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# Evaluation and Treatment of Postoperative Periprosthetic Humeral Fragility Fractures

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# Evaluation and treatment of postoperative periprosthetic humeral fragility fractures

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**Summary:** Postoperative periprosthetic humeral shaft fractures represent a growing and difficult complication to treat given the aging patient population and associated bone loss. Determining the best treatment option is multifactorial, including patient characteristics, fracture pattern, remaining bone stock, and implant stability. Possible treatment options include nonoperative management with bracing or surgical intervention. Nonoperative treatment has been shown to have higher nonunion rates, thus should only be selected for a specific patient population with minimally displaced fractures or those that are unfit for surgery. Surgical management is recommended with prosthetic loosening, fracture nonunion, or failure of nonoperative treatment. Surgical options include open reduction and internal fixation, revision arthroplasty, or hybrid fixation. Careful evaluation, decision making, and planning is required in the treatment of these fractures.

**Keywords:** postoperative periprosthetic humeral fractures, shoulder arthroplasty, open reduction, internal fixation, revision arthroplasty



## 1. Introduction

Anatomic total shoulder arthroplasty (TSA) and reverse total shoulder arthroplasty (RTSA) have become mainstay treatment options for various shoulder pathologies, including osteoarthritis, rotator cuff arthropathy, massive rotator cuff tear, and proximal humeral fractures. Although the survivorship of these implants at 10 and 20 years have been reported to be over 90% and 80%, respectively,[1,2] complications do occur including instability, scapular notching, infection, neuropraxia, component loosening, and periprosthetic fracture.[3] Postoperative periprosthetic humeral fractures are uncommon, but their incidence is increasing because of the aging population and growing frequency of these procedures.[4–6] The incidence of periprosthetic humeral fractures has dramatically increased by 133% from 2013 to 2019 as reported by the National Joint Registry and is of particular significance because many of these fractures will require revision surgery.[7,8]

Fractures may include the tuberosities, surgical neck, or humeral diaphysis as seen in native humeral fractures. Fractures of the proximal and middle third humeral shaft are the most significant because these are considered fragility fractures and present a challenge in clinical and surgical management.[9] In addition, stress shielding, osteolysis, and loose implants can pose further issues with operative treatments. The aim of this article is to review the epidemiology, risk factors, diagnosis, and current treatment strategies of postoperative periprosthetic humeral fractures.

## 2. Etiology and Risk Factors

The most common cause of postoperative periprosthetic humeral fracture is a ground level fall onto the extremity.[10–12] Fractures can also be low-energy or atraumatic, secondary to prosthetic loosening, causing cortical weakening. These fractures most commonly occur at the sites of highest stress risers in the diaphysis adjacent to the end of a standard-length stem or more proximal in shorter stems and stemless implants.[10]

The reported occurrence rate of periprosthetic humeral shaft fractures is 0.5%–3% after anatomic TSA, which is similar to the rate of periprosthetic hip and knee arthroplasty fractures.[12,13] Singh et al demonstrated in a 33-year study that of those patients who sustain a postoperative periprosthetic humeral fracture, all fractures after stemmed TSA occurred in the humeral shaft, as did 94% of fractures after humeral head replacement.[14] The reported rate is 3 times higher in RTSA and accounts for approximately 20% of all complications.[3,6,13] There is no significant difference in rates between uncemented and cemented arthroplasties.[13,15]

Risk factors of postoperative periprosthetic humeral shaft fractures are mainly patient-related. These factors include advanced age, female sex, osteoporosis, rheumatoid arthritis, and increased comorbidity index.[13,14,16–18] The mean age of patients

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with periprosthetic fractures increased to 80 years in 2018 compared with 71 years in 1994.[10,19] Patients with advancing age are at higher risk of falls and osteoporosis.

## 3. Preoperative Evaluation

On initial evaluation, patient demographics, complete medical and surgical history, and physical examination are critical to obtain. Establishing traumatic versus atraumatic mechanisms and symptom chronicity may provide insights into etiology and appropriate treatment options. Determining functional and activity levels is important to understand the degree of impairment from the injury and can help tailor expectations from treatment. Physical examination should include assessment of skin condition, prior scars, muscle function, and neurovascular status, specifically axillary and radial nerve function. Surgical reports of the existing implant are especially important when considering revision arthroplasty. Workup for the presence of infection is controversial in the setting of an acute injury without signs of implant loosening. In cases of low-energy or atraumatic periprosthetic fractures with radiographic signs of implant loosening or osteolysis, infection workup should begin with obtaining serum laboratory studies, such as complete blood count and inflammatory markers. Although of poor sensitivity, an aspiration has high specificity for diagnosis of periprosthetic joint infection and may be considered.[20]

