An Original Study

Management of Isolated Greater Tuberosity Fractures: A Systematic Review

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Abstract

As isolated fractures of the greater tuberosity present a therapeutic challenge, we systematically reviewed all studies of greater tuberosity fracture management. Inclusion criteria were level I to IV evidence and 2-year follow-up. Thirteen studies and 429 shoulders were included in our analyses, which compared 3 paired groups: treatment type (nonoperative vs operative), fracture displacement amount (<5 mm vs >5 mm), and surgery type (open vs arthroscopic).

Concomitant anterior glenohumeral instability was documented in 28.1% of patients and was significantly more common in displaced vs nondisplaced fractures (44.3% vs 14.5%; $P < .01$). Compared with nonoperative patients, operative patients had significantly fewer radiographic losses of reduction (48.6% vs 5.2%; $P < .01$) but increased shoulder stiffness (0.0% vs 5.7%; $P < .01$). Heterotopic ossification was more common in displaced vs nondisplaced fractures (7.5% vs 0.0%; $P < .01$). There were no significant differences in outcome between arthroscopic and open surgery, but with screw fixation (vs suture constructs) there were significantly fewer cases of stiffness (0% vs 12.0%; $P < .01$) and reoperation (0% vs 8.0%; $P = .051$).

Surgery for displaced fractures is associated with high patient satisfaction and low rates of complications and reoperations, regardless of technique and fixation mode.

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Although proximal humerus fractures are common in the elderly, isolated fractures of the greater tuberosity occur less often. Management depends on several factors, including fracture pattern and displacement.[1,2] Nondisplaced fractures are often successfully managed with sling immobilization and early range of motion.[3,4] Although surgical intervention improves

Take-Home Points

- Fractures of the greater tuberosity are often mismanaged.
- Comprehension of greater tuberosity fractures involves classification into nonoperative and operative treatment, displacement >5mm or <5 mm, and open vs arthroscopic surgery.
- Nearly a third of patients may suffer concomitant anterior glenohumeral instability.
- Stiffness is the most common postoperative complication.
- Surgery is associated with high patient satisfaction and low rates of complications and reoperations.

outcomes in displaced greater tuberosity fractures, the ideal surgical treatment is less clear.[5]

Displaced greater tuberosity fractures may require surgery for prevention of subacromial impingement and range-of-motion deficits.[2] Superior fracture displacement results in decreased shoulder abduction, and posterior displacement can limit external rotation.[6] Although the greater tuberosity can displace in any direction, posterosuperior displacement has the worst outcomes.[1] The exact surgery-warranting displacement amount ranges from 3 mm to 10 mm but is yet to be clearly elucidated.[5,6] Less displacement is tolerated by young overhead athletes, and more displacement by older less active patients.[5,7,8] Surgical options for isolated greater tuberosity fractures include fragment excision, open reduction and internal fixation (ORIF), closed reduction with percutaneous fixation, and arthroscopically assisted reduction with internal fixation.[3,9,10]

We conducted a study to determine the management patterns for isolated greater tuberosity fractures. We hypothesized that greater tuberosity fractures displaced <5 mm may be managed nonoperatively and that greater tuberosity fractures displaced >5 mm require surgical fixation.

Methods

Search Strategy

We performed this systematic review according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) checklist[11] and registered it (CRD42014010691) with the PROSPERO international prospective register of systematic reviews. Literature searches using the PubMed/Medline database and the Cochrane Central Register of Clinical Trials were completed in August 2014. There were no date or year restrictions. Key words were used to capture all English-language studies with level I to IV evidence (Oxford Centre for Evidence-Based Medicine) and reported clinical or radiographic outcomes. Initial exclusion criteria were cadaveric, biomechanical, histologic, and kinematic results. An electronic search algorithm with key words and a series of NOT phrases was designed to match our exclusion criteria:

