Operative Treatment of Isolated Greater Tuberosity Fractures: Retrospective Review of Clinical and Functional Outcomes

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abstract

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Displaced isolated greater tuberosity fractures are rare injuries that require operative treatment to optimize rotator cuff function and prevent painful subacromial impingement. A lack of consensus exists regarding ideal management of these injuries because of the paucity of literature on the subject.

The outcomes of 17 patients treated with open (n=15) or arthroscopic (n=2) fixation at the authors' institution between 2001 and 2009 were retrospectively reviewed. Postoperative range of motion, American Shoulder and Elbow Surgeons (ASES) score, visual analog scale (VAS) score, and overall patient satisfaction were recorded at final follow-up. At a mean of 5.2 years (range 1.5-9.7 years), average postoperative active forward elevation was 150.3° (range, 60°-180°), ASES score was 82.9 (range, 46.7-100), and VAS score was 1.4 (range, 0-5). According to Neer's criteria, the overall outcome was excellent in 11 (65%) patients, satisfactory in 5 (29%) patients, and unsatisfactory in 1 (6%) patient. Final postoperative radiographs were available for 15 patients at a mean of 6.64 months. Radiographic union with near-anatomic position of the greater tuberosity was achieved in 13 (87%) of 15 patients. The presence of rotator cuff and rotator interval tears requiring repair, history of dislocation, age 60 years or older, and delayed time to surgery ⩾10 days did not significantly ($P>.05$) influence the patients' final active forward elevation and ASES scores.

Favorable patient outcomes can be achieved when fractures with >5 mm of displacement are treated with anatomic reduction and secure fixation. For a specific injury, the ideal surgical approach and method of fixation is dictated by patient characteristics and fracture pattern.

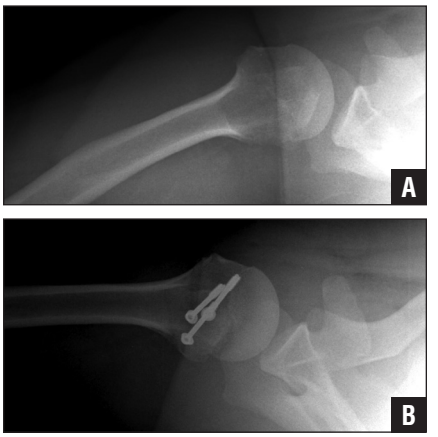

Figure: Preoperative axillary radiograph of the right shoulder in an 18-year-old right-hand-dominant man showing a displaced isolated greater tuberosity fracture where the greater tuberosity fragment is unusually large, with 36 mm of superior displacement (A). Postoperative axillary radiograph after open reduction and internal fixation using partially threaded cannulated screws showing anatomic reduction of the fracture (B).

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Although fractures of the proximal humerus are common injuries, isolated fractures of the greater tuberosity are relatively rare, accounting for less than one-fifth of proximal humerus fractures.[1,2] Most isolated greater tuberosity fractures are nondisplaced and can be successfully treated nonoperatively with short-term sling immobilization followed by rehabilitation focused on range of motion (ROM) exercises.[3-6] Isolated greater tuberosity fractures with significant displacement are uncommon, and patients with these fractures often have other associated shoulder injuries, such as rotator cuff tears and glenohumeral dislocations, making for a heterogeneous patient cohort. Thus, a paucity of literature exists on the operative treatment of displaced isolated greater tuberosity fractures.

Although a consensus exists that surgery is needed to treat displaced isolated greater tuberosity fractures, multiple questions about operative management remain unanswered by the current literature. Greater tuberosity fractures tend to displace in a superior and posterior direction due to the force vector of the rotator cuff attachments. Significant superior greater tuberosity displacement is not well tolerated because it leads to symptomatic subacromial impingement and limited abduction, whereas posterior displacement blocks external rotation.[4,7]

