Open Reduction Internal Fixation for Proximal Humerus Fractures
Indications, Techniques, and Pitfalls

Brandon S. Shulman, B.A., and Kenneth A. Egol, M.D.

Abstract
Proximal humerus fractures account for approximately 5% of all fractures. It is estimated that due to our aging population, orthopaedic surgeons will see a three-fold increase in proximal humerus fractures over the next 30 years. Internal fixation with locked plating is the current mainstay of treatment for functionally active patients who desire minimal loss of function. A thorough understanding of the indications, techniques, and drawbacks of treatment with internal fixation is essential to achieve the highest quality of patient care.

The treatment of proximal humerus fractures has been discussed in medical literature dating as far back as the 3rd Century BC. For well over a thousand years, management of these injuries consisted of the Hippocratic method of reduction by forceful extension and manipulation followed by bandaging and delayed splinting. Great progress was made in the 19th Century with the development of advanced splinting techniques and again in the 20th Century with internal fixation for displaced fractures. Today, proximal humerus fractures account for approximately 5% of all fractures and represent the most common humerus fracture. They often occur in patients with poor bone quality, with over 70% occurring in patients 60 years or older, and a 3:1 female predominance. It is estimated that due to the aging population of the USA, orthopaedic surgeons will see a three-fold increase in proximal humerus fractures in the next 30 years. Thus, the importance of skilled and appropriate management techniques cannot be overstated.

Many different techniques have been used to treat displaced or comminuted proximal humerus fractures. Percutaneous pinning and intramedullary nailing have been employed with generally satisfactory results and carry a low risk for infection, soft tissue disruption, and blood loss. However, many of these constructs are less stable than open reduction and internal fixation (ORIF) with locking plates. Thus, they are often fraught with high rates of malunion and nonunion, and nails present the potentioal for hardware migration and neurovascular injury. Conventional buttress plate fixation, while more rigid than minimally invasive techniques, has also been known to undergo fixation loss due to screw cutout in osteoporotic bone. Mechanical studies have shown that conventional plates have decreased stiffness and poorer dynamic loading properties than locked plates. Prior to the advent of locked plating, hemiarthroplasty was the treatment of choice for displaced three- and four-part fractures, as it mitigated many of the problems associated with fixation loss and chronic pain. Patients treated with hemiarthroplasty often had poor functional outcomes. Locked plating has been shown to be an advancement over previous fixation techniques in that it allows for rigid fixation with low rates of fixation loss. Although hemiarthroplasty and more recently reverse total shoulder arthroplasty are used in select cases when reduction cannot be achieved, locked plating is the current mainstay of treatment for functionally active patients who desire minimal loss of function.

Indications for ORIF with Locking Plates
Three major factors must be considered when implementing a treatment plan for patients who have sustained a proximal humerus fracture: the physiological status of the patient, the expertise of the orthopaedic surgeon, and the severity of the fracture. Since the majority of proximal humerus fractures occur in the elderly, age and functional status must

be considered when deciding the appropriate treatment. In our experience, functional status is a better guide to treatment than age. Nonoperative treatment or hemiarthroplasty resulting in a functional deficit may be a greater impediment to an active older patient than a sedentary younger patient. Likewise, operative treatment is rarely recommended for patients with significant medical or mental comorbidities, as the risks of surgery do not outweigh the potential functional gains. The most common comorbidities associated with poor outcomes or increased complication risks are severe osteoporosis, substance abuse, diabetes mellitus, rheumatoid arthritis, compromised immune status, steroid medications, and malignancy. Surgeons must weigh their own expertise and clinical judgment when deciding whether patients are candidates for treatment with internal fixation or arthroplasty.

Fracture severity is also an important consideration when indicating patients for surgical repair. Most fractures of the proximal humerus have a stable configuration and will heal acceptably without surgical intervention. Nonoperative treatment is indicated if there is contact between bone fragments, minimal rotation and translation, and minimal intraarticular involvement. The most commonly used classification system is that of Neer (Fig. 1). Fractures that do not meet the requirements of displacement are often considered one-part fractures. Isolated one-part fractures of the neck, greater and lesser tuberosities, as well as impacted Neer two-part fractures with minimal angulation and rotation may be treated nonoperatively. Significantly displaced Neer two-, three-, and four-part fractures may also be treated nonoperatively in low demand, inactive patients. The percentage of proximal humerus fractures that are non or minimally displaced and treated nonoperatively varies in the literature. Robinson and coworkers in their 2011 review largely agree with Neer that approximately 80% of proximal humerus fractures are non or minimally displaced and therefore not indicated for operative treatment. However, Court-Brown and colleagues in a 2001 prospective study of 1,000 patients reported that only 49% of patients were non or minimally displaced.

