Review Article

Surgical Treatment of Displaced Greater Tuberosity Fractures of the Humerus

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Abstract

Greater tuberosity fractures of the humerus can be successfully treated nonsurgically in most patients. However, as little as 3 to 5 mm of superior greater tuberosity displacement may adversely affect rotator cuff biomechanics and lead to subacromial impingement in patients who are active. In these cases, surgical treatment is recommended. Multiple surgical techniques include open and arthroscopic options tailored to fracture morphology, and strategies for repair include the use of suture anchors, transosseous sutures, tension bands, and plates/screws. Three classification systems are commonly used to describe greater tuberosity fractures: the AO, Neer, and morphologic classifications. Several hypotheses have been discussed for the mechanism of greater tuberosity fractures and the deforming forces of the rotator cuff, and the use of advanced imaging is being explored.

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In the upper extremity, proximal humerus fractures are common injuries,[1,2] second in frequency only to distal radius fractures.[2] Proximal humerus fractures usually occur in older patients with osteoporotic bone following low-velocity trauma, and women are affected three times more often than are men.[3] The incidence of proximal humerus fractures is expected to triple over the next three decades.[4]

Greater tuberosity (GT) fractures, in contrast, usually occur in younger patients with strong bone following high-velocity trauma,[5] occur more frequently in men, and constitute one fifth of all proximal humerus fractures.[1,6] Of these injuries, 5% to 57% are the result of a glenohumeral dislocation,[1,7] whereas 15% to 30% of all anterior glenohumeral dislocations[7] result in GT fracture.

As with all proximal humerus fractures, most GT fractures (85% to 95%) are minimally displaced and may be treated nonsurgically.[8,9] Superior displacement of <5 mm is generally considered an indication for nonsurgical treatment,[6,10] and several authors have reported good results following a variety of physiotherapy protocols.[9,11,12] A full description of the treatment of GT fractures and the results of nonsurgical management are beyond the scope of this article.

Surgical treatment of isolated GT fractures is indicated in healthy patients who have >5 mm of superior GT displacement (approximately 5% to 15% of cases).[6,8,10] However, because of the increased demands in this typically active young patient population and the anatomic constraints of the GT beneath the acromion, some authors suggest that patients with as little as 3 mm of superior displacement may benefit from surgical reduction and fixation.[9,13] Although 3 mm of GT displacement is sufficient to alter rotator cuff (RC) biomechanics, the study by Platzer et al[9] on 135 minimally displaced GT fractures should be interpreted with caution because the inferior results found in patients with GT displacement of >3 mm did not reach statistical significance. Therefore, until higher-quality studies are performed, 5 mm of superior GT displacement remains the accepted indication for surgical management of GT fractures in the general healthy population. Surgical treatment may be considered for as little as 3 mm of superior GT displacement in active patients who are engaged in a profession or sport that requires prolonged overhead activity (eg, electrician).[9]

Posterior GT displacement is increasingly recognized as a significant cause of functional impairment.[14-16] Bono et al[15] demonstrated that 1 cm of combined posterior and superior displacement led to a greater change in deltoid force required for abduction than did superior displacement alone. In a study by Verdano et al[14] on 38 patients with isolated GT fractures, the authors conducted follow-up for an average of 17 months and showed that patients with GT displacement in the posterior-superior direction had significantly worse outcomes than did patients with GT displacement in anterior-inferior or anterior-superior directions. However, the magnitude of "acceptable" posterior GT displacement remains unclear. Resch and Thöni[16] suggested that GT reduction and fixation should be performed for >3 mm of GT displacement in any direction, but this finding was derived from a subset of patients with GT fractures associated with glenohumeral dislocation. Little evidence was given to support this approach.

Although initial GT displacement is an important consideration in these fractures, between 50% and 60% of minimally displaced GT fractures (<5 mm) demonstrate further displacement at follow-up.[9] Platzer et al[9] noted that younger patients (age, 30 to 50 years) and men had an increased tendency for further fragment displacement over time. In a recent study at our institution on 55 patients with combined GT fracture and anterior glenohumeral dislocation, late GT migration was seen in 19% of patients and those <70 years were 5.6 times more likely to have late GT displacement than did patients >70 years.[17] An association between GT fracture morphology and late displacement has not yet been described. These findings suggest that close radiographic follow-up is warranted in patients who are undergoing nonsurgical treatment for minimally displaced GT fractures.

Multiple surgical techniques have been proposed for GT fracture fixation and the various surgical options are chosen according to fracture morphology.