((greater[Title/Abstract]) AND tuberosity [Title/Abstract] OR tubercle [Title/Abstract]) AND fracture[Title/Abstract]) AND proximal[Title/Abstract] AND (English[lang]))) NOT intramedullary[Title] AND (English[lang]))) NOT nonunion[Title] AND (English[lang]))) NOT malunion[Title] AND (English[lang]))) NOT biomechanical[Title/Abstract] AND (English[lang]))) NOT cadaveric[Title/Abstract] AND (English[lang]))) NOT cadaver[Title/Abstract] AND (English[lang]))) NOT ((basic[Title/Abstract]) AND science[Title/Abstract] AND (English[lang])) AND (English[lang]))) NOT revision[Title] AND (English[lang]))) NOT pediatric[Title] AND (English[lang]))) NOT physeal[Title] AND (English[lang]))) NOT children[Title] AND (English[lang]))) NOT instability[Title] AND (English[lang]))) NOT imaging[Title])) NOT salter[Title])) NOT physis[Title])) NOT shaft[Title])) NOT distal[Title])) NOT clavicle[Title])) NOT scapula[Title])) NOT ((diaphysis[Title]) AND diaphyseal[Title]))) NOT infection[Title])) NOT laboratory[Title/Abstract])) NOT metastatic[Title/Abstract])) NOT (((((((malignancy[Title/Abstract]) OR malignant[Title/Abstract]) OR tumor[Title/Abstract]) OR oncologic[Title/Abstract]) OR cyst[Title/Abstract]) OR aneurysmal[Title/Abstract]) OR unicameral[Title/Abstract]).

Study Selection

We obtained 135 search results and reviewed them for further differentiation. All the references in these studies were cross-referenced for inclusion (if missed by the initial search), which added another 15 studies. Technical notes, letters to the editor, and level V evidence reviews were excluded. Double-counting of patients was avoided by comparing each study's authors, data collection period, and ethnic population with those of the other studies. In cases of overlapping authorship, period, or place, only the study with the longer follow-up, more patients, or more comprehensive data was included. For studies separating outcomes by diagnosis, only outcomes of isolated greater tuberosity fractures were included. Data on 3- or 4-part proximal humerus fractures and isolated lesser tuberosity fractures were excluded. Studies that could not be deconstructed as such or that were devoted solely to one of our exclusion criteria were excluded. Minimum follow-up was 2 years. After all inclusion and exclusion criteria were accounted for, 13 studies with 429 patients (429 shoulders) were selected for inclusion (**Figure, Table 1**).[2,5,12-22]

Data Extraction

We extracted data from the 13 studies that met the eligibility criteria. Details of study design,

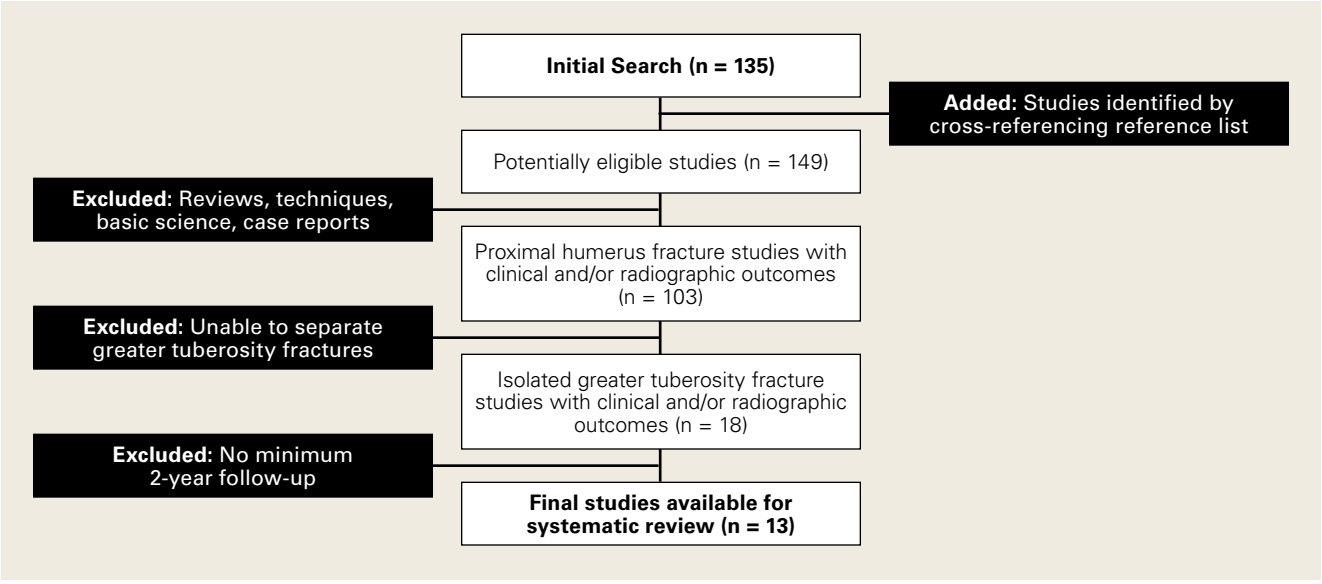

Figure. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart of search strategy.