Many displaced two-part proximal humerus fractures require surgical intervention (Fig. 2). When two-part fractures are allowed to heal in varus, 32% to 36% of patients will suffer from severe disability and functional deficit at two years follow-up. Surgical neck fractures that are reducible and in patients with high-quality bone do not necessarily need ORIF and can be treated with minimally invasive techniques. Two-part fractures that are interposed with soft tissue or are in osteoprotic bone generally require ORIF. Greater tuberosity fractures displaced more than 5 mm in the superior direction are at risk for subacromial impingement and nonunion; fractures with significant posterior displacement are associated with weakness and mechanical obstruction to external rotation. Both fracture patterns have been reported to have better outcomes with ORIF.

Three-part fractures (Fig. 3) are unstable in nature due to the deforming forces of rotator cuff, pectoralis major, and deltoid musculature attaching to the proximal humerus. In multi-part fractures of the proximal humerus, the greater tuberosity can become superiorly and posteriorly displaced due to the forces exerted by the supraspinatus and external rotators. The lesser tuberosity can become medially displaced due to forces exerted by the subscapularis. The humeral shaft can become displaced medially by the pectoralis major. Proximal fragments can become abduced due to the force exerted by the deltoid. In patients with three-part fractures and good baseline functional status, treatment with locking plates is the optimal choice for dependable surgical repair and the preservation of shoulder function. In patients with poor baseline status who do not require extensive shoulder function, hemiarthroplasty remains the treatment of choice.

Four-part proximal humerus fractures present a greater management challenge (Fig. 4). Valgus-impacted four-part fractures are associated with low rates of osteonecrosis and respond well to treatment with reduction followed by internal fixation. Locked plates can also be utilized in displaced four-part fractures when the humeral head is reduced within the glenoid fossa and there is continuous soft tissue coverage. However, the incidence of osteonecrosis in patients with four-part fractures has been reported to be as high as 35%. Solberg and associates in a 2009 study of 122 patients with displaced three- and four-part proximal humerus fractures reported higher complication rates but better functional outcomes in patients who received treatment with locked plates versus hemiarthroplasty.
Treatment of other complex fracture types often requires operative management. While closed treatment may be appropriate for two-part fracture dislocations with acceptable reductions, three- and four-part fracture dislocations generally require surgical repair. Similarly, patients with articular surface fractures affecting greater than 40% of the humeral head generally require surgical repair. Younger patients should be considered for ORIF of both fracture dislocations and articular surface fractures. In the elderly, locking plates with fixed angle capability can be considered if ORIF is chosen. Only rarely is surgical treatment for proximal humerus fractures a medical necessity. Open fractures,
concomitant vascular injury, true head-splitting fractures, and pathologic fractures requiring biopsy comprise the vast majority of instances when nonoperative care is not a viable treatment option for patients with proximal humerus fractures.4

For the majority of patients with relative or absolute indications for operative repair with anatomic restoration of anatomy, locked plate fixation offers the best chance for satisfactory function once the fracture heals.2-4 Ideal candidates for locked plate fixation are patients whose fractures meet the above criteria and whose preoperative function is robust enough that the functional benefits of surgery outweigh the inherent surgical risk.

**Surgical Technique**

It is the preference of the senior investigator that repair of proximal humerus fractures with internal fixation (locked plating) is best performed through the deltopectoral approach with the patient in the beach chair position.4,15 However, a deltoid splitting approach, although more limiting, also allows for implantation of hardware.2 The incision starts proximally at the AC joint and curves lateral to corocoid process toward the deltoid tuberosity. The incision should then be carried from the skin to the external deltoid fascia. The cephalic vein should be exposed carefully using a metzenbaum scissor. While the cephalic vein can be taken medially or laterally, we prefer taking the vein medially along with pectoralis major. The deltopectoral interval should be developed by finger dissection, and a deltoid retractor should be inserted beneath the deltoid muscle. Bursa should then be excised from the fracture site, and the humeral shaft exposed subperiosteally. Several heavy braided nonabsorbable sutures should be passed through the rotator cuff bone-tendon junction, which allows for mobilization of the associated tuberosity and the humeral head.

