Proximal Humeral Locking Plate Fixation in a Skeletally Immature, High-Demand Adolescent Athlete

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Proximal humerus fractures in the skeletally immature population are predominately treated in a non-operative fashion due to the tremendous remodeling potential of the proximal humerus. If indications for operative treatment are met, Kirschner wires, cannulated screw fixation, or flexible nails have been traditionally used. Yet, the high-demand, adolescent athlete who engages in contact sports may be undertreated utilizing these techniques. We report on the successful treatment of a high-school football player with a displaced Salter-Harris I fracture of the proximal humerus with locking plate fixation: allowing for rapid recovery.

INTRODUCTION

Proximal humerus fractures comprise 0.45% of all fractures in children and 4% to 7% of all epiphyseal fractures[1-3]. The proximal humeral physis contributes 80% of humeral length[2,4]. Traditionally, proximal humerus fractures in skeletally immature patients have been treated non-operatively due to the tremendous potential for remodeling and the wide functional arc of motion of the shoulder. As a result, even significantly angulated and displaced fractures have achieved union in positions that have allowed for normal or near-normal functional outcomes. Because of the age dependency of the remodeling capacity, excellent therapeutic results after proximal humeral fractures are expected in children younger than 11 years of age regardless of the amount of fracture displacement and angulation[2,4-6]. Non-operative management generally consists of a sling, or less often, a hanging arm cast or assorted braces. Several authors have demonstrated painless range of motion, reliable healing, and full remodeling with non-operative treatment, and note that nonsurgical management is appropriate for proximal humerus fractures in children, even in the setting of extensive fracture displacement[2,4,6].

While the only absolute indications for fixation of a proximal humerus fracture in a skeletally immature patient include open fracture, neurovascular injury, or a severely displaced fracture, relative indications have become increasingly widened with the emergence of new data. Though original studies demonstrated that even severely displaced fractures could be successfully treated without surgery, a subsequent study has recognized that the majority of outcome studies evaluating displaced proximal humeral epiphyseal fractures included few patients that were 15 years or older[7]. Furthermore, the authors who did examine this subset of patients found worse outcomes in severe fractures treated non-operatively[4,8,9]. Operative management has generally included obtaining a closed or open reduction followed by stabilization and fixation with Kirschner (K) wires, cannulated screws, or flexible intramedullary nailing (FIN). Open reduction is necessary if there is soft tissue entrapment (i.e. periosteum or biceps tendon) at the fracture site[10]. Several studies have demonstrated excellent results with these surgical techniques and suggest that anatomic reduction of severely displaced proximal humerus fractures is justified especially in patients over 15 years of age[9-11]. Despite this, each technique carries operative risks including the need for secondary procedure(s), hardware failure, and physeal damage.

As the operative indications and techniques for treating proximal humerus fractures in skeletally immature patients continue to evolve, the high-demand, adolescent athlete who seeks a quick and reliable return to sport may not fit the historic treatment algorithms, and may be undertreated. Athletic, adolescent patients may lack the remodeling potential of younger children and may require more stable fixation than can be afforded by traditional methods. In skeletally mature patients, the use of proximal humerus locking plates has become commonplace; however, their use in a skeletally immature patient population has not been well explored[12,13]. We report the use of proximal humeral locking plate fixation in a high-demand adolescent athlete to allow immediate range of motion and return to sport.

CASE REPORT

A 17-year-old right hand dominant high school defensive back presented to our office approximately four days after injuring his right shoulder during an organized football game. The patient was tackling another player and led with his shoulder, making significant impact. The patient presented to our office with a chief complaint of significant right shoulder pain and limited range of motion. The patient denied any history of prior shoulder pain, instability, or dislocation. His past medical and surgical history was otherwise unremarkable. On physical examination, the patient had significant

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tenderness to palpation about the right proximal humerus and extremely limited range of motion. He otherwise had an intact neurovascular exam. Radiographs demonstrated a displaced Salter-Harris I fracture of the proximal humerus (Figure 1).

Due to the significant displacement, potential for altered rotator cuff mechanics, the patient nearing skeletal maturity, and the desire of the patient to return to high-impact sporting activities as soon as possible (with the possibility of playing at the collegiate level), surgery was presented as a treatment option. The patient and his mother consented after a discussion of the risks and benefits of surgery. Due to concerns about the patient's high level of activity and stability/strength of traditional operative constructs, the decision was made to treat the patient operatively with locking plate fixation. The patient and his mother provided written informed consent for print and electronic publication of this report.