sample size, and patient demographics, including age, sex, and hand dominance, were recorded, as were mechanism of injury and concomitant anterior shoulder instability. To capture the most patients, we noted radiographic fracture displacement categorically rather than continuously; patients were divided into 2 displacement groups (<5 mm, >5 mm). Most studies did not define degree of comminution or specific direction of displacement per fracture, so these variables were not included in the data analysis. Nonoperative management and operative management were studied. We abstracted surgical factors, such as approach, method, fixation type (screws or sutures), and technique (suture anchors or transosseous tunnels). Clinical outcomes included physical examination findings, functional assessment results (patient satisfaction; Constant and University of California Los Angeles [UCLA] shoulder scores), and the number of revisions. Radiologic outcomes, retrieved from radiographs or computed tomography scans, focused on loss of reduction (as determined by the respective authors), malunion, nonunion, and heterotopic ossification. Each study's methodologic quality and bias were evaluated with the 15-item Modified Coleman Methodology Score (MCMS), which was described by Cowan and colleagues.[23] The MCMS has been used to assess randomized and nonrandomized patient trials.[24,25] Its scaled potential score ranges from 0 to 100 (85-100, *excellent;* 70-84, *good;* 55-69, *fair;* <55, *poor*).

Statistical Analysis

We report our data as weighted means (SDs). A mean was calculated for each study that reported a respective data point, and each mean was then weighed according to its study sample size. This calculation was performed by multiplying a study's individual mean by the number of patients enrolled in that study and dividing the sum of these weighted data points by the number of eligible patients in all relevant studies. The result was that the nonweighted means from studies with smaller sample sizes did not carry as much weight as the nonweighted means from larger studies. We compared 3 paired groups: treatment type (nonoperative vs operative), fracture displacement amount (<5 mm vs >5 mm), and surgery type (open vs arthroscopic). Regarding all patient, surgery, and outcomes data, unpaired Student *t* tests were used for continuous variables and 2-tailed Fisher exact tests for categorical variables with $\alpha = 0.05$ (SPSS Version 18; IBM).

Results

Demographic information and treatment strategies are listed in **Table 2**. Fifty-eight percent of patients were male, 59.0% of dominant shoulders were affected, and 59.2% of fractures were displaced <5 mm. Concomitant shoulder instability was reported in 28.1% of patients. Mechanism of injury was not reported in all studies but most commonly (n = 75; 49.3%) involved a fall on an outstretched hand; 31 patients (20.4%) had a sports-related

Table 1. **All 13 Analyzed Studies**

Study	Year	Journal	N[a]	Country	Study Period
Keene et al[16]	1983	*Orthopedics*	4	United States	1968-1977
Flatow et al[15]	1991	*J Bone Joint Surg Am*	12	United States	1982-1990
Chen et al[21]	1998	*J Trauma*	2	China	July 1995-August 1996
Kim & Ha[20]	2000	*Arthroscopy*	23	South Korea	Not listed
Platzer et al[17,b]	2005	*Injury*	135	Austria	1992-2000
Bhatia et al[14]	2006	*Injury*	21	South Africa	January 2005-December 2005
Dimakopoulos et al[13,c]	2007	*J Bone Joint Surg Am*	20	Greece	1993-2003
Dimakopoulos et al[19,c]	2007	*J Orthop Trauma*	34	Greece	1993-2002
Platzer et al[5,b]	2008	*J Trauma*	61	Austria	1992-2003
Ji et al[22,d]	2010	*Arthroscopy*	16	South Korea	August 2004-December 2007
Yin et al[2]	2012	*Orthopedics*	17	United States	2001-March 2009
Rath et al[12]	2013	*J Shoulder Elbow Surg*	69	Israel	June 2007-May 2008
Park et al[18,d]	2014	*Eur J Orthop Surg Traumatol*	15	South Korea	January 2007-August 2010