Figure 1

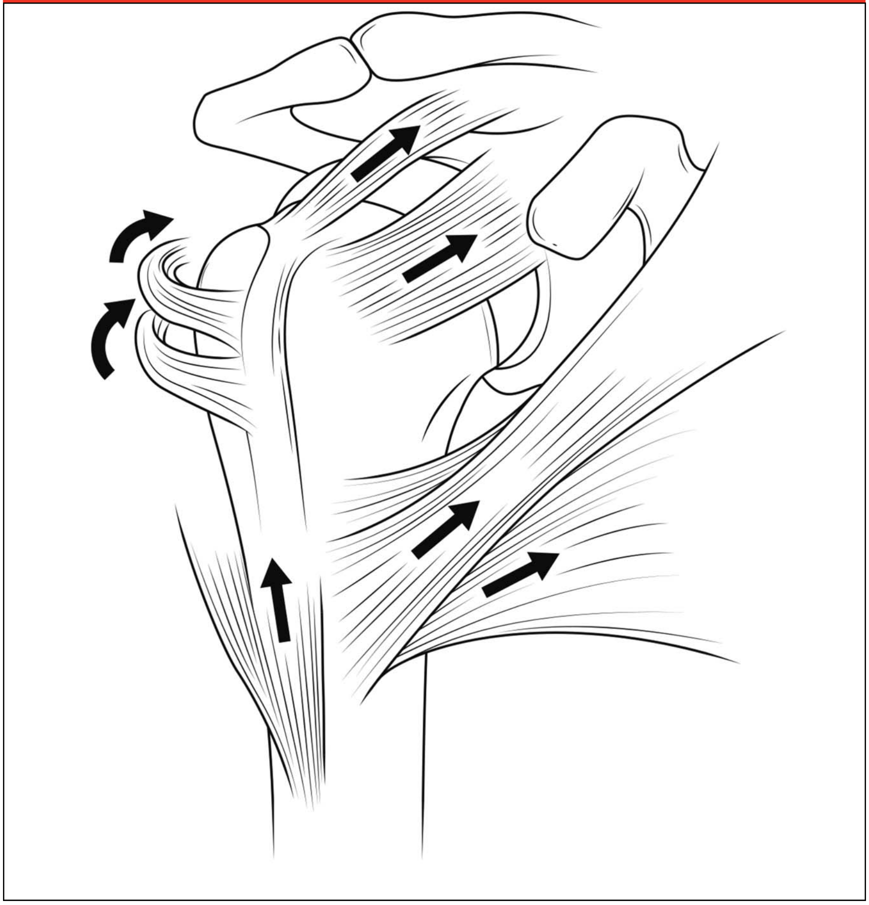


Illustration demonstrating the deforming forces in proximal humerus fractures.

Fracture Displacement Biomechanics

The deforming forces resulting from the pull of the RC muscles should be taken into consideration when choosing the optimal surgical fixation strategy for GT fractures. The supraspinatus, infraspinatus, and teres minor muscles all insert on the GT and their coupled forces are of primary importance in shoulder function (Figure 1). In a series of 163 shoulders, Ogawa et al[18] reported

Figure 2

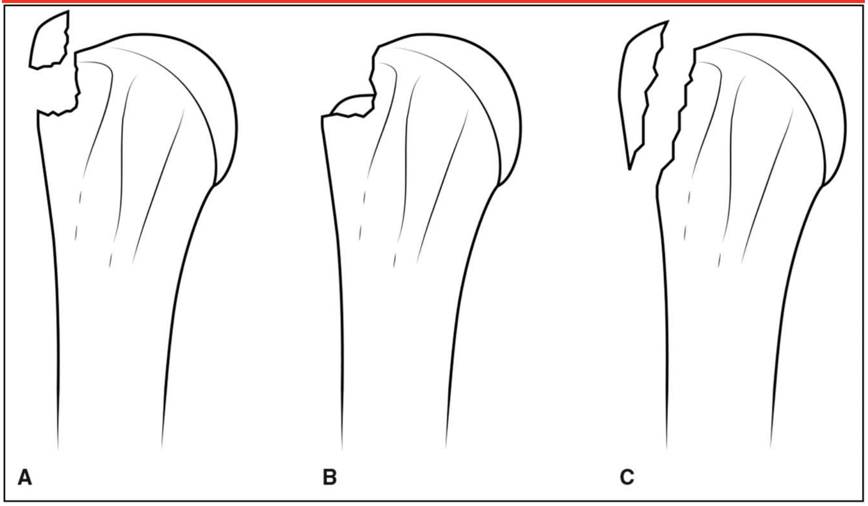


Illustration of the morphologic classification of greater tuberosity fractures. **A,** The avulsion type involves a smaller fragment with a horizontal fracture line. **B,** The depression type involves an inferiorly displaced and impacted greater tuberosity. **C,** The split type is a large fragment characterized by a vertical fracture line.

that most GT fractures (57%) involved both the supraspinatus and infraspinatus facets, leading to superior and posterior GT displacement. With an intact infraspinatus tendon, posterior displacement is particularly important to note because it is often underestimated. Posterior GT displacement cannot reliably be measured using standard radiography, even with the inclusion of a lateral Neer view.[10] Therefore, CT is used to evaluate posterior displacement in these fractures, especially in active patients in which a moderate amount of displacement may affect function.[19] If the GT fracture is comminuted, there may be both a superomedially displaced fragment attached to the supraspinatus tendon and a posteromedially displaced fragment attached to the infraspinatus tendon.

