosthetic glenoid fractures. These fractures are relatively rare and most often occur intraoperatively. It is anticipated that the incidence of these fractures may increase as un cemented glenoid components in the setting of both total shoulder arthroplasty and reverse shoulder arthroplasty become more popular. Periprosthetic glenoid fractures noted intraoperatively require a careful assessment of remaining glenoid bone stock and the anticipated stability of the implanted prosthesis. Often, the fracture occurs during preparation or impaction of an un cemented glenoid component, leading to a split of the anterior or the posterior aspect of the glenoid surface. If the fracture can be reduced and appropriately stabilized and the prosthesis can be placed on stable host glenoid bone, then insertion of the glenoid component can proceed. In the setting of reverse shoulder arthroplasty, screw fixation placed through the base plate may further facilitate both fracture and implant stability. If stability of the implant cannot be achieved with fracture fixation, consideration should be given to staging the procedure with a humeral hemiarthroplasty or an excision arthroplasty and a plan to return after the glenoid fracture has healed sufficiently to implant a stable glenoid component. Postoperative glenoid fractures are often displaced and may be associated with glenoid component wear and/or loosening. Most often, this necessitates revision surgery. At the time of surgery, glenoid bone stock must be assessed, and consideration should be made for using structural bone graft if primary fixation of the fracture is not possible. After reconstruction of the glenoid, the construct should be evaluated, and the anticipated stability of the glenoid assessed. If there is uncertainty regarding the stability of the glenoid, consideration should be given to a staged procedure.

Humeral Fractures

Periprosthetic humeral fractures associated with either hemiarthroplasty of the shoulder or total shoulder arthroplasty are relative uncommon, occurring at a rate of 0.5% to 3%. There are several classification systems for periprosthetic humeral fractures. The Wright and Cofield classification system describes the location of the fracture relative to the prosthesis (Table 3; Figure 10).

Intraoperative periprosthetic humeral fractures often occur secondary to poor bone quality in association with overzealous reaming, broaching, and trialing, particularly with un cemented prostheses. Careful preoperative templating to anticipate implant sizing may help decrease fracture risk. Metaphyseal fractures can occur with aggressive proximal humeral retraction for access to the glenoid. When identified intraoperatorily, humeral shaft and metaphyseal fractures should be reduced and stabilized with cerclage wires and/or plate and screw fixation or allograft struts combined with a longstem humeral component to bypass the fracture by at least two cortical diameters. Tuberosity fractures should be addressed with anatomic reduction and suture fixation to the surrounding bone.

<table>
<thead>
<tr>
<th>Type</th>
<th>Fracture Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type A</td>
<td>Begins at the tip of the prosthesis and extends proximally</td>
</tr>
<tr>
<td>Type B</td>
<td>Begins at the tip of the prosthesis and extends distally</td>
</tr>
<tr>
<td>Type C</td>
<td>Occurs well distal to the stem</td>
</tr>
</tbody>
</table>

Table 3 Wright and Cofield Classification of Periprosthetic Humeral Fractures in Shoulder Arthroplasty
bone and/or prosthesis. Humeral component stability must be assessed; if a stable, uncemented construct cannot be achieved, the surgeon should consider cementing the component and accepting the associated increase in nonunion risk.35

Periprosthetic fractures of the humerus noted in the postoperative period can occur because of trauma or may be a delayed presentation of an intraoperative fracture. Nonetheless, treatment is dictated by the stability of the humeral component and the overall fracture alignment. Substantially displaced tuberosity fractures will inevitably lead to poor rotator cuff function, and consideration should be made for reconstruction.36 Fractures of the humeral shaft associated with a stable prosthesis and reasonable fracture alignment can be treated nonsurgically.30,35 However, consideration can be given for surgical fixation to allow for early range of motion. Fractures associated with unstable humeral components require revision surgery and fracture fixation. Humeral shaft fractures with substantial displacement or unacceptable alignment should be considered for surgical fixation and are often treated with a combination of plate and screw, cable, and allograft strut fixation (Figure 11).

Periprosthetic Fractures After Total Elbow Arthroplasty
The incidence of fractures after total elbow arthroplasty has been reported to be approximately 5% after primary surgery.37 Fractures of the humerus or the ulna associated with total elbow arthroplasty are treated in a similar manner to periprosthetic humeral fractures associated with shoulder arthroplasty.

Classification
Periprosthetic fractures about a total elbow arthroplasty are described by the Mayo classification37 (Figure 12). Type I fractures occur in the
periarticular or the metaphyseal region, including the humeral condyles and the olecranon. Type II fractures occur at the level of the humeral or the ulnar component, and type III fractures occur either proximal to the humeral component or distal to the ulnar component. These are further subdivided to account for bone quality and implant stability.

**Humeral Fractures**

Similar to the shoulder, intraoperative humeral fractures occurring during total elbow arthroplasty can occur as a result of poor bone quality, retraction, or overzealous reaming and broaching. Fractures proximal to the tip of the prosthesis (type III) should be exposed, reduced, and reconstructed using allograft strut or plate and screw or cable techniques. Fractures about the stem (type II) may be treated with reduction, cemented long-stem components, and cerclage wiring with or without allograft struts. Fractures involving the medial or lateral columns of the distal humerus (type I) may be left in situ, reconstructed, or resected in the setting of a semiconstrained hinged prosthesis. In the setting of an unconstrained elbow implant, these fractures must be anatomically reduced and fixed because postoperative elbow stability depends on these structures; otherwise, revision to a constrained implant may be necessary. Postoperative fractures associated with substantial displacement or prosthesis loosening should undergo revision and fixation, whereas fractures with stable components and reasonable alignment may be considered for nonsurgical management in selected patients. Because bone stock is often an important issue with these fractures, the frequent use of allograft struts is required in their management.

**Ulnar Fractures**

Periprosthetic ulnar fractures are uncommon. In general, these fractures are managed surgically to maintain forearm function. Intraoperative ulnar fractures may occur secondary to poor bone quality and ulnar component preparation. Periprosthetic olecranon fractures (type I) must be evaluated for stability. Very proximal unstable fractures can be treated with either suture fixation or triceps advancement techniques. More distal olecranon fractures may adequately be treated with a tension-band wiring technique or plate fixation. Ulnar metaphyseal fractures (type II) can be treated with cerclage wires and long-stem components, whereas fractures occurring distal to the implant (type III) often require fixation with plate and screw or allograft and cerclage wire constructs. Fractures of the ulna noted in the postoperative period commonly require surgical fixation and/or revision based on the stability of the implant. As with periprosthetic humeral fractures, allograft struts are often required.

**Summary**

Periprosthetic fractures associated with total joint arthroplasty are expected to increase dramatically in the future.
Determining the ideal management requires a careful analysis of fracture patterns and implant stability. The goals of treatment are fracture reduction and healing, while allowing for early mobilization of both the patient and the affected joint. Ultimately, both fracture fixation techniques and revision arthroplasty expertise are required for effective management.

References

The Treatment of Periprosthetic Fractures

Chapter 13


**Video Reference**