[a]Number of patients eligible for systematic review (may differ from number of patients per study). [b]Platzer et al contributed to 2 studies (2005, 2008) with overlapping study periods. All patients in the 2005 cohort had fractures displaced <5 mm, and all patients in the 2008 cohort had fractures displaced >5 mm. Therefore, patients were not duplicated between the 2 studies. [c]Dimakopoulos et al contributed to 2 reports (both 2007) on studies with overlapping study periods. The report in *J Orthop Trauma* involved only anterior shoulder dislocations. Therefore, only patients with 2-part greater tuberosity fractures without anterior shoulder dislocations (n = 20) were selected from the report in *J Bone Joint Surg Am*. Therefore, patients were not duplicated between the 2 studies. [d]Ji et al and Park et al had overlapping authors, as well as study periods overlapping 1 year (2007). However, both studies listed the surgeons who performed all the operations, and the list showed that the surgical teams differed between studies. Therefore, patients were not duplicated between the 2 studies. No other studies had overlapping authors.

injury, and another 37 (24.3%) were injured in a motor vehicle collision. Of the 429 patients, 217 (50.6%) were treated nonoperatively, and 212 (49.4%) underwent surgery. Open, arthroscopic, and percutaneous approaches were reported. No studies presented outcomes of fragment excision.

Postoperative physical examination findings were underreported so that surgical groups could be compared. Of all the surgical studies, 4 reported postoperative forward elevation (mean, 160°; SD, 9.8°) and external rotation (mean, 46.4°; SD 26.3°).[14,15,18,22] No malunions and only 1 nonunion were reported in all 13 studies. No deaths or other serious medical complications were reported. Patients with anterior instability more often underwent surgery than were treated nonoperatively (39.2% vs 12.0%; $P < .01$) and more often had fractures displaced >5 mm than <5 mm (44.3% vs 14.5%; $P < .01$).

Comparisons of treatment type are listed in **Table 3**. Compared with nonoperative patients, operative patients had significantly fewer radiographic losses of reduction ($P < .01$) and better patient satisfaction ($P < .01$). Operative patients had a significantly higher rate of shoulder stiffness ($P < .01$). Eight operative patients (3.8%) and no nonoperative patients required reoperation during clinical follow-up ($P < .01$). All 12 reported cases of stiffness were in the operative group, and 3 required revision surgery. One patient required revision ORIF. There were 2 cases of postoperative superficial infection (0.9%) and 4 neurologic injuries (1.9%).

Comparisons of displacement amount are listed in **Table 4**. Compared with fractures displaced >5 mm, those displaced <5 mm had more radiographic losses of reduction ($P < .01$) but fewer instances of heterotopic ossification ($P < .01$). Fractures displaced >5 mm were significantly more likely than not to be managed with surgery ($P < .01$) and significantly more likely to develop stiffness after treatment ($P = .01$). One patient (0.4%) with a fracture displaced <5 mm eventually underwent surgery for stiffness, and 6 patients (3.6%) with fractures displaced >5 mm required reoperation ($P = .02$).

Comparisons of surgery type are listed in **Table 5**. All open procedures were performed with a deltoid-splitting approach. Screw fixation was used

in 4 cases: 2 percutaneous[5,21] and 2 open.[2,5] The other open and arthroscopic studies described suture fixation, half with anchors (77/156 patients; 49.4%) and half with transosseous tunnels (79/156; 50.6%). There were no statistically significant differences between open/percutaneous and arthroscopic techniques in terms of stiffness, superficial infection, neurologic injury, or reoperation rate.

Fisher exact tests were used to perform isolated comparisons of screws and sutures as well as suture anchors and transosseous tunnels. Patients with screw fixation were significantly ($P = .051$) less likely to require reoperation (0/56; 0%) than patients with suture fixation (8/100; 8.0%). Screw fixation also led to significantly less stiffness (0% vs 12.0%; $P < .01$) but trended toward a higher rate of superficial infection (3.6% vs 0%; $P = .13$). There was no statistical difference in nerve injury rates between screws and sutures (1.8% vs 3.0%; $P = 1.0$). There were no significant differences in reoperations, stiffness, superficial infections, or nerve injuries between suture anchor and transosseous tunnel constructs.

For all 13 studies, mean (SD) MCMS was 41.1 (8.6).