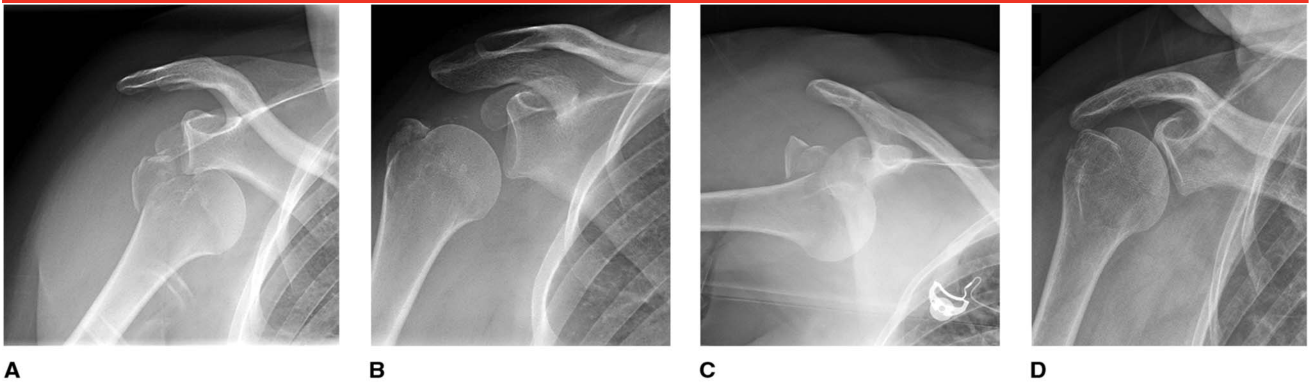
Classifications

Two major classifications systems exist for proximal humerus fractures: the Neer and the AO classifications.[20,21] In 1970, Neer[20] published a four-part classification for fractures of the proximal humerus. A "part" included the GT, the lesser tuberosity, and the humeral head or the humeral shaft if there was displacement of >1 cm or angulation of >45° with respect to the other humerus "parts." This definition of displacement was intended to classify the "parts" as stable or unstable and use 1 cm and 45° as surrogate measures. However, these cutoffs were set arbitrarily and GT fractures received no specific attention. The AO classified GT fractures as nondisplaced, displaced, or associated with shoulder dislocation. Fracture displacement was defined as translation of the GT fragment of ≥5 mm from its anatomic position.[21] However, both the Neer and the AO classifications have received criticism for poor interobserver and intraobserver reliability for proximal humeral fractures (Neer interobserver/intraobserver 0.37 to 0.80/0.20 to 0.85 and AO interobserver/intraobserver 0.30 to 0.64/0.16 to 0.79).[22-26] This poor reliability persists even when GT fractures are evaluated in isolation (Neer interobserver/intraobserver 0.31 to 0.35/0.54 to 0.63 and AO interobserver/intraobserver 0.30 to 0.35/0.59 to 0.65).[26,27] The poor reliability of the AO and Neer classifications is likely the result of difficulty in measuring GT displacement using radiography.[18,19,28] However, many studies have shown persistently poor reliability despite the use of radiographic aids, such as stereovisualization and three-dimensional CT.[22,23,26]

The Neer and AO classification systems are based solely on fragment displacement[20,21] and do not take into account GT fragment size, morphology, or orientation. These variables influence not only treatment and fixation strategies but likely also reflect the mechanism of fracture and may be associated with differing risks of concomittant injury, such as RC tear, glenoid fracture, and glenohumeral dislocation.

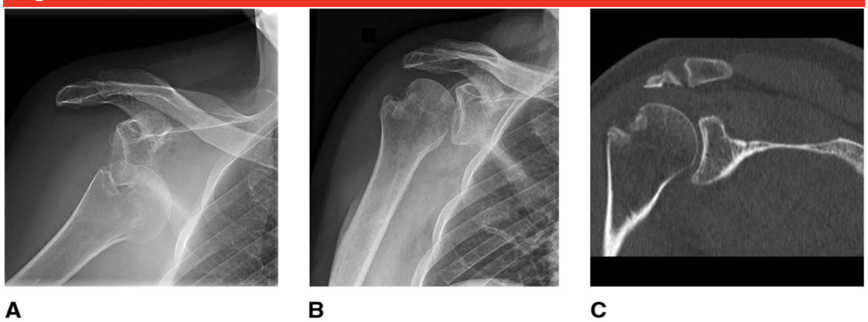
In 2014, Mutch et al[27] proposed a morphologic classification using a series of 199 isolated GT fractures. The interobersever/intraobserver reliability was 0.73 to 0.77 and 0.69 to 0.86, respectively.[27] Three fracture types were described: avulsion, split, and depression. Forty percent of GT fractures were avulsion fractures that involved a small fragment with a fracture line perpendicular to the humeral shaft. Twenty percent of these fractures were treated surgically.[27] In addition, 40% of the GT fractures were split fractures; they represent the classic GT fracture as described in the AO and Neer classifications in which the fragment is large and the fracture line is parallel to the humeral shaft beginning proximally at the junction of the RC footprint and humeral head cartilage and extending distally and laterally to the level of the surgical neck. Twenty-eight percent of these fractures were treated surgically.[27]

Figure 3



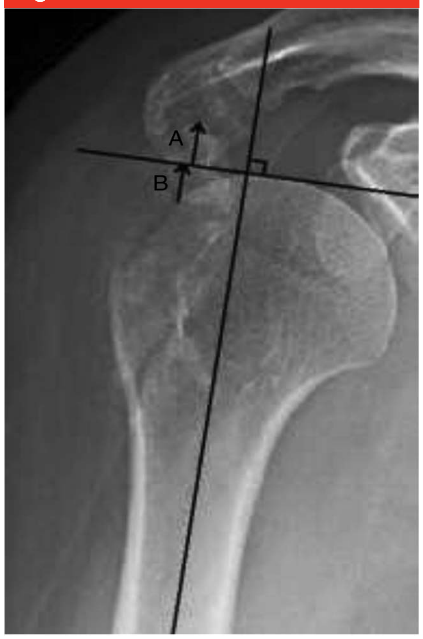
Prereduction AP (**A**) and postreduction AP (**B**) radiographs of a split-type greater tuberosity fracture/dislocation. Prereduction AP (**C**) and postreduction AP (**D**) radiographs of an avulsion-type greater tuberosity fracture/dislocation.