Imaging is critical in the evaluation of the fracture pattern and in determining component loosening. Anteroposterior (AP) and lateral radiographic imaging of the humerus should be obtained routinely, with shoulder AP, true glenohumeral AP (Grashey), scapular-Y, and axillary views of the glenohumeral joint. Evidence of implant loosening has been described as the presence of radiolucent lines measuring >2 mm in 3 or more zones around the stem.[21,22] Comparison with prior imaging is helpful to determine subsidence or subtle implant tilt from a prior position. Campbell et al described a method of determining osteopenia on imaging based on the ratio of the combined width of the mid-diaphyseal cortices to the diameter of the diaphysis at the same level.[16] A ratio of >50% indicated normal bone, 25%–50% demonstrated mild osteopenia, and severe osteopenia was in <25%. An additional described predictor of poor bone quality is the measurement of the cortical index.[17] Cortical index is the ratio between the cortical thickness and the total diameter of the humeral diaphysis with the fracture risk limit value of 0.231.[23] In addition, in cases of humeral bone loss, bilateral full-length AP humeral radiographs are useful in determining premorbid humeral length.

Metal suppression computed tomography is used to demonstrate the extent of comminution and further delineate the fracture pattern. In addition, it may be a useful tool for preoperative planning because it can assess remaining bone stock and glenoid version if revision arthroplasty is required.[24] Finally, several commercially available preoperative arthroplasty planning software programs exist that allow revision planning, which may be beneficial in selecting implant lengths and diameters.

## 4. Classifications

The oldest and most commonly used classification system is by Wright and Cofield, which describes postoperative periprosthetic humeral shaft fractures in relation to the tip of the humeral stem.[25] Type A fractures are proximal to the tip of the stem or start at the tip and extend proximally; type B are at the tip and may extend distally and type C are distal to the tip of the stem. Worland et al illustrated a similar classification with subdivision of type B fractures based on implant stability.[26] Type B1 and B2 are spiral fractures and oblique fractures, respectively, with stable implants. Type B3 are fractures with an unstable stem. Implant stability can be determined using imaging as described above; however, the most accurate technique in determining stability is intraoperative assessment.

A classification system by Campbell et al defined fractures based on the location of the fracture in the humerus (tuberosities, surgical neck, proximal shaft, and mid-to-distal humerus) and was historically described for intraoperative fractures.[16] Most fractures occur at the distal tip of standard-length stems due to the stress riser effect; however, tuberosity and surgical neck fractures are becoming more common with the use of short-stem and canal-sparing implants. Most recently, a more comprehensive classification system was published by Kirchhoff et al[27] with an algorithm to guide possible treatment options. This system considers implant stability, type of humeral prosthesis, fracture pattern and location, and rotator cuff status. They found a 94% good clinical outcome when their reported algorithm was used for treatment.[27]

## 5. Treatment

All patient-specific and fracture-specific factors must be considered when deciding the most appropriate treatment option, including fracture pattern, bone quality, implant stability, patient health, and baseline functional demands. The goal of surgery is to achieve functional recovery to baseline levels while minimizing complications. Treatment options range from nonoperative management to revision arthroplasty.

Outcomes are usually reported using patient-reported outcome scores including the Constant Shoulder Score[28]; Disabilities of the Arm, Shoulder, and Hand questionnaire (DASH)[29]; Simple Shoulder Test (SST); American Shoulder and Elbow Surgeons Standard Shoulder Assessment Form (ASES)[30]; and visual analogue pain scale (VAS).[31] Postoperative range of motion (ROM) is evaluated at follow-up appointments with forward flexion, abduction, external rotation, and internal rotation behind the back. This is helpful in determining functional range and effects on the activity level.

### 5.1. Nonoperative Treatment

Conservative options include coaptation splinting, followed by bracing. Functional bracing uses the soft tissues and muscles to prevent soft-tissue expansion during muscle contraction and translates it into compressive forces within the brace to stabilize the fracture.[32] This compression cannot be maintained with an excessive soft-tissue envelope and requires patient tolerance and compliance to bracing.[16,32] Nonoperative treatment may be indicated for type C fractures with a well-fixed prosthesis because these can be treated similarly to native humeral shaft fractures.[12,16,26] Although it remains controversial, a nondisplaced or minimally displaced fracture proximal to or at the tip of a well-fixed implant (type A and B fractures) may be amenable to nonoperative treatment.[7,25] Commonly described satisfactory alignment amenable for nonoperative treatment of shaft fractures includes <20 degrees flexion or extension deformity, <30 degrees varus or valgus deformity, and <20 degrees rotational malalignment.[12] However, the above thresholds for nonoperative management are guidelines, and often these values may be surpassed in patients with substantial medical comorbidities that are not ideal candidates for surgery.