Table 2. **Demographics of Final Cohort of Patients Included in the Analysis**

Parameter	n (%)[a]
Sample size[2,5,12-18,20-22]	
Total number of patients	429
Mean (SD) number of patients per study	23.8 (26.5)
Sex[2,5,12-15,17,18,20-22]	
Male	235 (58.0%)
Female	170 (42.0%)
Mean (SD) age, y[2,5,12-15,17,18,20-22]	50.7 (9.2)
Shoulder dominance[2,5,13,17,20]	
Dominant	154 (59.0%)
Nondominant	107 (41.0%)
Concomitant anterior shoulder instability[2,5,12-15,17,20,22]	109 (28.1%)
Fracture displacement[2,5,13-18,20,22]	
<5 mm	242 (59.2%)
>5 mm	167 (40.8%)
Treatment	
Nonoperative[5,12,16,17]	217 (50.6%)
Operative	212 (49.4%)
Open reduction and internal fixation[2,5,13-15]	132 (30.9%)
Arthroscopic fixation[2,18,20,22]	56 (13.1%)
Percutaneous fixation[5,21]	24 (5.6%)

[a]Except where noted otherwise.

Discussion

Five percent of all fractures involve the proximal humerus, and 20% of proximal humerus fractures are isolated greater tuberosity fractures.[26,27] In his classic 1970 article, Neer[6] formulated the 4-part proximal humerus fracture classification and defined greater tuberosity fracture "parts" using the same criteria as for other fracture "parts." Neer[6] recommended nonoperative management for isolated greater tuberosity fractures displaced <1 cm but did not present evidence corroborating his recommendation. More recent cutoffs for nonoperative management include 5 mm (general population) and 3 mm (athletes).[7,17]

In the present systematic review of greater tuberosity fractures, 3 separate comparisons were made: treatment type (nonoperative vs operative), fracture displacement amount (<5 mm vs >5 mm), and surgery type (open vs arthroscopic).

Treatment Type. Only 4 studies reported data on nonoperative treatment outcomes.[5,12,16,17] Of these 4 studies, 2 found successful outcomes for fractures displaced <5 mm.[12,17] Platzer and colleagues[17] found good or excellent results in 97% of 135 shoulders after 4 years. Good results were defined with shoulder scores of ≥80 (Constant), <8 (Vienna), and >28 (UCLA), and excellent results were defined with maximum scores on 2 of the 3 systems. Platzer and colleagues[17] also found nonsignificantly worse shoulder scores with superior displacement of 3 mm to 5 mm and recommended surgery for overhead athletes in this group. Rath and colleagues[12] described a successful 3-phase rehabilitation protocol of sling immobilization for 3 weeks, pendulum exercises for 3 weeks, and active exercises thereafter. By an average of 31 months, patient satisfaction scores improved to 9.5 from 4.2 (10-point scale), though the authors cautioned that pain and decreased motion lasted 8 months on average. Conservative treatment was far less successful in the 2 studies of fractures displaced >5 mm.[5,16] Keene and colleagues[16] reported unsatisfactory results in all 4 patients with fractures displaced >1.5 cm. In a study separate from their 2005 analysis,[17] Platzer and colleagues[5] in 2008 evaluated displaced fractures and found function and patient satisfaction were inferior after nonoperative treatment than after surgery. The studies by Keene and colleagues[16] and Platzer and colleagues[5] support the finding of an overall lower

Table 3. **Comparison of Outcomes Between Nonoperative (n = 217) and Operative (n = 212) Groups**

	n (%)[a]		
Parameter	**Nonoperative**	**Operative**	***P***
Mean (SD) age, y	52.2 (8.1)	44.7 (9.1)	.12
Concomitant anterior shoulder instability	26 (12.0%)	83 (39.2%)	<.01[c]
Fracture displaced >5 mm	13 (6.0%)	154 (72.6%)	<.01[c]
Number of patients with radiographic follow-up	144	172	
Mean (SD) total radiographic follow-up, mo	46.1 (15.2)	50.9 (17.0)	.39
Loss of fracture reduction	70 (48.6%)	9 (5.2%)	<.01[c]
Heterotopic ossification	5 (3.5%)	8 (4.7%)	.78
Number of patients with clinical follow-up	217	212	.09
Mean (SD) total clinical follow-up, mo	41.5 (15.3)	49.5 (16.6)	.67
Mean (SD) Constant Shoulder Score	85.7 (11.7)	87.1 (4.2)	.95
Mean (SD) UCLA Shoulder Score	30.8 (4.2)	31.1 (1.2)	<.01[c]
Mean (SD) patient satisfaction	46.1% (47.1%)	90.4% (13.0%)	<.01[c]
Stiffness	0 (0%)	12 (5.7%)	.24
Superficial infection	0 (0%)	2 (0.9%)	<.01[c]
Reoperation[b]	0 (0%)	8 (3.8%)	.11
Reoperation for stiffness[b]	0 (0%)	3 (1.4%)	.49
Revision fixation[b]	0 (0%)	1 (0.5%)	

[a]Except where noted otherwise. [b]For nonoperative management, *reoperation* refers to surgery performed later in the follow-up period. [c]Statistically significant.
Abbreviation: UCLA, University of California Los Angeles.

patient satisfaction rate in nonoperative patients.