Figure 4



A and **B,** AP radiographs of an anterior glenohumeral dislocation with a depression-type greater tuberosity fracture. **C,** CT of the same patient.

Figure 5



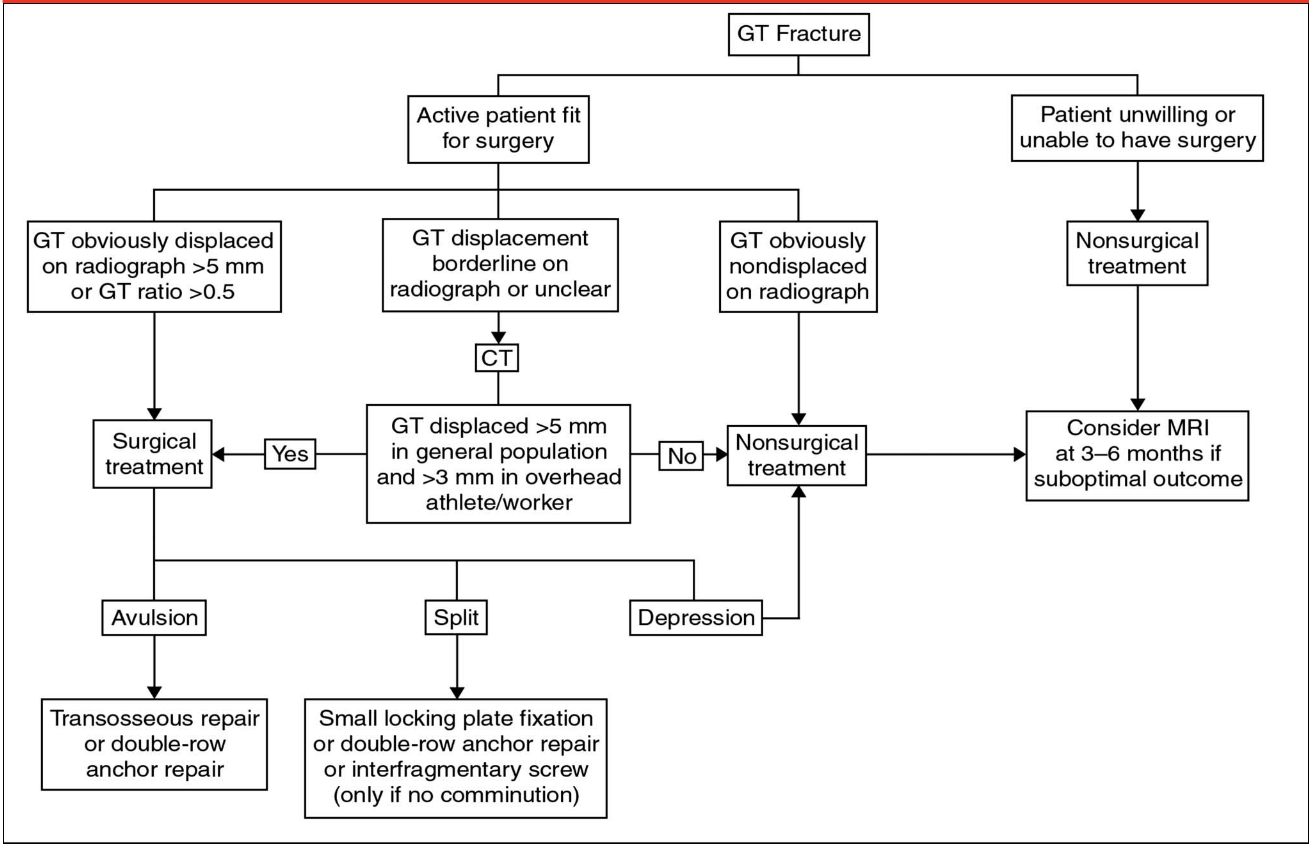
AP radiograph demonstrating the ratio method for displaced superior greater tuberosity (GT) fractures. A line is traced along the center of the humeral shaft and humeral surgical neck. All measurements are taken parallel to this axis. A tangent is then drawn perpendicular to this line along the most superior aspect of the GT fragment. Distance B is measured from this tangent to the most lateral aspect of the humeral head articular surface. The ratio is then calculated using the formula (A + B)/B. A ratio of ≥0.50 represents a displaced GT fracture.[33]