Controversy exists regarding the amount of displacement that warrants operative treatment. Traditionally, Neer's[4] criteria of displacement >1 cm in any direction has been used to indicate patients for surgery. More recently, the trend has been to operate on fractures with >5 mm of displacement or >3 mm of displacement in active patients involved in overhead activities.[7-10] Agreement is lacking regarding the optimal surgical approach and fixation method. Several case series have reported promising results using various methods of fixation via open or arthroscopic approaches, but these studies do not address the relative indications for each surgical tactic.[8,9,11-14] Associated soft tissue injuries, including tears of the rotator cuff or rotator interval, are commonly identified at the time of greater tuberosity fixation, but the role of soft tissue repair is ill defined by the current literature; it is not known whether concomitant soft tissue injury has any influence on long-term clinical outcome following these injuries.[12,15] A lack of literature exists profiling the complications associated with displaced isolated greater tuberosity fracture fixation and ways to avoid and manage these complications.

The purpose of the current study was to review the experience of displaced isolated greater tuberosity fracture fixation at the authors' institution to discern some principles of surgical management for these rare injuries. This article describes a series of patients with displaced isolated greater tuberosity fractures who were treated operatively with open or arthroscopic fixation and the surgical indications, techniques, and mid- to long-term functional results. Although the literature shows that displaced isolated greater tuberosity fractures may be successfully treated via a variety of surgical approaches and fixation techniques, the current authors hypothesized that each injury is associated with a unique set of patient factors and fracture characteristics that can be used by the surgeon to determine the ideal treatment plan.

Materials and Methods

Following Institutional Review Board approval, 17 patients (17 shoulders) were reviewed who were treated operatively for displaced isolated greater tuberosity fractures at the authors' institution between January 2001 and March 2009 by 4 attending surgeons. To be included in this review, patients were required to have an objectively documented ROM examination from their final office visit and to be reachable by mail or telephone for clinical follow-up, allowing the authors to determine an outcome grade of excellent, satisfactory, or unsatisfactory as defined by Neer's criteria.[16] Patients with 3- or 4-part proximal humerus fractures involving the greater tuberosity were not included in this study.

Mean patient age was 59 years (range, 18-81 years), and 12 (70.6%) patients were women (Table 1). The dominant shoulder was injured in 11 (65%) patients. The fracture was associated with traumatic anterior shoulder dislocation in 11 (65%) patients. Mechanism of injury was a fall in 15 patients and a motor vehicle accident and seizure in 1 patient each. Average time from injury to surgery was 14 days (range, 2-60 days).

A standard radiographic series of the shoulder, consisting of anteroposterior (AP) and lateral views in the plane of the scapula and an axillary view, was used to delineate the fracture pattern and determine fracture displacement (Figure 1). The Velpeau axillary view was obtained in some cases when patients were unable to abduct the injured shoulder. Superior and posterior displacement were assessed on the AP and axillary radiographs, respectively, as described by Flatow et al.[14] For the purposes of this review, radiographs were scaled using 8 mm as the vertical distance between the top of the greater tuberosity fracture footprint to the most superior point of the humeral head.[17] Preoperative images for all patients were available for review, and the most common directions for displacement were confirmed as posterior (67%) and superior (58%). In 8 (47%) of 17 patients, significant displacement (>5 mm) existed in both directions. The greatest magnitude of displacement in any direction averaged 12.3 mm (range, 5-36 mm).

The indication for surgery was displacement of ≥5 mm in any direction in a patient healthy enough to tolerate operative intervention. An open procedure via the anterosuperior approach was used in the majority of patients (15/17; 88%), and an arthroscopic procedure was performed

Table 1

Patient Demographics

Patient No./Sex/ Age at Injury, y	Occupation	Hand Dominance	Side of Injury	MOI	Dislocation	Days From Injury to Surgery
1/F/59	Secretary	R	R	Fall	Y	28
2/F/81	Retired	R	R	Fall	Y	11
3/F/57	Housewife	R	R	Fall	N	7
4/M/64	Surgeon	R	R	Fall	Y	2
5/F/78	Retired	R	R	Fall	Y	9
6/F/57	Lawyer	R	L	Fall	N	6
7/F/79	Retired	R	L	Fall	Y	15
8/F/59	Housewife	R	L	Fall	Y	19
9/M/18	Student	R	R	Seizure	N	3
10/F/60	Retired	R	R	Fall	N	5
11/M/62	Attorney	L	R	Fall	Y	10
12/F/63	Retired	R	R	Fall	Y	7
13/F/67	Retired	R	R	Fall	N	15
14/M/25	Real estate agent	R	L	MVA	Y	31
15/M/55	Physician	R	L	Fall	N	60
16/F/61	Administrator	R	R	Fall	Y	13
17/F/52	Theater manager	R	R	Fall	Y	4