The patient was subsequently taken to the operating room three days after presentation. After placement of an interscalene nerve block by anesthesia for post-operative pain control, the patient was placed under general endotracheal anesthesia. The patient was placed in the beach chair position, and prepped and draped in a standard fashion. A standard deltopectoral approach was utilized with an incision spanning from just lateral to the coracoid process to the deltoid insertion on the humerus. After identification of the cephalic vein, the deltopectoral interval was entered with medial retraction of the cephalic vein. The conjoint tendon was then retracted medially, and both the musculocutaneous and axillary nerves were identified and protected. The subdeltoid space was subsequently developed.

At this point, the proximal humeral fracture was identified with significant displacement. Heavy non-absorbable sutures were then placed in the intact supraspinatus and subscapularis tendons. Traction was placed on the sutures to reduce the fracture, which was subsequently held in a reduced position with K-wires and a pointed reduction clamp. Fluoroscopic imaging confirmed anatomic reduction in multiple planes.

A three-hole Depuy© S3 proximal humeral locking plate (Warsaw, Indiana; United States) was then applied to the bone 2.5 cm below the level of the greater tuberosity; just lateral to the bicipital groove. The rotator cuff sutures were passed through the proximal aspects of the plate. Provisional fixation of the plate to bone was performed with K-wires, and the rotator cuff sutures were securely tied down. Care was taken to ensure that the biceps tendon was not entrapped in the fracture site or compressed by the plate.

A non-locking 3.8 mm shaft screw was then utilized to compress the plate to bone distally. A combination of four

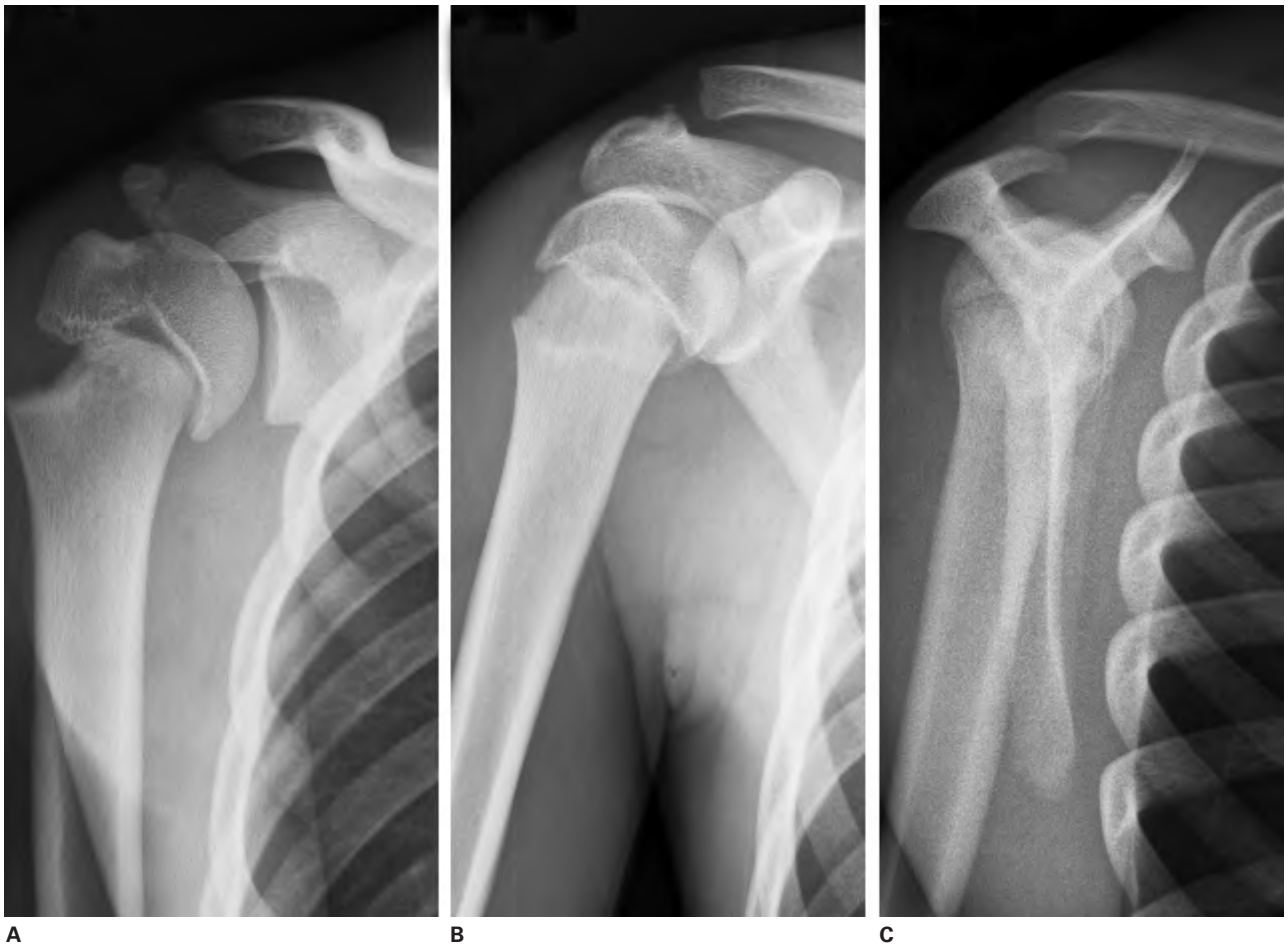

Figure 1. Anteroposterior in the scapular plane (A), anteroposterior (B), and scapular-Y (C) radiographic views of the right shoulder demonstrating a displaced Salter- Harris I fracture of the proximal humerus.