Finally, depression fractures are an impaction of the GT similar to a Hill-Sachs lesion but are located more laterally on the GT rather than on the humeral head cartilage.[29] This fracture type accounts for 20% of GT fractures. Nearly half of depression fractures (46%) occur following anterior glenohumeral dislocation.[27] Surgery for a depression fracture was performed in only 7% of cases and then, subacutely because of RC tears and persistent pain.[27] This morphologic classification complements the standard GT fracture evaluation of displacement and comminution and may help guide the technique of surgical treatment, if indicated (Figure 2). It should be noted, however, that differences in clinical outcomes as a result of fracture morphology were not found in this study. The study was retrospective and the fracture types varied in terms of GT displacement, associated glenohumeral dislocation, and surgical treatment.[27]

Mechanism of Injury

There are several hypotheses for the mechanism of GT fractures, and the morphology of the fracture fragment may provide some insight. Avulsion fractures likely result from a forceful contraction of the RC against a humeral head that is distracted from

Figure 6



Treatment algorithm for greater tuberosity (GT) fractures.

the glenoid or in an anteriorly subluxated or dislocated position[30] (Figure 3, A and B). The classic split-type fracture has been hypothesized to result from either an impaction of the posterior GT on the anterior glenoid during glenohumeral dislocation[31] or from a RC muscle contraction following glenohumeral dislocation that shears the GT off of the humeral head using the anterior glenoid as a fulcrum.[31] However, the actual mechanism is likely a combination of the two; during glenohumeral dislocation, the posterior aspect of the humeral head and GT are weakened by an impaction fracture from the glenoid. A spasm of the RC muscle then pulls the GT posteriorly and superiorly, resulting in propagation of the fracture line and a GT split. The frequent association of posterior humeral head impaction supports this theory[31] (Figure 3, C and D). Lastly, the depression-type fracture has been hypothesized to result from hyperabduction and traction of the humerus that causes impaction of the lateral aspect of the acromion into the GT[32] (Figure 4). However, in the series by Mutch et al,[27] nearly half of depression-type fractures (46%) occurred following documented glenohumeral dislocation. This may indicate that either the hyperabduction subsequently levers the humeral head into an anteriorly dislocated position or that the depression fracture results from the glenohumeral dislocation itself, through impaction of the GT underneath the inferior glenoid.

Treatment and Investigation Algorithm

Advanced imaging, such as CT or MRI, is helpful in the evaluation of GT fractures. If radiography shows that the GT fragment is obviously displaced (>5 mm superior translation or the GT ratio is >0.5), then surgical management can be discussed with the patient based on expected activity level and functional objectives[33] (Figure 5). When viewing radiographs, caution should be exercised with GT fractures that appear to be minimally displaced because posterior displacement can be underestimated;[34] thus, lateral and axillary radiographs are essential. In images that are unclear or borderline (ie, 3 to 5 mm), CT may be used to

Table 1

Functional Outcome After Nonsurgical Treatment for Greater Tuberosity Fracture

Study	No. of Patients	Displacement[a]	Mean Follow-up	Treatment	Outcome	ROM	Notes
Neer[20]	NA (300 total)	<1 cm	NA	Early functional ROM	Unclear	NA	GT fracture unlikely to be adequately treated closed
Platzer et al[9]	135	<6 mm	3.7 yr	PT after 3 wk	97% good to excellent Constant, 81.6 VSS, 6.2 UCLA, 30.8	NA	>3 mm tended to do worse, females and young patients had better outcomes
Platzer et al[35]	9	>5 mm	5.9 yr	PT program of RC strengthening and ROM; timing not specified	Constant, 66.5 VSS, 15.7 UCLA, 23.7 Surgical better	NA	Excluded from surgical treatment for medical reasons
Mattyasovsky et al[12]	14	<5 mm	3 yr	Oscillation after 1 wk Active ROM after 3–4 wk	100% good to excellent DASH, 13 Constant, 71	Flexion, 155° Abduction, 147° ER, 54° IR, 72°	>50% loss to follow-up
Jellad et al[11]	22	<5 mm	3 mo	Passive ROM after 1 wk Active ROM after 3 wk	90% good to excellent VAS, 0.9 Constant, 65.2	Flexion, 180° Abduction, 178° ER, 77°	Poor results with older patients + severe initial pain
Rath et al[36]	69	<3 mm	31 mo	PT after 3 wk Active ROM after 6 wk	Constant, 95 Satisfaction 9.5/10	NA	Full recovery took an average of 8.1 mo

[a] All displacement values are for superior greater tuberosity (GT) displacement; posterior GT displacement was not formally evaluated.
Constant = Constant-Murley score, DASH = Disabilities of the Arm, Shoulder, and Hand scale, ER = external rotation, IR = internal rotation, NA = not assessed, PT = physiotherapy, RC = rotator cuff, ROM = range of motion, UCLA = University of California Los Angeles shoulder rating scale, VAS = visual analog scale for pain evaluation (out of 10), VSS = Vienna Shoulder score

evaluate both fracture displacement and morphology (Figure 6).