Abbreviations: L, left; MOI, mechanism of injury; MVA, motor vehicle accident; N, no; R, right; Y, yes.

in 2. An associated soft tissue injury that required repair existed in 7 (42%) patients. Four (24%) of these were rotator cuff tears, and 3 (18%) were defects in the rotator interval. Of the 15 patients who underwent an open procedure, the fracture was fixed using nonabsorbable rotator cuff-incorporating sutures in 12 patients, cannulated screws in 2 patients (Figure 2), and double-row suture anchors in 1 patient.

SURGICAL TECHNIQUE

The preferred method of anesthesia was interscalene block. The patient was placed in a beach-chair position in a well-padded headrest with all bony prominences adequately padded. The patient was brought to the edge of the operating table to facilitate access to the proximal humerus in both open and arthroscopic approaches.

Open Reduction and Internal Fixation

All cases of open reduction and internal fixation were performed as previously described by Freehill and Levine.[18] The anterosuperior deltoid-splitting approach used a skin incision made along Langer's lines at the anterolateral border of the acromion. The deltoid was split in the direction of its fibers for 3 or 4 cm, and an antipropagation suture was placed at the distal end of the split to prevent axillary nerve injury. Fracture exposure was facilitated by gentle deltoid retraction and thorough lysis of subacromial adhesions and removal of inflamed soft tissues. On clear identification of the tuberosity fragment and the fracture bed, the fragment was mobilized with traction sutures. Most commonly, internal fixation was performed using #5 nonabsorbable sutures through bone tunnels. A double-row suture anchor technique may be used to fix a similar fracture pattern using the same principles. If the tuberosity fragment is particularly large and the patient is not osteopenic, the fracture may be fixed with partially threaded cannulated screws (Figure 1). Any associated rotator cuff or interval tears were repaired with #0 nonabsorbable sutures.

Arthroscopic Fixation

Arthroscopic reduction was chosen for cases where the fracture fragment was thin or comminuted, making it amenable to arthroscopic mobilization and suture-bridge fixation. With the patient in a beach-chair position, a diagnostic arthroscopy was performed from a posterior portal. Any concomitant rotator cuff, rotator interval, or labral injuries were noted so they could be repaired following fracture fixation. An anterior portal was then made, and synovectomy was performed to

Table 1 (Continued)

Patient Demographics

Patient No.	Approach	Method of Fixation	Soft Tissue Injury Repaired	Active FE, deg	ASES Score	Neer Grade	Comments
1	AS	Nonabsorbable suture	N	150	91.7	E	
2	AS	Nonabsorbable suture	N	140	78.3	S	
3	AS	Nonabsorbable suture	RCT	170	95	E	
4	AS	Nonabsorbable suture	RI	60	71.7	NS	Loss of fixation, revision ORIF
5	AS	Nonabsorbable suture	N	130	100	E	
6	AS	Nonabsorbable suture	N	140	80	S	
7	AS	Nonabsorbable suture	N	150	90	E	
8	AS	Cannulated screws	N	90	55	S	
9	AS	Cannulated screws	N	180	93.3	E	
10	AS	Nonabsorbable suture	RI	170	90	E	
11	Scope	Double-row suture anchors	RCT	180	100	E	
12	Scope	Double-row suture anchors	RCT	160	76.7	E	
13	AS	Nonabsorbable suture	RI	170	86.7	S	Adhesive capsulitis, arthroscopic lysis of adhesions
14	AS	Nonabsorbable suture	N	175	90	E	Preoperative axillary neuropraxia
15	AS	Double-row suture anchors	N	140	85	E	
16	AS	Nonabsorbable suture	RCT	170	46.7	S	
17	AS	Nonabsorbable suture	N	180	80	E	