locking screws/pegs (4.0 mm) was then placed in the humeral head. Care was taken in multiple fluoroscopic planes to ensure that the humeral articular surface and glenohumeral joint were not violated. Two additional 3.8 mm non-locking screws were then placed in the humeral shaft. The shoulder was then taken through a full range of motion. No impingement of the plate in the subacromial space was seen with attainment of full flexion, extension, internal rotation, external rotation, or abduction of the shoulder. The fracture was noted to be stable as well in multiple planes. The wound was closed in a standard fashion and the patient was placed in a shoulder sling.

The patient presented for his first post-operative visit five days after surgery. His incision was clean, dry, and intact. Radiographs at that time demonstrated maintenance of anatomic alignment. He was instructed to begin gentle passive range of motion exercises out of the sling two times a day. Repeat radiographs at eleven days after surgery showed continued anatomic alignment. At this time, the patient was instructed on more aggressive passive range of motion in the scapular plane and told that the sling could be discontinued after one more week; however, the patient was to remain non-weightbearing on the extremity.

The patient presented again four weeks post-operatively. At this point, the patient (against our advice) had begun to use the arm freely and had starting performing push-ups. The patient had full painless range of motion compared to the contralateral extremity. Radiographs demonstrated a healing fracture in continued anatomic alignment (Figure 2). At this point, the patient was allowed to begin a physical therapy program for isometric strengthening and capsular stretching.

Figure 2. Anteroposterior (a) and scapular-Y (b) radiographic views of the right shoulder showing plate fixation and anatomic reduction of the patient's proximal humeral fracture.

At final follow-up (1 year) the patient demonstrated full painless range of motion of the shoulder, and had returned to sporting activities. Patient-perceived shoulder function was measured with the PENN/ASES score on a 0-100 scale. The patient scored a 100. The patient has been cleared for full sport participation and is currently awaiting the start of next season. At present, the patient reports no irritation or complication from the hardware.

DISCUSSION

Adolescent patients are increasingly participating in high-demand, high-impact sports and traditional treatment methods (operative and non-operative) for proximal humerus fractures may not be adequate for this specific patient population.[14] We demonstrated successful treatment using locking plate technology in a skeletally immature football player with a displaced, Salter-Harris I physeal fracture. We believe that the stability afforded by this method of treatment allowed for early painless range of motion, full weight bearing, and rapid return to sport without the need for additional surgical procedures or hardware removal. Though only a single case, this report is unique in that at four weeks post-operatively the patient was weightbearing and engaging in painless strenuous activities without loss of reduction or hardware failure; and maintained his excellent clinical outcome at one year follow-up.

It is now known that up to 10 years of age, axial malalignment of the proximal humerus of as much as 60 degrees in varus, anteversion, or retroversion can be corrected by remodeling; however, beyond 10 years of age, correction can be expected only with axial deformities of up to 20-30 degrees[15]. Additionally, it has been noted by other authors that much of the data regarding non-operative management of proximal humerus fractures in skeletally immature patients includes a significant number of nondisplaced or minimally displaced fractures, and a small number of older children or adolescents[16]. As early as 1969, Dameron and Reibel evaluated 46 patients with proximal humeral physeal fractures and noted poor outcomes in patients aged 14 years or older who lost fracture reduction during the treatment period[4]. As a result of this and other studies, operative indications have expanded with some advocating for operative treatment of displaced proximal humerus fractures in adolescents greater than 15 years of age[8]. Despite this, strict criteria for amount of displacement and angulation have not been established. In the same vein, a gold standard surgical technique has also not been established for operative treatment. Traditionally, K-wires, cannulated screws, or flexible nailing have been utilized.

Burgos-Floves et al noted excellent results in 22 patients with Neer grade III and IV proximal humeral epiphyseal fractures treated with closed or open reduction and K-wire fixation at mean 6.8 years follow-up[9]. They noted that since there is a greater occurrence of residual deformity and limitation of motion in older patients, a more aggressive approach to correct the initial displacement and angulation is warranted in those over the age of 13 years. The wire method of fixation does involve some significant disadvantages including unstable osteosynthesis, postoperative immobilization, pin

tract infection, and need for secondary procedure to remove hardware.