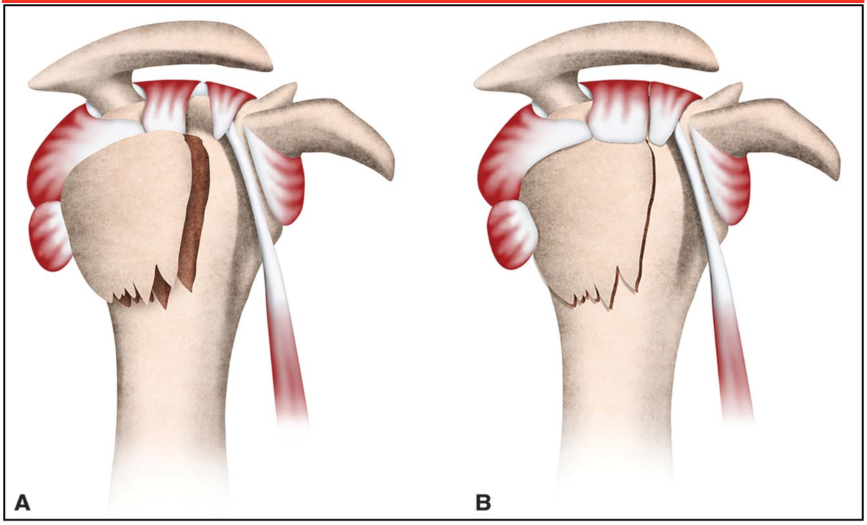
Nonsurgical

No level I or II studies describe the nonsurgical treatment of GT fractures, and the period of immobilization varies from 1 to 4 weeks in studies.[9,10,12,20] A summary of the literature on nonsurgical treatment of GT fractures is seen in Table 1. If pain or limited active range of motion persists following nonsurgical treatment, MRI can be used to evaluate for RC tears or biceps pathology.[20] Patten et al[32] noted a 5% and 33% incidence of RC tears in acute and subacute GT fractures, respectively. In a study of 50 patients by Mutch et al,[37] 20% had full-thickness RC tears at 1 year following injury; these tears were associated with lower Constant scores and decreased external rotation. MRI is less useful in acute injuries because differentiating full-thickness RC tears from post-traumatic edema is difficult. However, ultrasonography can be used acutely to diagnose discontinuity or irregularity of the humeral cortex in occult GT fractures.[32] In the subacute or chronic setting, ultrasonography has the advantage of being a dynamic study and is as effective as MRI in detecting RC atrophy.[38] A disadvantage of ultrasonography is that it is operator-dependent.

Senior Author's Preferred Technique

The senior author (D.M.R.) recommends immobilization in abduction and external rotation for 1 month with weekly radiographs in the early follow-up period to assess for secondary displacement. Gentle progressive active-assisted range of

Figure 7



A, Illustration of the lateral view of a right shoulder demonstrating a posteriorly overreduced greater tuberosity split fracture. A gap is seen between the fragment and the intact anterior cortex. **B,** Illustration of the lateral view of a right shoulder after proper reduction. The fracture gap is closed and the rotator cuff covers the humeral head.

Figure 8

AP fluoroscopic view demonstrating an inferiorly malreduced greater tuberosity fracture.

motion is then initiated. Stiffness is a frequent complication following treatment and although more aggressive mobilization protocols exist, they have not been used at our institution to minimize the risk of secondary GT displacement. If significant pain or loss of function persists at 3 to 6 months following injury, further evaluation is conducted using MRI or ultrasonography.

Surgical Treatment

Multiple surgical techniques have been described in the literature to treat displaced GT fractures. Open or arthroscopic surgical techniques may be employed depending on the fracture type, pattern, and surgeon preference with the ultimate goal of anatomic reduction.

Guides to Reduction

The most superior aspect of the GT lies 3 to 8 mm distal to the most superior aspect of the humeral head.[39] Intraoperative fluoroscopy as well as direct visualization of the fracture are helpful to guide anatomic reduction.

Senior Author's Preferred Technique

The senior author (D.M.R.) notes that GT fractures associated with anterior glenohumeral dislocations often have a zone of impaction on the posterior aspect of the humeral head and the GT. A common mistake is to reduce the GT into this defect; this results in posterior malreduction that may restrict external rotation and weaken the posterior RC. This malreduction can be recognized intraoperatively by an inability to close the rotator interval, an uncovering of the humeral head by the RC, and anterior fracture gapping (Figure 7). We recommend using the anterior fracture line as a more reliable reduction guide for anteroposterior positioning of the GT fragment. The superoinferior position of the GT fragment is often difficult to determine because of an intact RC (Figure 8). We recommend temporarily holding the GT fragment in place with a Kirschner wire and confirming GT reduction with intraoperative fluoroscopy.

Avulsion-type Fractures

Avulsion-type fractures are best treated similar to full-thickness RC tears because of the small size of the bone fragment and the need for secure fixation through the RC tendon to prevent GT escape. An arthroscopic or mini-open surgical technique may be employed, with comparable outcomes.[40] Both double-row suture-anchor repair and transosseous fixation techniques have been described, but no biomechanical or clinical studies have been done that compare them in terms of strength or functional outcome for avulsion-type fractures.