The reported success rates of nonoperative treatment are as low as 50%–60% with 47% requiring surgical treatment at a mean of 4 months after injury.[8] Complication rates of nonoperative treatment are as high as 31% and include malunion, nonunion, glenohumeral stiffness, and skin pressure necrosis.[8] There is an increased risk of nonunion with transverse and short oblique fractures compared with long spiral fracture morphologies.[33] These high rates may be secondary to disruption of endosteal blood supply, distraction at the fracture site, and additional transmission of forces through the fracture site secondary to the prosthesis.[33] Furthermore, there is an elevated risk of glenohumeral stiffness because patients will likely not mobilize their injured extremity even with functional bracing. Because of these notable complications, nonoperative treatment may be suitable for stable fractures, frail patients with little functional demand, and those who are unfit for surgery. Despite the fracture morphology, if the implant is loose, surgical intervention is typically indicated.

### 5.2. Operative Treatment

Indications for surgical intervention include unstable fracture patterns, loose prostheses, type B fractures with interposed prosthesis at the fracture site, and patients who failed 3–4 months of nonoperative treatment. The goal of operative intervention is to achieve stable fixation to allow healing that permits early range of motion and return of function. Surgical intervention may use open reduction and internal fixation (ORIF) with suture, cerclage, or plate and screw fixation; revision arthroplasty; or a hybrid construct

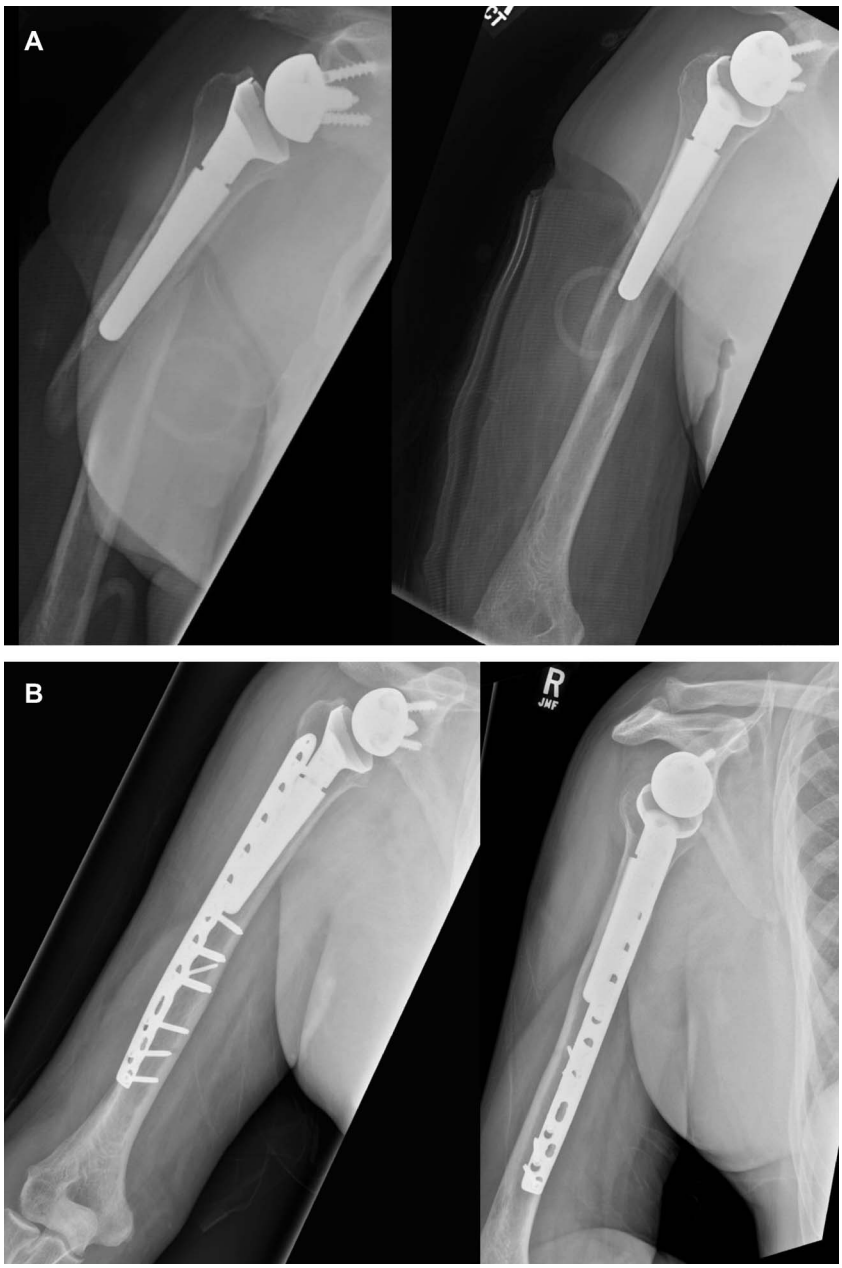


**Figure 1.** A, Long oblique type B periprosthetic fracture with a stable implant. B, Treatment of the fracture amenable with lag screws to provide compression at the fracture site and large fragment plating with unicortical screws proximally at the stem.

