Proximal Periprosthetic Femur Fractures: Strategies for Internal Fixation

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Abstract

As the number of patients living with total hip arthroplasty continues to rise, there will be an increase in periprosthetic fractures requiring surgical treatment. Treatment of periprosthetic femur fractures below a well-fixed hip arthroplasty stem presents a unique set of challenges. A review of the existing literature on surgical technique, including plate selection and configuration, proximal fixation options, and use of allograft, can serve to guide treatment of these challenging injuries. While not conclusive, the literature supports using soft tissue preserving techniques, bicortical proximal fixation, and fixation spanning the length of the femur.

The rate of total hip arthroplasty (THA) is rising and demand is expected to increase by 174% to 572,000 by 2030.[1] The rate of periprosthetic fracture around primary THA is frequently reported at around 1%,[2-4] though a recent study of over 32,000 THAs quotes the 20-year probability of periprosthetic fracture at 3.5%.[5] Revision THA is also increasing in frequency and associated rates of periprosthetic fracture range from 1.5% to 7.8% following revision THA,[3,4,6] with the probability of fracture at 20 years of 11%.[7] Projection models predict that the number of periprosthetic fractures will rise by 4.6% per decade over the next 30 years.[8]

Broadly, treatment options include open reduction internal fixation (ORIF), revision THA, and combined approaches. The Vancouver classification, based on fracture location, stem stability, and bone loss, is often used to guide fracture treatment, with stable implants treated with ORIF and unstable implants requiring revision arthroplasty.

Fixation strategies for treatment of periprosthetic fracture around a well-fixed arthroplasty stem have evolved over time, and there continue to be a variety of available internal fixation options with no clear consensus on the optimal strategy.[9] Rates of reoperation following ORIF of periprosthetic femur fracture are reported from 13% to 23%,[8,10-12] confirming that there remains room for improvement in management of these injuries.

Locking Plate Fixation

Early fixation strategies included allograft and cables alone as well as nonlocked plate and cerclage constructs. In response to the complication and reoperation rate for nonlocked plate constructs, reported at 33%,[13] locking plates were introduced as a treatment option, allowing for both improved osseous vascularity and added screw options.[14] When compared to the traditional nonlocked Ogden construct, locking plate constructs are more resistant to axial and torsional load.[15] Clinically, the relative risk of nonunion after nonlocking plate fixation is reported at 11.9 times that of fixation with locking plate technology.[16]

Successful use of lateral locking plate fixation for treatment of this injury has been reported on in several clinical series.[17-20] Froberg and colleagues[12] evaluated 60 Vancouver B1 and C fractures treated by locking plate osteosynthesis and reported no nonunions, an improvement from previous constructs. However, 8 out of 60 patients with 2-year follow-up required reoperation—4 for infection, 3 for refracture, and 1 for stem loosening—making it clear that the locking plate alone was not a panacea.

With locking plate fixation a mainstay of modern treatment of periprosthetic femur fractures, many questions still remain.

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Proximal Fixation

Even with the introduction of locked plates, treatment success after ORIF of Vancouver B1 fractures relies on adequate proximal fixation. Options for proximal fixation around the stem include cerclage wires or cables, unicortical locked screws, obliquely directed bicortical screws, and use of the locking attachment plate to insert bicortical locked screws. These strategies can be used in the presence of cemented or uncemented stems, with biomechanical evidence that screw fixation through the cement mantle does not cause failure.[21]

Several biomechanical studies address the stiffness and strength of varying proximal fixation strategies. While early fixation relied heavily on cables, the use of cables alone as proximal fixation has been linked to significantly higher rates of failure when compared to other constructs in a large clinical series.[11] Multiple biomechanical studies have shown that newer methods of proximal fixation provide more rigid constructs.[22,23]

Unicortical locked screws appear to outperform cables biomechanically. The use of unicortical screws in lieu of or in addition to cables provides added resistance to lateral bending as well as torsion when compared to cables alone.[24] A second group found that unicortical locked screws alone were superior to combined fixation with cerclage wires and unicortical locked screws.[25]