Abbreviations: AS, anterosuperior; ASES, American Shoulder and Elbow Surgeons; deg, degrees; E, excellent; FE, forward elevation; N, none; NS, not satisfactory; RCT, rotator cuff tear; RI, rotator interval; S, satisfactory; Scope, arthroscopic.

remove loose, fibrillated tissue. Following redirection of the arthroscope into the subacromial space, a systematic bursectomy, coracoacromial ligament release, and acromioplasty were performed as needed to facilitate fracture visualization. An accessory anterosuperior portal was made for the placement of suture anchors. A double-row repair was performed as described previously.[19] Following abrasion of the fracture bed and mobilization of the greater tuberosity fragment to its anatomic location, 2 suture anchors were placed, 1 anteromedially and 1 posteromedially, and passed in horizontal mattress fashion. Next, tap holes were placed for the 2 push-in anchors, 1 anterolaterally and 1 posterolaterally. The sutures were then appropriately tensioned and tapped into place, achieving a suture-bridge repair with anatomic footprint restoration.

Postoperative Care

Patients were placed in a sling before leaving the operating room, with gentle passive shoulder ROM beginning on postoperative day 1. Active ROM was delayed until evidence of tuberosity healing was apparent on radiographs, generally at 6 weeks. Patients returned for regular clinical and radiographic follow-up until their ROM and strength had peaked and radiographic evidence existed of fracture union.

At final follow-up by telephone and mail, a functional assessment was obtained using a custom questionnaire that included the American Shoulder and Elbow Surgeons (ASES) score.[20] This functional assessment was used in conjunction with the patients' medical records to determine an overall outcome grade as defined by Neer et al's criteria.[16] Subgroup analysis using the *t* test was performed with Excel (Microsoft Corp, Redmond, Washington).

Results

Average time to final functional assessment with study questionnaires was 5.2 years (range, 1.5-9.7 years) postoperatively, at which time the mean ASES score was 82.9 (range, 46.7-100) and the mean visual analog scale score was 1.4 (range, 0-5). According to Neer et al's criteria,[16] the overall outcome was excellent in 11