Fracture Displacement Amount. Only 2 arthroscopic studies and no open studies addressed surgery for fractures displaced <5 mm. Fewer than 16% of these fractures were managed operatively, and <1% required reoperation. By contrast, almost all fractures displaced >5 mm were managed operatively, and 3.6% required reoperation. Radiographic loss of reduction was more common in fractures displaced <5 mm, primarily because they were managed without fixation. Radiographic loss of reduction was reported in only 9 operatively treated patients, none of whom was symptomatic enough to require another surgery.[5] Reoperations were most commonly performed for stiffness, which itself was significantly more common in fractures displaced >5 mm. Bhatia and colleagues[14] reported the highest reoperation rate (14.3%; 3/21), but they studied more complex, comminuted fractures of the greater tuberosity. Two of their 3 reoperations were biceps tenodeses for inflamed, stiff tenosynovitis, and the third patient had a foreign body giant cell reaction to suture material. Fewer than 1% of patients with operatively managed displaced fractures required revision ORIF, and <2% developed a superficial infection or postoperative nerve palsy.[19,22] For displaced greater tuberosity fractures, surgery is highly successful overall, complication rates are very low, and 90% of patients report being satisfied.

Surgery Type. Patients were divided into 2 groups. In the nonarthroscopic group, open and percutaneous approaches were used. All studies that described a percutaneous approach used screw fixation[5,21]; in addition, 32 patients were treated with screws through an open approach.[2,5] The other open and arthroscopic studies used suture fixation. Interestingly, no studies reported on clinical outcomes of fragment excision. There were no statistically significant differences in rates of reoperation, stiffness, infection, or neurologic injury between the arthroscopic and nonarthroscopic groups. Patient satisfaction scores were slightly higher in the nonarthroscopic group (91.0% vs 87.8%), but the difference was not statistically significant.

Table 4. **Comparison of Outcomes Between <5 mm (n = 242) and >5 mm (n = 167) Fracture Displacement**

	n (%)[a]		
Parameter	**<5 mm**	**>5 mm**	***P***
Mean (SD) age, y	50.9 (7.4)	50.9 (10.0)	>.99
Concomitant anterior shoulder instability	35 (14.5%)	74 (44.3%)	<.01[d]
Operative treatment	38 (15.7%)	154 (92.2%)	<.01[d]
Number of patients with radiographic follow-up	150	146	.07
Mean (SD) total radiographic follow-up, mo	42.4 (11.8)	53.1 (16.8)	<.01[d]
Loss of fracture reduction	64 (42.7%)	15 (10.3%)	<.01[d]
Heterotopic ossification	0 (0.0%)	11 (7.5%)	
Number of patients with clinical follow-up	242	167	<.01[d]
Mean (SD) total clinical follow-up, mo	37.9 (9.3)	54.2 (14.6)	.55
Mean (SD) Constant Shoulder Score	86.6 (7.7)	84.5 (8.9)	.68
Mean (SD) UCLA Shoulder Score	31.5 (1.0)	29.6 (3.4)	N/A[c]
Mean (SD) patient satisfaction	N/A[c]	87.4% (30.1%)	.01[d]
Stiffness	2 (0.8%)	9 (5.5%)	.17
Superficial infection	0 (0%)	2 (1.2%)	.02[d]
Reoperation[b]	1 (0.4%)	6 (3.6%)	.57
Reoperation for stiffness[b]	1 (0.4%)	2 (1.2%)	.41
Revision fixation[b]	0 (0%)	1 (0.6%)	

[a]Except where noted otherwise. [b]For fractures displaced <5 mm, *reoperation* refers to surgery performed later in the follow-up period (if initially managed nonoperatively) or to reoperation (if initially managed operatively). [c]Insufficient data to report satisfaction of patients with fractures displaced <5 mm. [d]Statistically significant.
Abbreviations: N/A, not available; UCLA, University of California Los Angeles.