Added stability can be demonstrated by bicortical fixation strategies, which offer increased rigidity when compared to cables or unicortical screws.[22] In vitro work has shown enhanced fixation stability with bicortical screw fixation using the locking attachment plate when compared to cerclage wires alone.[23,26]

Clinically, some authors have demonstrated success with the use of reversed distal femoral locking plates in order to enhance proximal locking options and allow for bicortical fixation around the stem.[19]

As noted above, the data favor the opinion that clinical failure rates with cerclage wires alone are high, and biomechanically, bicortical fixation around the femoral stem appears to be superior to unicortical locked screw fixation or cerclage wires. If rigid proximal fixation is desired, an effort should be made to obtain bicortical fixation around the femoral stem.

Allograft

Allograft strut, either alone or in addition to plate osteosynthesis, has long been used in treatment of periprosthetic fractures. Proponents of this technique cite improved biomechanical stability[17] and allograft incorporation resulting in restoration of bone stock.

Figure 1. (A, B) Anteroposterior and (C, D) lateral x-rays of an 85-year-old man with a comminuted Vancouver B1 fracture between a cemented hip hemiarthroplasty and a total knee arthroplasty.

Early treatment of periprosthetic femur fractures consisted solely of allograft and cable fixation, but data on the technique is limited. A small series reported reasonable success, with only 2 out of 19 patients developing nonunion.[27] More recently Haddad and colleagues[28] reported malunions in 3 out of 19 patients treated with allograft and cables alone. Allograft alone has been largely abandoned in favor of plate fixation, and biomechanical evidence shows that plate and screw or cerclage constructs are more resistant to torsion and lateral bending than allograft with cables alone.[29]

However, the role of allograft in treatment of periprosthetic femur fractures is not clearly defined. Some authors advocate routinely supplementing plate fixation with allograft[28,30] and others go as far as to suggest superior union rates of strut allograft augmented plate fixation when compared to plate fixation alone for periprosthetic fractures around a stable femoral stem.[31] However, in that series, the failure rate of 5/11 patients treated with plate alone is higher than current series,[12] and others have demonstrated good success without allograft, even with nonlocked plates.[32]

As recently as 2016, a lateral locking plate supplemented with allograft has been described as a successful technique, with no nonunions reported in a small series.[30] However, without a comparison group, it is unclear what role the allograft plays in success in that construct.

Despite some proposed benefits, the additional soft tissue stripping required to place allograft has raised the question of delayed healing and increased infection rate as a result of this technique. A systematic review by Moore and colleagues[33] looking at the use of allograft strut in Vancouver B1 fractures found increased time to union (4.4 vs 6.6 months) and deep infection rate (3.8% vs 8.3%) with the use of allograft strut, leading them to recommend cautious use of allograft when treating Vancouver B1 fractures.

With improved fixation strategies available, the role of allograft may be best reserved for patients with inadequate bone stock.

Dual Plate Fixation

Dual plate fixation has been proposed as one mechanism to increase construct strength. A periprosthetic fracture model has shown that, biomechanically, orthogonal plates have higher bending stiffness, torsional stiffness, cycles to failure, and load to failure when compared to a single lateral plate with use of a locking attachment plate proximally.[34] Choi and colleagues[35] compared lateral locking plates alone, lateral locking plates with allograft, and lateral locking plates with an orthogonal anterior plate and found the addition of an anterior plate resulted in the strongest construct.

Clinically, Müller and colleagues[36] reported on a series of 10 patients treated with orthogonal (anterior and lateral) plating for periprosthetic femur fractures, including 3 nonunions. In their series, there was 1 plate failure and they conclude that dual plating is not associated with an increased risk of complications, and can also be used as a salvage procedure.