Cannulated screw fixation has also been utilized as another method of treating these injuries. Watford et al described the successful treatment of a 16 year old patient with 7.3 mm cannulated screws with full return of motion and function[17]. Carey et al compared K-wire and cannulated screw fixation of proximal humerus fractures in pediatric patients[18]. They found that thirty percent of patients treated with K-wire fixation developed pin tract infections that required treatment. The only complication noted in the cannulated screw group was transient axillary nerve parestheshias. There was no difference between the two groups in terms of operative time, rate of open reduction, or length of hospitalization ($p > 0.05$). With both treatment methods, there was complete fracture healing and no difference in rate of physeal closure.

The advent of retrograde FIN has provided a method of fixation with minimal soft tissue damage that allows for early mobilization of the injured arm. Several studies have demonstrated encouraging outcomes in skeletally immature patients after nailing[15,19]. Rajan et al examined 14 patients (10 to 15 years of age) with severely displaced proximal humerus physeal fractures who underwent FIN at mean 30 month follow-up, noting excellent functional outcomes and 100% union. All nails were removed via a secondary surgical procedure and they reported no major complications[16]. Fernandez et al reported on 35 children (mean 12.7 years of age) who underwent FIN of proximal humerus fractures. At 26 month follow-up, they noted in all of their patients improved functional outcomes and return to sports[15]. Yet, all nails were removed as a secondary surgical procedure and they noted several complications including two perforations of the nail at the head of humerus with loss of position, one loss of position without nail perforation, one misplacement of a nail, one revision due to hematoma, and two difficult hardware removals.

Proximal humeral locking plates have become the gold standard for fixation of adult fractures. These plates have been noted to afford an anatomically contoured, fixed angle construct that allows for ease of use and promotes a stable construct. Though use of locking plate technology has been described in cases of subtrochanteric and diaphyseal femur fractures in skeletally immature patients with successful outcomes, to our knowledge there are no reports on locking plate technology used for fixation of a proximal humeral physeal fracture[13,20-22]. It is thought that locking plates provide greater stability during fracture fixation compared with standard plate and screw constructs. A biomechanical study in a cadaveric Neer two-part proximal humerus fracture model demonstrated that locking plates displayed significantly greater holding power of the humeral head[23]. Despite this, a clinical advantage to using locked plating in the treatment of proximal humerus fractures in skeletally immature patients has not been established

Our patient was treated with a proximal humerus plate for several reasons. Given the patient's high-demand, active lifestyle and significant fracture displacement, operative fixation was considered a reliable means of promoting stability and healing without residual deformity. Although the varus alignment could be considered an indication for surgery, the resultant medial displacement of the greater tuberosity also leads to altered rotator cuff mechanics. Additionally, this method obviated a need for a secondary surgical procedure to remove hardware and allowed the patient to start full range of motion immediately postoperatively. While the patient's noncompliance with the postoperative plan was not expected, it served to underscore the stability of the construct.

Though it is argued that plate fixation damages the epiphysis in a skeletally immature patient, at seventeen years of age this patient's growth potential at the proximal humeral epiphysis was considered to be marginal. Additionally, plate fixation created an epiphysiodesis, which obviated potential angular deformity associated with physeal bar formation after fracture; however, given the low likelihood of significant remaining growth at the epiphysis this remained a minor concern. Other forms of fixation were considered; however, percutaneous or open treatment with K-wires or screws was felt to lack the stability needed to reliably allow immediate range of motion. Nailing involves less tissue dissection; however, it would have required a secondary procedure for nail removal, it provides theoretically less axial stability as it is not a locking construct, and it would also necessitate growth plate violation.

Though locking plates have become exceedingly more popular in the surgical treatment of proximal humerus fractures in adults, their higher cost and questionable clinical advantage in the setting of healthy bone make their standard use a cause for debate. It is possible that this patient could have been treated with equally successful outcome using a standard, non-locking plate. However, we believe our case report demonstrates that the proximal humeral locking plate is another option in the treatment of high-demand adolescents with a displaced proximal humeral fracture.

Though proximal humerus fractures in skeletally immature patients are predominately treated in a non-operative fashion due to the tremendous remodeling potential of the proximal humerus, high-demand, adolescent athletes who engage in high-impact sports may be undertreated without surgery. Generally, surgical treatment of proximal humerus fractures in skeletally immature patients involves K-wire, cannulated screw, or flexible nailing; however, these methods may lack the stability required to allow early range of motion, with some requiring a secondary procedure for removal of hardware. We report on the treatment of a high-school football player with a displaced Salter-Harris I fracture of the proximal humerus with locking plate fixation and demonstrate a rapid return to full activity.

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