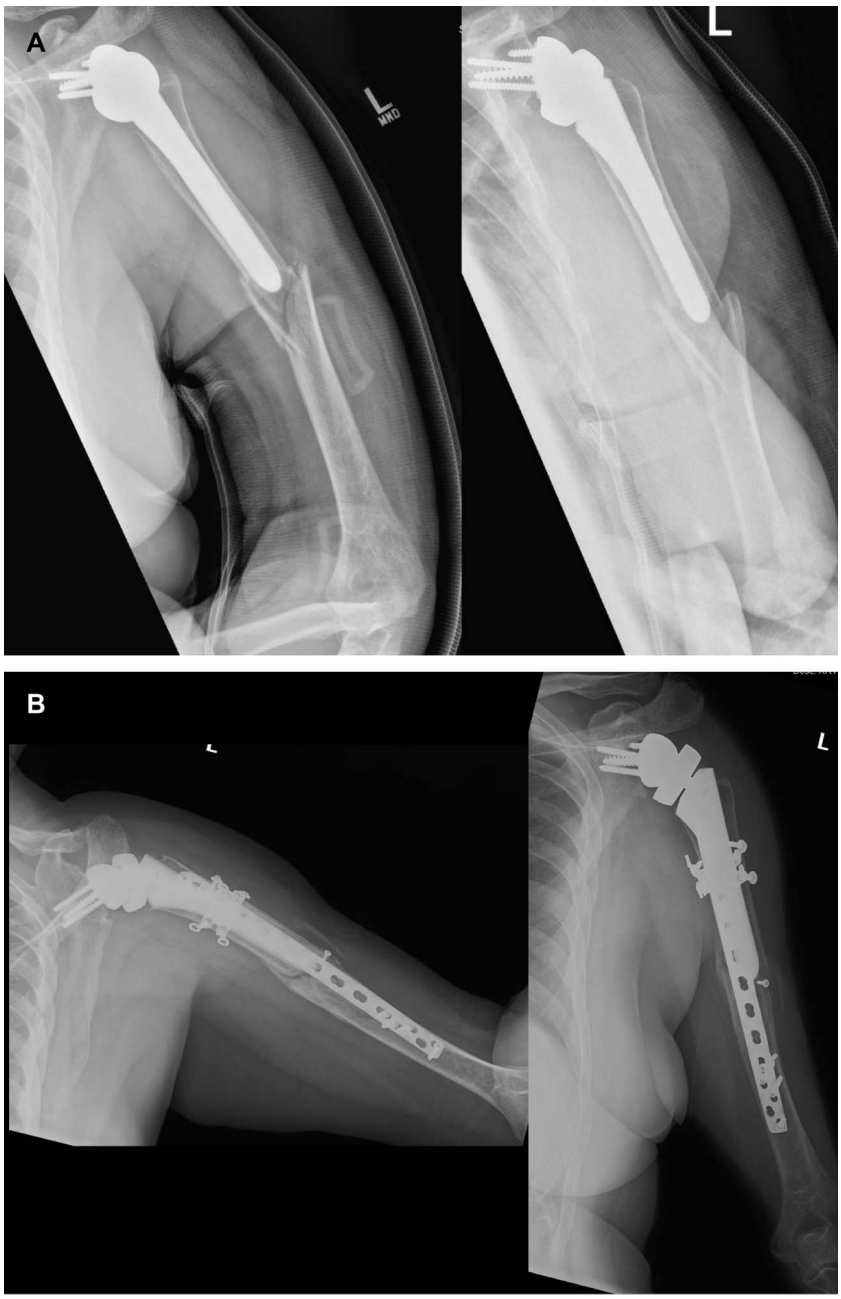


**Figure 2.** A, Comminuted type B periprosthetic fracture with a stable implant. B, Treatment of the fracture with lag screws through larger fragments and large fragment plating with an extension plate for screw fixation around the humeral implant.

between these options. Type A fractures or tuberosity fractures may be treated with suture or cerclage fixation, a proximal humeral locking plate, or revision to RTSA.[12,34] Type B fractures with a stable implant may be amenable to ORIF along with retention of the implant.[7,13] If the implant is loose, revision to a long-stem prosthesis should be strongly considered.[7,10,12,33,35] Type C fractures with a well-fixed stem can be treated with osteosynthesis with plate and screw constructs and additional suture/wire/cable cerclage.[27,36–38]

***5.2.1. Open Reduction and Internal Fixation.*** ORIF is the most common surgical treatment and can be applied in most fracture morphologies in which the prosthesis is well-fixed without evidence of radiographic loosening.[11,27,35] There are 3 approaches to the humerus: anterior, anterolateral, and posterior. The anterior approach is an extension of the deltopectoral approach and provides access to the proximal and middle thirds of the humeral shaft. The disadvantage to this approach is the limited distal exposure. For more distal humeral shaft fractures, the anterolateral (can be extended from deltopectoral incision) and posterior approaches are used and provide direct visualization of the radial nerve. The patient may be positioned in beach chair or supine for anterior or anterolateral approaches or lateral decubitus or prone if the posterior approach is preferred. Given ease of positioning and the extensile approach, the anterolateral approach incorporating the prior deltopectoral incision is commonly used. Intraoperative evaluation of the stability of the implant should