While the evidence for dual plating is limited, it may provide needed additional stability in cer-

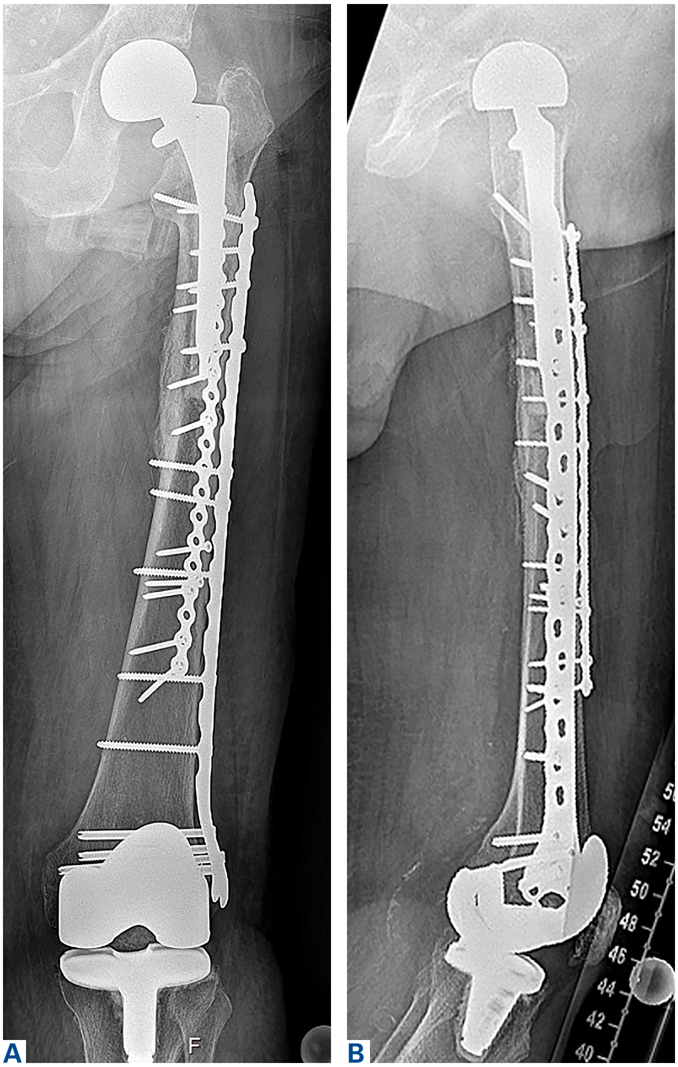

Figure 2. (A) Anteroposterior and (B) lateral x-rays demonstrate a healed fracture at 2-year follow-up. Fixation construct consisted of a 3.5-mm reconstruction plate anteriorly and a laterally based condylar locking plate. A combination of 3.5 and 4.5 mm screws is directed around the stem proximally.

tain cases without the added cost and exposure required for allograft.

Minimally Invasive Plate Osteosynthesis

Contrary to the extensive exposure required to place allograft, minimally invasive plate osteosynthesis (MIPO) of periprosthetic femur fractures is advocated by some authors.[18,20] Ricci and colleagues[18] reported no nonunions in 50 patients treated with indirect reduction techniques and laterally based plating alone without use of allograft. A combination of cables, locking, and nonlocking screws were used. Critical to their technique was preservation of the soft tissue envelope at the level of the fracture.

In further support of MIPO techniques, a systematic review of 1571 periprosthetic hip fractures reported significantly increased risk of nonunion with open approaches when compared to minimally invasive osteosynthesis,[16] emphasizing the role of preservation of vascularity in treating these fractures.

Length of Fixation

For some time it was recommended that fixation of Vancouver B1 fractures end 2 cortical diameters below the level of the fracture.[37,38] More recently there has been interest in the potential benefits of increased length of fixation.

A biomechanical study comparing long (20-hole) and short (12-hole) plates for periprosthetic fracture with regard to failure found no difference in failure rates between groups.[39] While plate length did not appear to affect construct stiffness, the issue of subsequent fracture distal to the construct remains.