The focus then becomes fracture reduction. A bone hook can be used to pull the shaft distally for gross reduction, and the pull sutures and an elevator or osteotome can be used to lever the humeral head. Once reduction is radiographically confirmed, Kirschner wires (K-wires) should be employed to hold reduction in place until definitive fixation is applied. The plate should be applied lateral to the bicipital grove. It is critical to carefully choose the position of the plate, as plates affixed too proximally can cause subacromial impingement and too distally can interfere with placement of the inferomedial calcar screws.17 It is best to confirm the plate height with a centrally placed K-wire that corresponds to central portion of the humeral head when viewed under fluoroscopy. Nonlocked screws or other push-pull devices can be used to pull the humeral head to the plate. With radiographic confirmation of fracture reduction, locked screws are applied through the plate into the humeral head and shaft. The number and types of screws used are left up to the surgeon. After the plate has been affixed to the bone with screws, the pull sutures should be inserted through the plate and tied down for extra fixation. Large bone voids can be filled with calcium phosphate cement through a cortical window or inserted through the central hole in the plate if no cortical window exists. This helps decrease fracture settling and reduces the rate of intraarticular screw penetration.18 It is imperative to check the range of motion of the shoulder at this point to ensure proper plate fixation and mechanical performance.

**Figure 4** Four-part fracture treated with locking plate. A. Preoperative AP radiograph demonstrating a displaced four-part fracture. B. Intraoperative AP radiograph following reduction and internal fixation.
function. The wound should then be thoroughly irrigated and final radiographs should be taken prior to closure (Figs. 2B,3B, and 4B). It is important to confirm hardware placement on multiple views to make certain that no screws are penetrating the glenohumeral joint—a common complication of this procedure. Closure is based on the preference of the operating surgeon.

Pitfalls
The traumatic mechanism of proximal humerus fractures can cause injury to the surrounding nervous and vascular structures. The axillary artery is injured in approximately 5% of patients, generally at a site proximal to the anterior circumflex artery and in patients with atherosclerotic disease.5 Brachial plexus injuries are reported to occur at a similarly low rate.3 However, the axillary nerve is somewhat more vulnerable to disruption, especially with anterior fracture-dislocations where it is subject to traction and laceration injuries.5

As with any procedure, the treatment of proximal humerus fractures with locking plates is not without its difficulties. Infection is a relatively uncommon complication due to the abundant vascularity of the region and is estimated to account for approximately 4% of complications.3,19 Block anesthesia can reduce anesthetic complications commonly associated with general anesthesia.20 Nonunion is a rare complication of locking plate treatment. Thanasas and coworkers in a 2009 review of proximal humerus fractures treated with locking plates reported an 8.8% incidence of nonunion leading to reoperation in all fracture classes.15 Solberg and associates reported a similarly low rate in a cohort exclusively consisting of three- and four-part fractures.21 Malunion after treatment with locking plates generally indicates a failure to achieve reduction at time of surgery.5 Like other shoulder injuries, shoulder stiffness can become problematic following treatment with locking plates, especially if patients do not exercise or attend physical therapy.4,5

Two major complications commonly seen with locking plate fixation are osteonecrosis of the humeral head and intraarticular screw penetration. These complications often occur concurrently, as osteonecrosis caused by the initial trauma can facilitate screw penetration through collapse of the humeral head.19 Thanasas and colleagues reported a 7.9% incidence of osteonecrosis in their full cohort of 791 patients and a 14.5% incidence when limiting their cohort to patients with four-part fractures.15 The incidence of intraarticular screw penetration has been reported to be as high as 23%.22 However, we suspect that the incidence of screw penetration is far lower in institutions that frequently treat proximal humerus fractures with locking plates. In a prospective study of 51 patients reported by our group in 2008, we found that 16% of patients had screw penetration on radiographic follow-up.21 We have seen even fewer instances of screw penetration since the publication of that study.

Treatment of displaced proximal humerus fractures with locking plates has been widely reported to afford patients the opportunity for better functional outcomes than other treatment modalities.2,3,8,10,16 However, not all patients treated with internal fixation return to baseline function. Patients with multi-part fractures treated with locking plates do reasonably well; however, they do have statistically worse outcomes when compared with patients with less complex one-part fractures treated nonoperatively as controls.24 Patients with initial varus angulation of the humeral head have also been reported to have significantly worse clinical outcomes than patients with similar initial fracture patterns in valgus angulation.21

Conclusion
Treatment of proximal humerus fractures with locking plates through a deltopectoral approach is an appropriate treatment for active patients with surgically indicated displaced or comminuted fractures. Despite the complications associated with the procedure, locking plates appear to be the best available treatment modality for active patients desiring the functional use of their shoulder when internal fixation is chosen.

Disclosure Statement
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