Arthroscopic repair can be performed by a surgeon experienced in shoulder arthroscopy. Some bleeding and soft-tissue swelling are expected in the acute setting. Automated suture passers, such as the "Scorpion" (Arthrex) or "True Pass" (Smith & Nephew) will not work because the bone fragment prevents closure of the jaws. Instead, sharp "Arthro-Pierce" (Smith & Nephew) or "BirdBeak" (Arthrex) instruments

Figure 9

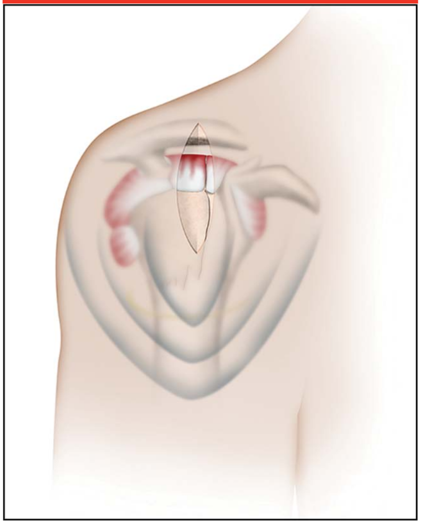


Illustration of the lateral approach using a mini-open deltoid-split technique. The location of the axillary nerve is shown with respect to the incision and the deltoid-split. The nerve is located a mean distance of 72 mm (range, 62 to 85 mm) from the lateral acromion.

Figure 10

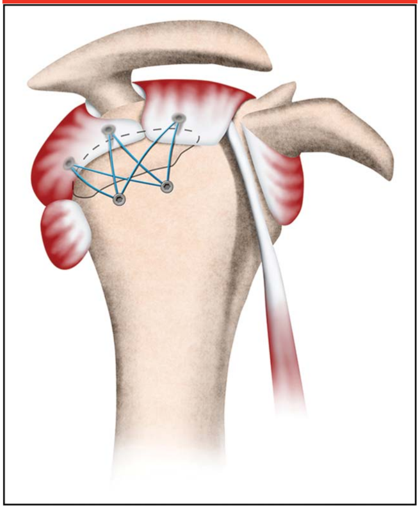


Illustration demonstrating a lateral view of a greater tuberosity avulsion fracture fixed with three anchors (blue) and simple knots over the rotator cuff tendon. Sutures are then crossed and fixed distally with interference screws (bottom two gray circles). The dotted line represents the GT fracture line underneath the cuff.

Figure 11

AP radiograph demonstrating a split-type fracture fixed using a modified calcaneus plate and anchors. This is the same patient seen in Figures 3A and 3B.

or variable angle relay suture passers can be used. Anchors should be placed in normal bone distal to the fracture bed or proximal in the cartilage on the lateral aspect of the humeral head.

The senior author (D.M.R.) prefers to use a double-row suture-anchor technique that uses a mini-open deltoid-split approach to optimize fracture compression and to prevent GT escape (Figure 9). Special care is taken during the deltoid-split because the axillary nerve is situated a mean distance of 72 mm (range, 62 to 85 mm) from the lateral acromion.[41] A stay suture is placed in the distal deltoid fibers and fascia to prevent progression of the muscle split. Inspection for fracture comminution and reduction of the GT fragment is then performed with the aid of traction sutures, direct inspection, Kirschner wires, and fluoroscopy. The superior and posterior RC tendons are incorporated into the fixation construct and up to three anchors may be used in the proximal row. Two anchors or an interference screw placed distal to the fracture bed make up the distal row (Figure 10). External rotation with minimal abduction may reduce tension on the repair while fixation is being performed. Use of metallic anchors is preferred to aid in radiologic monitoring for secondary displacement.

Transosseous fixation can be used instead of anchors and has the advantage of lower cost. A bone bridge of at least 1 cm and the use of multiple nonresorbable sutures placed through the RC tendon is recommended.[42] However, failure is a concern in patients with osteoporotic bone because of suture cut-out. Tension band fixation in isolation is not recommended because of poor rotational stability.

Split-type Fractures

As with avulsion-type fractures, both arthroscopic and mini-open techniques may be employed to repair split-type fractures. Regardless of the technique used, the GT fracture bed should be examined for comminution, impaction, or an associated Hill-Sachs lesion. Three methods of fixation have been described for split-type fractures: double-row suture-bridge, interfragmentary compression screws, or a small locking plate augmented with sutures through the RC tendon.

The interfragmentary compression screw method is inexpensive and efficient, with favorable results reported in biomechanical studies. However, postoperative fragmentation of the GT may be seen with subsequent fragment displacement and RC deficiency. Therefore, we recommend this technique be used only in young patients with a large fracture fragment and minimal or no comminution.

The double-row suture-bridge is performed the same as described earlier for avulsion-type fractures. However, with large GT fragments, access to the most lateral/inferior aspect of the GT fragment may be difficult or even impossible arthroscopically.