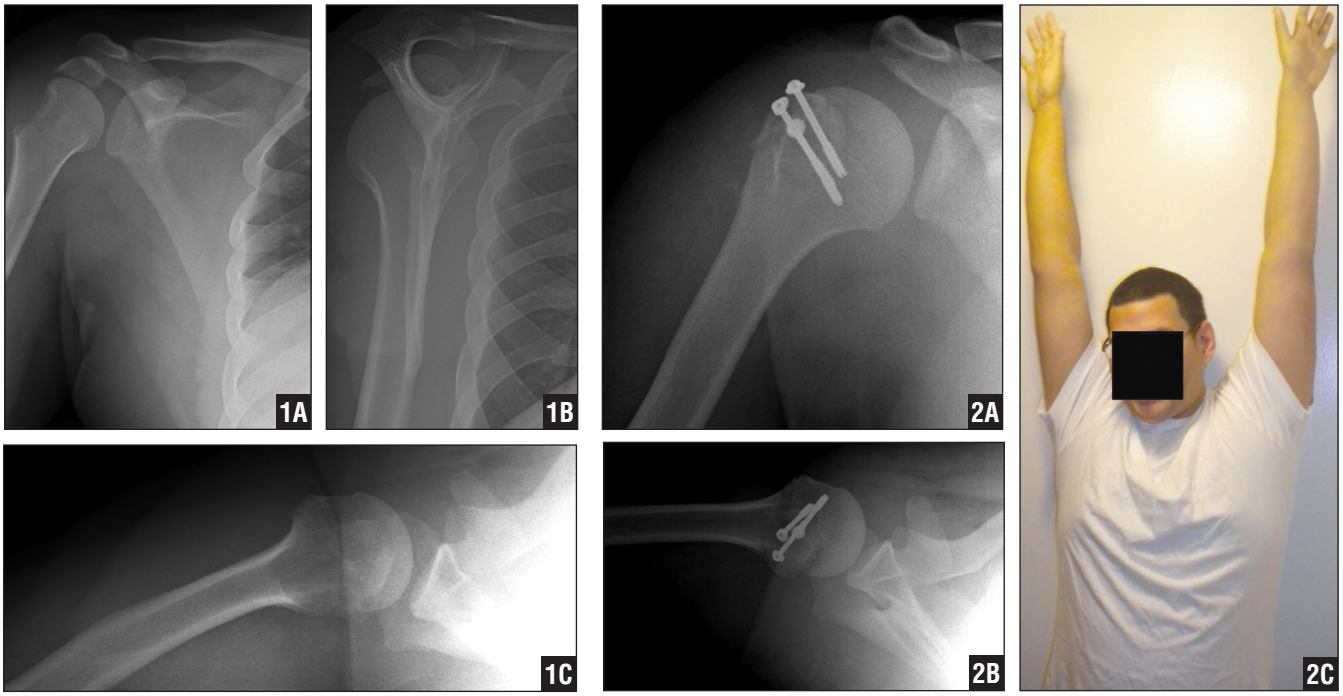

Figure 1: Preoperative anteroposterior (A), lateral (B), and axillary (C) radiographs of the right shoulder in an 18-year-old right-hand-dominant man showing a displaced isolated greater tuberosity fracture where the greater tuberosity fragment is unusually large, with 36 mm of superior displacement.

Figure 2: Postoperative anteroposterior (A) and axillary (B) radiographs after open reduction and internal fixation using partially threaded cannulated screws showing anatomic reduction of the fracture. Clinical photograph taken 18 months postoperatively showing excellent range of active forward elevation (C).

(65%) patients, satisfactory in 5 (29%), and unsatisfactory in 1 (6%). Average duration to final clinical examination was 6.8 months (range, 2-24 months) postoperatively, at which time average active forward elevation was 150.3° (range, 60°-180°) and average active external rotation was 46.5° (range, 0°-75°). Mean internal rotation was to the T11 level (range, T6-L5).

Final postoperative radiographs were available for all patients at a mean of 6.64 months (range, 2-24 months). Radiographic union with near-anatomic position of the greater tuberosity was achieved in 15 (88%) of 17 patients. In these 15 patients, average vertical distance between the top of the tuberosity and the most superior point of the humeral head was 8.6 mm (range, 4.6-14.4 mm). The 2 patients who did not have anatomic tuberosity reduction had residual superior displacement of a tuberosity fragment. These 2 patients had active forward elevation of 180° and 160°, respectively, at final follow-up and subjectively rated their outcomes as very satisfied.

Table 2

Subgroup Analysis

Subgroup	n	Mean Active FE, deg	Mean ASES	*P*
No RC/RI injury	10	147.5	84.3	NS
RC/RI injury repaired	7	154.3	81	
Age <60 y	8	153.1	83.8	NS
Age ⩾60 y	9	147.8	82.3	
No dislocation	6	161.7	88.3	NS
Dislocated	11	144.1	80	
<10 d to surgery	8	148.8	85.8	NS
⩾10 d to surgery	9	151.7	80.4	

Abbreviations: ASES, American Shoulder and Elbow Surgeons; deg, degrees; FE, forward elevation; NS, not significant; RC, rotator cuff; RI, rotator interval.

Subgroup analysis showed that the presence or absence of dislocation, rotator cuff and interval tears requiring repair, age 60 years or older, and delayed time to surgery ⩾10 days did not significantly influence the patients' final active forward elevation and ASES score (Table 2).