With surgical techniques isolated, there were no significant differences between suture anchors and transosseous tunnel constructs, but screws performed significantly better than suture techniques. Compared with suture fixation, screw fixation led to significantly fewer cases of stiffness and reoperation, which suggests surgeons need to give screws more consideration in the operative management of these fractures. However, the number of patients treated with screws was smaller than the number treated with suture fixation; it is possible the differences between these cohorts would be eliminated if there were more patients in the screw cohort. In addition, screw fixation was universally performed with an open or percutaneous approach and trended toward a higher infection rate. As screw and suture techniques have low rates of complications and reoperations, we recommend leaving fixation choice to the surgeon.

Anterior shoulder instability has been associated with greater tuberosity fractures.[1,8,19] The supraspinatus, infraspinatus, and teres minor muscles all insert into the greater tuberosity and resist anterior translation of the proximal humerus. Loss of this dynamic muscle stabilization is amplified by tuberosity fracture displacement: Anterior shoulder instability was significantly more common in fractures displaced >5 mm (44.3%) vs <5 mm (14.5%). In turn, glenohumeral instability was more common in patients treated with surgery, specifically open surgery, because displaced fractures may not be as easily accessed with arthroscopic techniques. No studies reported concomitant labral repair or capsular plication techniques.

This systematic review was limited by the studies analyzed. All but 1 study[5] had level IV evidence. Mean (SD) MCMS was 41.8 (8.6). Any MCMS score <54 indicates a poor methodology level, but this scoring system is designed for randomized controlled trials,[23] and there were none in this study. Physical examination findings, such as range of motion, were underreported. In addition, radiographic parameters were not consistently described but rather were determined by the

Table 5. **Comparison of Outcomes Between Open/Percutaneous (n = 156) and Arthroscopic (n = 56) Fixation**

Parameter	n (%)[a] Open/ Percutaneous	Arthroscopic[b]	*P*
Mean (SD) age, y	44.1 (8.8)	46.4 (10.7)	.77
Concomitant anterior shoulder instability	65 (41.7%)	11 (19.6%)	<.01[c]
Screw fixation	56 (35.9%)	0 (0%)	<.01[c]
Suture fixation	100 (64.1%)	56 (100%)	<.01[c]
Suture anchors	21 (13.5%)	56 (100%)	<.01[c]
Transosseous tunnels	79 (50.6%)	0 (0%)	<.01[c]
Number of patients with clinical follow-up	156	56	
Mean (SD) total clinical follow-up, mo	57.4 (12.2)	27.4 (18.5)	<.01[c]
Mean (SD) patient satisfaction	91.0% (14.7%)	87.8% (7.4%)	.49
Stiffness	9 (5.8%)	3 (5.4%)	1.0
Superficial infection	2 (1.3%)	0 (0%)	1.0
Nerve injury	3 (1.9%)	1 (1.8%)	1.0
Reoperation[b]	6 (3.8%)	2 (3.6%)	1.0
Reoperation for stiffness[b]	1 (0.6%)	2 (3.6%)	.17
Revision fixation[b]	1 (0.6%)	0 (0%)	1.0

[a]Except where noted otherwise. [b]For nonoperative management, *reoperation* refers to surgery performed later in the follow-up period. [c]Insufficient radiographic data in arthroscopic fixation group for comparison with open fixation group. [d]Statistically significant.

respective authors' subjective interpretations of malunion, nonunion, and loss of reduction. Publication bias is present in that we excluded non-English language studies and medical conference abstracts and may have omitted potentially eligible studies not discoverable with our search methodology. Performance bias is a factor in any systematic review with multiple surgeons and wide variation in surgical technique.

Conclusion

Greater tuberosity fractures displaced <5 mm may be safely managed nonoperatively, as there are no reports of nonoperatively managed fractures that subsequently required surgery. Nonoperative treatment was initially associated with low patient satisfaction, but only because displaced fractures were conservatively managed in early studies.[5,16] Fractures displaced >5 mm respond well to operative fixation with screws, suture anchors, or transosseous suture tunnels. Stiffness is the most common postoperative complication (<6%), followed by heterotopic ossification, transient neurapraxias, and superficial infection. There are no discernible differences in outcome between open and arthroscopic techniques, but screw fixation may lead to significantly fewer cases of stiffness and reoperation in comparison with suture constructs.

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