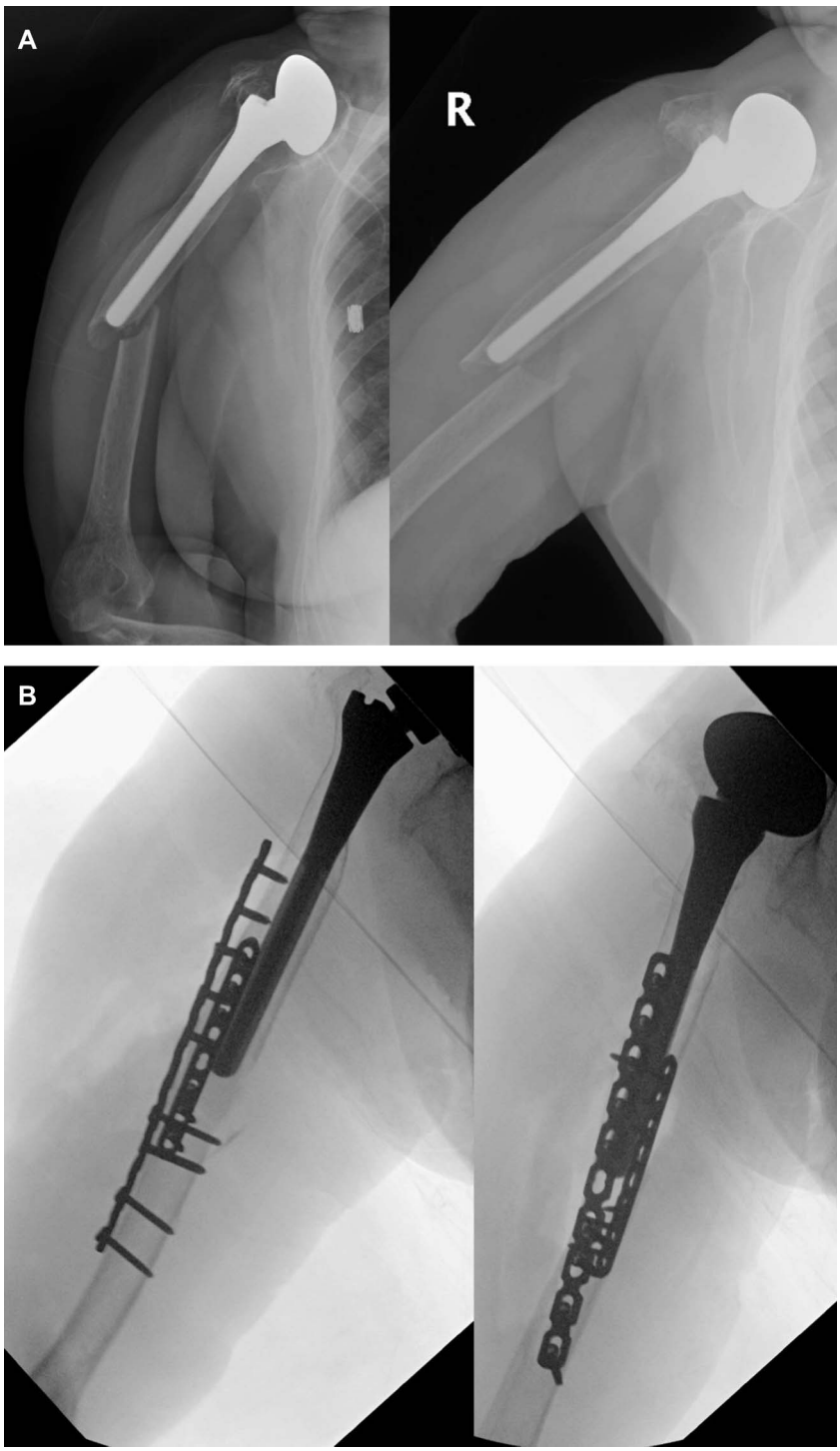


**Figure 3.** A, Type B short oblique fracture with a stable implant. B, Treatment of the fracture with a dual plating construct with mini fragment plating for initial reduction, followed by main plate fixation with a 3.5-mm locking compression plate.

be performed if the stability of the implant is in question. If the implant is loose, it should be treated with revision arthroplasty. In addition, efforts should be made to preserve the deltoid insertion on the lateral aspect of the humerus because detachment may render a RTSA unstable due to loss of tension.