No wound complications or infections occurred in the series. Two patients required subsequent surgery on the operated shoulder. One patient did not regularly attend physical therapy sessions and developed adhesive capsulitis, which required arthroscopic release 6 months following the index procedure. At final follow-up, she had an active forward elevation of 170° and an ASES score of 86.7, and she recently reported being satisfied with her shoulder surgeries, so her outcome was determined to be satisfactory according to Neer et al's criteria.[16] A second patient required reoperation on postoperative day 8 for loss of fixation in the setting of osteopenic bone. He developed impingement type symptoms that limited his ROM. His last documented forward elevation was 60° and ASES score was 71.7, representing the sole unsatisfactory result in the series. He elected not to undergo further revision surgery because he had little pain (VAS 1) and his shoulder function was acceptable to him.

One (6%) patient was noted to have a neurologic deficit preoperatively. He was diagnosed with axillary neurapraxia, which was fully resolved by final clinical follow-up at 13 months. Notably, he is the only patient in the series who sustained injury via a high-energy mechanism (motor-vehicle accident).

Discussion

Isolated fractures of the greater tuberosity represent a heterogeneous group of diverse injury patterns. The clinical and radiographic personality of each injury combined with individual patient characteristics dictates a specific operative plan. The experience at the authors' institution has shown that by critically evaluating each patient and injury, a surgeon can choose the optimal surgical approach, mode of fixation, and postoperative protocol to help the patient achieve a desirable outcome. In the current series of 17 patients treated with various surgical techniques, the mean ASES score was 82.9 and the overall outcome was excellent or satisfactory in 94% of patients.

Because displaced 2-part greater tuberosity fractures are uncommon injuries, few outcomes studies exist that can be used to guide treatment.[8,9,11-14] Flatow et al[14] retrospectively reviewed a series of 12 patients with displaced isolated greater tuberosity fractures with ⩾1 cm of displacement who were treated with open reduction and internal fixation using heavy, nonabsorbable sutures. At an average 5-year follow-up, 6 patients had good results and 6 had excellent results, with postoperative forward elevation averaging 170° across the cohort.[14] More recently, Park et al[13] reported 78% excellent and 11% satisfactory results for a cohort of 28 two- and 3-part proximal humerus fractures, 13 of which were displaced isolated greater tuberosity fractures treated with suture fixation. Other authors have reported similarly promising results using closed reduction and percutaneous fixation techniques.[8,21] The increasing sophistication of arthroscopic techniques has made some displaced isolated greater tuberosity fractures amenable to arthroscopic fixation, with good results reported in several small series.[15,22-25]

Although it is clear that anatomic reduction of the greater tuberosity is crucial for a satisfactory functional outcome, a lack of consensus remains regarding the amount of displacement to warrant surgery. Greater tuberosity displacement may dramatically alter deltoid abduction forces and lead to painful impingement symptoms with ROM limitations.[10,26] A biomechanical study showed that glenohumeral abduction force was increased by 27% with 1.0 cm of greater tuberosity displacement, suggesting that small alterations in greater tuberosity position can have significant effects on deltoid contraction.[4] Therefore, the current authors advocate a relatively aggressive approach to managing these potentially disabling injuries and recommend operative treatment for any fracture with ⩾5 mm of displacement. The current series included no laborers or athletes who performed repetitive overhead activities, so the authors cannot make specific recommendations regarding even more stringent displacement criteria in that patient population.

The personality of the fracture is an important determinant of surgical approach. Severely displaced fragments, or retracted fragments that are several weeks out from injury, are not readily amenable to arthroscopic repair because it may be exceedingly difficult to adequately mobilize the fragment to achieve anatomic reduction. Similarly, if the fragment is large, it may be difficult to visualize and manipulate arthroscopically, favoring an open approach. Conversely, fracture fragments that are small and thin (eggshell fragments) may favor arthroscopic treatment because they can be more delicately handled with arthroscopic instruments.

Fracture pattern can also determine the optimal mode of fixation. If the fragment is uncommonly large, it may be most amenable to fixation with cannulated screws rather than standard suture fixation (Figures 1, 2). Comminuted fractures may require the use of a double-mattress suture bridge technique to capture all of the fragments over the greater tuberosity footprint.[18] Biomechanical evidence supports the use of cancellous screws or tension banding over nonabsorbable suture fixation because of superior load-to-failure testing.[27] However, the potential hardware complications of prominence, joint penetration, failure, and migration in this relatively osteoporotic periarticular area has made suture fixation an attractive choice.[4,13,28-31] The current authors favor the use of nonabsorbable suture fixation, which was used in 12 (70.6%) of 17 patients of various ages and bone qualities, and good overall results were observed. The authors reserve suture anchor fixation for arthroscopic cases or for open cases in patients with especially strong bone stock.