Moloney and colleagues[40] proposed fixation of Vancouver B1 fractures using plates that span the length of the femur to the level of the femoral condyles to minimize peri-implant failures in osteoporotic patients. In 36 patients treated with standard-length plates, there were 2 fractures distal to the previous fixation compared to no subsequent fractures in 21 patients treated with spanning fixation.

Similarly, in Vancouver C fractures there is some evidence that fixation should span the femoral stem, regardless of available bone for fixation proximal to the fracture. Kubiak and colleagues[41] found increasing load to failure and decreased cortical strain in a biomechanical model comparing plates that stop short of the femoral stem with those that span the stem.

Clinically, this concept is supported by Froberg and colleagues.[12] In their series of 60 Vancouver B1 and C fractures treated with laterally based locked plating, 3 patients went on to refracture. All of these fractures occurred in patients with Vancouver C fractures treated with plates overlapping the preexisting stem by <50%. The fractures all occurred at the high stress area between the tip of the stem and the end of the plate.

Further support of extended plate length comes from Drew and colleagues,[8] who demonstrated a significantly decreased risk of reoperation following ORIF of periprosthetic femur fracture when >75% of the length of the femur was spanned compared to <50%. Although in some settings short fixation may produce satisfactory results, consideration should be given to extending the length of fixation, especially in the osteoporotic population.

Interprosthetic Fractures

With a rising number of patients with ipsilateral hip and knee arthroplasty, the rate of interprosthetic fractures is rising. These fractures present additional challenges given preexisting implants above and below the level of the fracture. The use of a single precontoured laterally based locked plate has been reported with good union rates approaching 90%.[42,43] In one series, all nonunions occurred in Vancouver B1 fractures,[43] again bringing to light the challenging nature of the B1 fracture.

Nonunion

Success in treating periprosthetic femur fractures has improved with improved fixation methods and understanding of technique. However, current rates of nonunion are still reported up to 27% for B1 and C fractures.[44]

There is limited evidence on the treatment of periprosthetic femur fracture nonunion. However, treatment is difficult and complication rates are high. Crockarell and colleagues[45] reported a 52% overall complication rate in their series of 23 periprosthetic femur fracture nonunions.

Nonunions of the femur near a prosthesis can be treated by revision of the fracture fixation using compression and grafting to achieve bone healing vs revision of the joint prosthesis to span the area of the nonunited bone. Case-by-case decision-making is based on the remaining bone stock and the type of revision prosthesis necessary to span the problem area. Given the challenges associated with their treatment, a focus on prevention of nonunion is of paramount importance.

Authors' Preferred Treatment

Our treatment of periprosthetic femur fractures with a well-fixed hip arthroplasty stem adheres to the principles supported in the literature (**Figures 1A-1D and Figures 2A, 2B**).

- Soft tissue friendly dissection with limited exposure at the fracture site is preferred as the fracture allows, particularly in cases with comminution where a direct assessment of the reduction is not available.
- Plate fixation strategy is dictated by the characteristics of the fracture. Fracture patterns amenable to anatomic reduction receive interfragmentary compression and absolute stability constructs. Highly comminuted fractures receive relatively stable bridging constructs to encourage callous.
- Locking screws are used rarely in diaphyseal fracture patterns, and when employed, are applied to only one side of the fracture to limit "over stiffening" the construct.
- Liberal use of dual plating, both as a method of maintaining fracture reduction while a structural plate is applied and increasing construct rigidity.
- Proximal fixation relies heavily on bicortical screws placed through the holes of the lateral plate. Cerclage wires and unicortical screws are rarely used in our practice. In the case of larger stems, a bicortical 3.5-mm screw can be placed through a 4.5-mm plate using a reduction washer.

Summary

Techniques for treatment of periprosthetic femur fractures around a well-fixed hip arthroplasty stem are constantly evolving. Several principles have emerged to decrease rates of treatment failure and subsequent reoperation. While there are several methods to do so, it is critical to achieve stable proximal fixation. Long spanning fixation constructs are linked to lower failure and reoperation rates in both B1 and C type fractures. Additionally, the importance of soft tissue management and maintenance of local vascularity should not be underestimated.

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