Methods used for ORIF include utilization of screws, cerclage wiring, and/or plate and screw fixation.[11] In stemless humeral components, standard proximal humeral precontoured locking plate systems can be used for fixation.[39] If the tuberosities are fractured in an anatomic TSA or hemiarthroplasty, suture fixation with transosseous sutures or cerclage wiring techniques can be used.[11,40] If the tuberosities cannot be reduced, conversion to RTSA may be performed. Especially in the setting of osteoporosis or bone loss, graft augmentation may also be used. Bone graft can

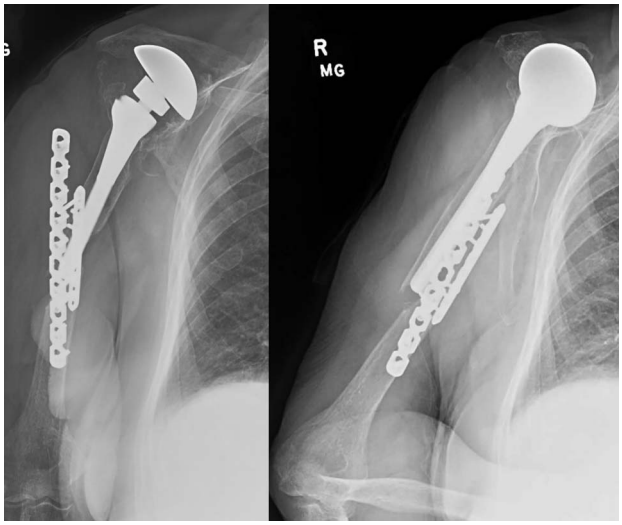


**Figure 4.** Failure of fracture union after ORIF of type B periprosthetic fracture.

give structural support while bridging areas of bone loss or be used at the fracture site to enhance biologic fracture healing.

The 2 main options for plating include large fragment plates and dual plating.[41] The selected plate should overlap the tip of the prosthesis by 2 cortical diameters to prevent stress risers. If the fracture is reducible with reduction clamps or K-wires, compression with lag screw fixation, followed by plate fixation, is most preferred, as shown in Fig. 1. The plate is initially fixed distal to the fracture and the tip of the stem with bicortical screws and then proximally with screws or cerclage wiring. Proximal screws may only be locking unicortical screws or angled around the prosthesis for nonlocking bicortical or polyaxial locking fixation. In Fig. 2, the Synthes plate (Paoli, PA) with an extension locking plate is used to angle screws for better fixation around the stem with bicortical locking screws. If cerclage wires are used, these should always be passed lateral to medial to decrease the risk of radial nerve damage and routine identification of the radial nerve has been recommended during any wire passage distal to the latissimus dorsi.[35,42] Studies have demonstrated better fixation with screw fixation compared with cerclage wiring, which is an important consideration when determining optimal fixation for fracture healing and stability.[43] In fractures that are difficult to reduce, such as short oblique or transverse fractures, the use of dual plating assists with provisional fixation through the initial plate and improves rotational stability (Fig. 3).[35,44] A mini or small fragment plate is used to reduce the fracture for provisional fixation and then the main large fragment plate is placed as described earlier.

Strut graft augmentation can be used to bridge the fracture site and is fixed with cable wiring or plates.[35] The plate is usually placed on the lateral humeral cortex with the strut graft placed medially; however, Vicenti et al described a technique placing the plate posteriorly and graft anteriorly with good outcomes.[45] The graft is compressed to the native bone, and tricortical screws are placed distal to the fracture. The construct is reinforced with unicortical screws, cerclage wires, or bicortical nonlocking or polyaxial locking screws angled away from the stem.[35]

In the setting of significant bone loss with a stable humeral stem, Thés et al described a technique of internal fixation while retaining the implant. The authors described a technique using 2 hemicylinders of allograft to form a "sarcophagus" fixed with cerclage wires and screw fixation.[38] The reported 6 cases all healed by the 6-month follow-up, with no further complications at 12 months postoperatively.

Various studies have described fracture healing at an average 5 to 7 months.[8,35] The overall success rate after ORIF has been reported as high as 93% without further treatments.[8] The mean ASES score, DASH score, and Constant scores improved significantly from preoperative levels.[8] Over 80% of patients are able to return to their preoperative scores after surgery, and approximately 72% of patients are satisfied with their treatment.[8,35] The most common reason for unsatisfactory results are loss of glenohumeral motion.[12,46]

Unfortunately, there is a 17% complication rate and 6% reoperation rate with surgery.[8] Overall, nonunion rates have been described at 13% and can lead to fixation failure from screw pullout (Fig. 4) or broken hardware.[5] Cerclage wiring may result in osseous vascular compromise due to circumferential stripping of soft tissues during passage, which may contribute to the nonunion rate.[11] Other notable complications not requiring revision surgery include nerve injury of the axillary or radial