Approximateley half (42%) of the patients in this series had a rotator cuff or in-

terval injury that required repair. The presence of these concomitant injuries was not associated with inferior outcomes (Table 2) because the injuries were anticipated preoperatively and carefully assessed and repaired intraoperatively. This is consistent with previous reports that patients have improved outcomes when associated soft tissue injuries, including tears of the rotator cuff or rotator interval, are repaired at the time of fracture fixation.[9,18,32]

The current series included a high percentage of women (70.6%) and a relatively high mean age (59 years). This is in contrast to a large series of patients reported by Kim et al,[1] who reviewed 115 consecutive patients with isolated greater tuberosity fractures and found that they were significantly younger (mean age, 42.8 vs 54.2 years) and more likely to be men (67.8% vs 32.9%) than patients with other types of proximal humerus fractures. This discrepancy in demographics may be due to the fact that all patients in the current series had displaced fractures that were indicated for operative treatment, whereas Kim et al's[1] series included nondisplaced and displaced fractures. This suggests that older women may be at increased risk for sustaining more severe greater tuberosity fractures that have significant displacement, which is similar to the risk profile for proximal humerus fractures in general.[10]

According to the literature, 19% to 57% of isolated greater tuberosity fractures occur during traumatic glenohumeral dislocation, and these fractures tend to assume an anatomic position when the joint is reduced.[6,7,33] In the current series, the majority (65%) of patients sustained an anterior shoulder dislocation as the primary mechanism of injury. This emphasizes the importance of carefully evaluating for greater tuberosity fractures in patients with traumatic dislocations. Furthermore, an initially nondisplaced greater tuberosity fracture may subsequently displace during the weeks following glenohumeral dislocation, as was observed in 2 patients in the current series, so serial radiographs to evaluate a nondisplaced greater tuberosity fracture are warranted at each clinical follow-up.

The importance of patient compliance with postoperative active ROM limitations and physical therapy cannot be stressed enough. Patients should receive counseling and education at every point in their pre- and postoperative care to maximize cooperation with these protocols because failure to comply is often attributable to poor patient education rather than frank patient refusal. The 2 patients who required reoperation in the current series, 1 for fixation failure and 1 for adhesive capsulitis, may have been spared from their second surgery had a higher level compliance with activity restrictions and physical therapy been achieved.

This study had several limitations. The number of patients was too low to adequately power direct comparisons of the different surgical approaches and fixation method. Although no significant differences were observed among the various subgroups that were analyzed (Table 2), the comparisons were underpowered, and the possibility cannot be eliminated that those factors would have a direct effect on outcome if greater numbers of patients had been enrolled. The duration of follow-up was limited by the retrospective design of the study, especially in patients who were treated in recent years. More objective data would have been available if these data were collected prospectively at the time of initial consultation and treatment. A control group receiving nonoperative treatment was lacking, so results of operative treatment could not be compared to functional outcomes of patients treated nonoperatively for nondisplaced greater tuberosity fractures. The retrospective study design limited the ability to definitively establish the best treatment for any given displaced isolated greater tuberosity fracture because a direct stratification between treatment and outcome was unable to be established.

CONCLUSION

Displaced isolated greater tuberosity fractures are rare injuries that require operative treatment to prevent shoulder dysfunction when >5 mm of displacement exists. Various surgical approaches and fixation methods are available, but the decision regarding which methods to use may be dictated by patient and fracture characteristics that are unique to each injury. The goals of operative treatment should be stable, anatomic fixation and strict compliance with postoperative weight-bearing restrictions and physical therapy. Using these treatment principles, satisfactory or excellent results were achieved in 94% of patients at a mean 5.2 years postoperatively.

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