The senior authors' (D.M.R., G.Y.L.) preferred technique for split-type

Table 2

Functional Outcome After Surgical Treatment for Greater Tuberosity Fracture

Study	No. of Patients	No. of Patients With Dislocation	Mean Follow-up	Treatment	Outcome	ROM	Notes
Flatow et al[45]	12	NA	5 yr	TO via deltoid split	100% good to excellent	Flexion	One transient palsy axillary nerve
Park et al[46]	13	4	4.4 yr	Direct parallel sutures	89% good to excellent ASES, 87.1	Flexion, 155° ER, 46° IR, to T11	Three-part fractures included in analysis
Bhatia et al[47]	21	11	3.5 yr	Double-row suture-anchor	86% good to excellent Constant, 85.5	Flexion, 152.5° ER, 74.5°	Three patients had reoperation
Dimakopoulos et al[48]	34	34	4.8 yr	5-point TO	90% good to excellent Constant, 88.4	Flexion, 170° ER, 55°–75°	Four patients with partial GT lysis
Platzer et al[35]	52	9	5.1 yr	Tension band or percutaneous pinning	80% good to excellent Constant, 84 VSS, 5.5 UCLA, 30.2	NA	Percutaneous screw tended toward better outcomes
Ji et al[49]	16	7	2 yr	Arthroscopic fixation, double-row suture anchor	VAS, 1.2 UCLA, 31 ASES, 88.1	Flexion, 148.7° Abduction, 145° ER, 24° IR, L1	All fractures comminuted
Mattyasovsky et al[12]	12	4	3 yr	Open/percutaneous screws ± sutures, or plate	DASH, 10–14 Constant, 69–72	Flexion, 142°–149° Abduction, 142°–146° ER, 40°–49° IR, 68°–69°	>50% loss to follow-up
Schöffl et al[44]	10	NA	6–12 mo	ORIF Bamburg plate	100% excellent Constant, 94.2	NA	Plates removed by request in two patients
Yin et al[50]	17	11	5.2 yr	Open TO, suture anchors or screws; arthroscopic suture-bridge	65% excellent ASES, 82.9 VAS, 1.4	Flexion, 150.3° ER, 46.5° IR, T11	RC requiring repair, dislocation, delay >10 d no effect on outcome
Chen et al[43]	19	11	33.2 mo	ORIF with plate	95% good to excellent Constant, 90.6	Flexion, 155° Abduction, 150°	No recurrent dislocations

ASES = American Shoulder and Elbow Surgeons score, Constant = Constant-Murley score, ER = external rotation, GT = greater tuberosity, IR = internal rotation, NA = not assessed, ORIF = open reduction and internal fixation, RC = rotator cuff, ROM = range of motion, TO = transosseous suture, UCLA = University of California Los Angeles shoulder rating scale, VAS = visual analog scale for pain evaluation (out of 10), VSS = Vienna Shoulder score

fracture fixation is with a small locking plate augmented with sutures through the RC tendon using a mini-open deltoid-split approach[43] (Figure 11). This technique was first published by Schöffl et al[44] using a "Bamberg" plate, but any small fragment plate, such as a distal radius or calcaneus plate, can be contoured and trimmed for use. After ensuring adequate reduction using direct visualization and intraoperative fluoroscopy, the plate is placed on the lateral aspect of the GT fragment at least 5 mm (preferably at 10 mm) inferior to the most superior aspect of the GT and posterior to the bicipital groove. This placement prevents impingement or biceps entrapment. Four to five unicortical locking screws are then placed through the plate with placement of an additional bicortical screw through the medial calcar, if needed. Suture augmentation is essential; multiple No. 2 nonabsorbable sutures are placed through the RC tendon and the plate. Any identified RC tears are also repaired in the standard fashion. With this technique, the axillary nerve is at risk of injury in the inferior aspect of the surgical wound as well as during medial calcar drilling.

Depression-type Fractures

Depression-type fractures rarely require surgery because the fragments are impacted into the humeral head and are generally nondisplaced. If displacement occurs later, the surgical approach used for avulsion-type fractures may be employed. In our experience, depression-type fractures undergo surgery subacutely or late following the identification of a full-thickness RC tear.

Outcomes

A review of the clinical outcomes following surgical treatment of GT fractures is presented in Table 2. No level I or II studies are reported in the literature.

In the small number of published studies, good outcomes have been observed following nonsurgical treatment of minimally displaced GT fractures (<3 to 5 mm superior GT displacement). Fractures displaced >5 mm have been treated surgically with a variety of techniques and have resulted in good to excellent outcomes in 80% to 100% of patients. Patients with tension-band fixation tend to have worse outcomes but this did not achieve statistical significance.

Studies directly comparing surgical with nonsurgical treatments of displaced GT fractures are currently lacking. In a study by Platzer et al,[35] 52 patients with surgically treated GT fractures were compared with 9 patients with nonsurgically treated GT fractures (all displaced >5 mm); inferior results were reported with nonsurgical treatment. However, in the nonsurgical treatment group there was an inherent bias toward inferior results because medical comorbidities resulted in their elimination from the surgical group.

Summary

Greater tuberosity fractures can be successfully treated nonsurgically in most cases (85% to 95%). However, surgical treatment results in better functional outcomes when patients have >5 mm of superior GT displacement. However, surgical treatment of GT fractures may be considered with as little as 3 mm of superior displacement in young, active patients who are engaged in a profession or sport that requires prolonged overhead activity. The amount of posterior displacement that warrants surgical intervention in the absence of superior displacement is not currently known. However, posterior GT displacement has been demonstrated to negatively impact functional outcome independent of superior displacement. Multiple surgical methods have been described for the treatment of GT fractures and should be employed strategically according to fracture morphology, displacement, and comminution.

References

Evidence-based Medicine: Levels of evidence are described in the table of contents. In this article, references 15 and 28 are level I studies. References 19, 22, 23, 33, 34, and 38 are level II studies. References 1, 2, 4, 7, 9, 14, 24-27, 31, and 35-37 are level III studies. References 5, 6, 10-12, 17, 18, 20, 29, 32, 40, 42, 43, and 45-50 are level IV studies. References 3, 8, 13, 16, 30, and 40 are level V expert opinion.

References printed in **bold type** are those published within the past 5 years.

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