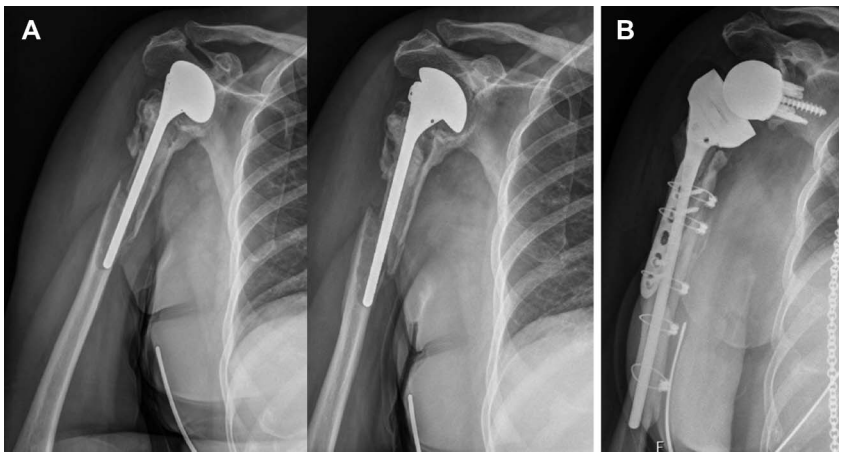


**Figure 5.** A, Type B periprosthetic fracture with obvious loosening of the humeral implant and tuberosity osteolysis. B, Treatment of the fracture with revision arthroplasty to RTSA with a longer humeral stem implant bypassing the fracture by at least 2 cortices and fracture fixation with a large fragment plate and screws with strut graft augmentation.

nerves (6%–25%) and glenohumeral stiffness.[5,47] Most common complications resulting in another revision surgery include deep infection, failure of fixation, and nonunion.

### 5.3. Revision Arthroplasty

Regardless of fracture morphology, revision arthroplasty is the most appropriate treatment option in the setting of a loose prosthesis. If the proximal bone is preserved, the prosthesis can be converted to a longer stem that bypasses the fracture by 2 to 3 cortical diameters.[11,16] This can be supplemented with plate fixation with or without strut graft augmentation (Fig. 5) or cementation. In addition, if the proximal bone stock allows a revision to a short-length implant, this can be performed with fixation of the distal fracture with plates/screws and allograft.

More complex techniques need to be used in the setting of severe bone loss after removal of prosthesis or tuberosity resorption from stress shielding, recurrent implant loosening, or failed revision arthroplasty. Cox et al and Sanchez-Sotelo et al described a technique of allograft prosthesis composite (APC) recommended for fractures with proximal humeral bone loss greater than 5 cm.[48–51] The technique described is using a humeral stem that bypasses the fracture site with proximal humeral allograft around the stem fixed with cable wiring or compression plating. Notable advantages for APC are to improve humeral component support and fixation, provide attachment sites for surrounding soft-tissue structures, and provide structural humeral length. Graft incorporation was seen in 53% of patients in the metaphysis and 84% in the diaphysis, with improvement of mean ASES scores postoperatively.

Another possible option in the setting of severe bone loss is using a humeral endoprosthesis to reconstruct large segmental defects, as shown in Fig. 6.[11] Traditionally used in tumor surgery, a case report was published using endoprosthesis as the salvage procedure in significant bone loss after failed revision arthroplasty and is now performing basic activities of daily living 14 months postoperatively.[52]



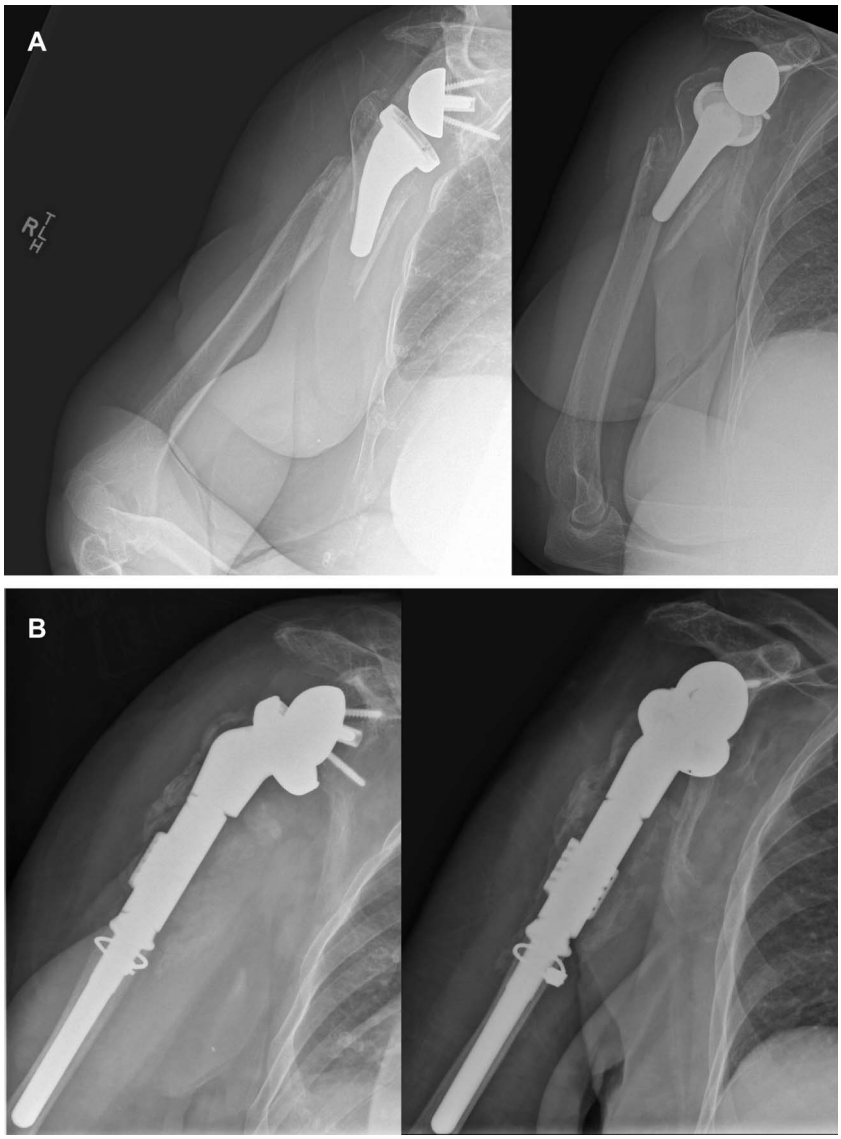


**Figure 6.** A, Periprosthetic fracture with poor bone stock and tuberosity osteolysis with obvious stem loosening. B, Treatment of the fracture with a humeral endoprosthesis.

Various studies report around an 83% success rate with an average time to union of 7.7 months.[8,35] However, mean reported functional outcomes are fair.[12,17] There is often substantial motion loss in abduction and forward elevation with an average value of only 80 degrees. A study reported ASES score at 54 (fair) with a 74% satisfaction rate at 42-month follow-up.[8] Basic activities of daily living were satisfactory in 69% of patients; however, activities requiring greater functional demand were satisfactory in only 38%.[17]

Complication rates are reported to be as high as 29%–39%, with a 16% intraoperative fracture rate and 19% reoperation rate.[8,25,35,53] Complications treated nonoperatively include transient nerve palsies, poor functional outcomes, and rotator cuff tears. Revision surgery is most commonly performed for nonunion, followed by dislocation or dissociation of prosthesis components, deep infection, or conversion of arthroplasty.

### 5.4. Postoperative Management

The goal of postoperative rehabilitation is early passive ROM when safely indicated and is based on adequate fracture fixation. Patients with good bone quality and proper fixation may start gentle passive ROM on the first postoperative day. Otherwise, patients should be immobilized in a shoulder sling postoperatively. Pendulum exercises are initiated early, and active ROM is progressed with formal physical therapy 4 to 6 weeks postoperatively. Active flexion and abduction of the shoulder should be limited to 90 degrees for at least 6 weeks.[5] Internal rotation should be restricted until 12 weeks. By 3 months postoperatively, patients should be able to initiate strengthening exercises and start a gradual return to normal activities.

## 6. Future Treatment and Prevention

The primary prevention of postoperative periprosthetic humeral fractures starts by addressing modifiable risk factors, such as comorbidities leading to increased risk of falls, osteoporosis, and any revision surgery.[40] Additional consideration should be given to the female population given the higher risk of associated osteoporosis.[13,14] Recognizing specific modifiable risk factors is important such as those with a higher comorbidity index because this relates to patients being more frail, the use of multiple pharmaceutical agents, and patients being more prone to falls.[54] Dementia represents a significant risk factor of 27% higher hazard ratio compared with those without dementia.[14]

Factors that may increase the risk of future periprosthetic fracture include poor bone quality, cortical thinning, and malunion of fracture. Graded medullary hand reamers are designed to compress, instead of remove cancellous bone, which may decrease the amount of bone removed.[33] Endosteal notching from aggressive reaming may predispose the humeral shaft because of creation of stress risers at the tip of the prosthesis, which may increase the risk of fracture with lower energy trauma.[33]

Future advancements in the treatment of these complex fractures need to focus on appropriate and stable fixation through the combination of ORIF, revision to long stems, and bone augmentation based on the fracture pattern and bone quality. It is important to mobilize the patient early postoperatively to decrease the risk of glenohumeral stiffness and improve patient satisfaction. In the setting of revision surgery and increased bone loss, the use of proximal humeral allograft and humeral endoprostheses will likely become more common and the techniques will be further developed and refined.

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