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Lesser tuberosity osteotomy in total shoulder arthroplasty: impact of radiographic healing on outcomes

Jonathan C. Levy, MD[a,*], Paul DeVito, DO[a], Derek Berglund, MD[b], Rushabh Vakharia, MD[a], Molly Moor, PhD, MPH[a], Andy Malarkey, DO[a], Scott Polansky, DO[c]

[a]*Shoulder and Elbow Surgery, Holy Cross Orthopedic Research Institute, Fort Lauderdale, FL, USA*
[b]*Department of General Surgery, Geisinger Medical Center, Danville, PA, USA*
[c]*Department of Orthopedic Surgery, Broward Health Medical Center, Fort Lauderdale, FL, USA*

Background: Lesser tuberosity osteotomy (LTO) has gained popularity in anatomic total shoulder arthroplasty (TSA); however, healing rates have not been universally high. This study examined differences in outcomes based on variations in LTO healing.

Methods: A retrospective review identified primary TSA patients with 2-year minimum follow-up treated with a LTO. Postoperative radiographs classified LTO healing as "bony union," "nondisplaced nonunion," "displaced nonunion," and "not seen," creating 4 cohorts. Comparisons were made among patient-reported outcome measures (PROMs), motion, and radiographic evidence of component loosening.

Results: The study cohort consisted of 189 patients who met inclusion criteria, with an average age of 69.5 years (range, 32-89 years) and follow-up of 50 months (range, 24-95 months). There were 143 patients with union, 16 with nondisplaced nonunion, 14 with displaced nonunion, and 16 not seen. There were no differences in preoperative comparisons. All cohorts demonstrated significant improvements in PROMs and ranges of motion; however, the displaced nonunion cohort had no improvement in Single Assessment Numeric Evaluation (0.114) or internal rotation ($P = .279$). Patients with displaced nonunion had lower postoperative functional scores (Simple Shoulder Test and American Shoulder and Elbow Surgeons scores; $P < .01$), and higher pain scores (visual analog scale for pain; $P < .01$). However, 85.7% of patients reported they would have the same procedure again. Simple Shoulder Test (2.5) and American Shoulder and Elbow Surgeons score (37.5) improvements exceeded minimal clinically important difference thresholds for TSA. A higher rate of glenoid gross loosening was present in the displaced nonunion cohort (3 patients [21.4%]; $P < .01$). There were no cases of loose humeral stems.

Conclusion: Patients with a displaced nonunion LTO site have lower functional scores and higher pain scores but still achieve substantial clinical improvement and high satisfaction rates.

The Western Institutional Review Board approved this study (Study #:1179001).

*Reprint requests: Jonathan C. Levy, MD, Holy Cross Orthopedic Institute, Shoulder and Elbow Surgery, 5597 N Dixie Hwy, Ft. Lauderdale, FL 33334, USA.

E-mail address: jonlevy123@yahoo.com (J.C. Levy).

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Multiple surgical approaches to subscapularis management have been described for anatomic total shoulder arthroplasty (TSA). With ample evidence to support each approach, subscapularis tenotomy, peel, and lesser tuberosity osteotomy (LTO) all have been associated with successful outcomes.[15] Nonetheless, the surgical approach to subscapularis management remains a critical step in TSA and is typically the factor limiting the progression of the speed of recovery.

Although no consensus exists regarding the optimal approach, advocates of LTO cite improved mechanical strength and high rates of healing.[11,13,21,22] Nonetheless, displacement of LTO repairs has been described.[18] Small et al[28] described radiographic characteristics of LTO repair and characterized the integrity of the LTO site as "united," "nondisplaced nonunion," "displaced nonunion," and "not seen." However, clinical outcomes for each subtype were not described.

When displacement of the LTO is observed early, there is an opportunity to repair the displaced subscapularis. This has been typically advocated based on the assumption that poor clinical outcomes with anterior instability will result.[28] Unfortunately, when patients present late, the opportunity to repair the displaced tuberosity becomes a much more challenging endeavor. How LTO nondisplaced or displaced nonunion may affect clinical outcomes remains unclear. The purpose of this study was to report clinical outcomes associated with each of the described radiographic characteristics of LTO after anatomic TSA. We hypothesized that patients with an LTO displaced nonunion would have worse functional outcomes compared with those with nondisplaced nonunion, union, or even those that could not be seen.

Materials and methods

A retrospective query of our institution's Shoulder and Elbow Surgery Registry was conducted with a focus on identifying all patients undergoing primary anatomic TSA using an LTO for subscapularis management between April 2009 and October 2015. Inclusion criteria identified consented patients treated with the same primary (TSA) system (DJO Turon, Austin, TX, USA) using an LTO with complete preoperative data and minimum of 2-year follow-up. Patients were excluded if the TSA implant system was different from the implant referenced above or if they were treated with other subscapularis mobilization techniques.

All TSA procedures were performed by the same surgeon using a deltopectoral approach and a fleck-LTO.[8] A press-fit humeral component was used for all cases, typically obtaining metaphyseal fixation augmented by placing morselized bone graft from the humeral head into the humeral canal before stem implantation. The glenoid was prepared using standard noncannulated instrumentation, asymmetrically reaming the glenoid in cases of eccentric wear. All glenoid components were cemented. A keeled glenoid component was used when the glenoid vault was narrow. The LTO was repaired using a series of 4 transosseous high-tensile sutures (No. 2 Force Fiber; Stryker, Mahwah, NJ, USA) placed through the biceps groove with an additional FiberTape suture (Arthrex, Naples, FL, USA) placed as a cerclage suture through the greater tuberosity, wrapped around the humeral stem, and passed through the bone-tendon junction of the subscapularis.

Postoperatively, all patients were managed with the same rehabilitation protocol consisting of wearing a shoulder immobilizer with a self-directed therapy protocol focused on pendulum exercises only for the first 6 weeks, followed by an active-assisted stretching program. Strengthening and lifting were delayed for 3 months.

All preoperative radiographic analysis was performed using midglenoid axial computed tomography scans. Glenoid wear was classified as concentric or eccentric using the Levine classification.[17] The humeral head subluxation index was calculated using the technique described by Walch et al.[9] Glenoid version was calculated using the Friedman angle.[9] Image review was conducted using a consensus of at least 2 trained reviewers and subsequent confirmation by the senior author (J.C.L.).

Postoperative radiographs were reviewed using a similar consensus method. Sequential postoperative anterior-posterior, scapular Y, and axillary lateral radiographs were used to evaluate the integrity of the LTO. If integrity of the LTO was unclear after review of the initial series of radiographs, the subsequent follow-up was reviewed and assessed for LTO healing. LTO healing was classified as bony union, nondisplaced nonunion, displaced nonunion, and not seen.[28] When the osteotomy site or fleck osteotomy could not be clearly identified to assess integrity, healing was classified as not seen. These groups defined the 4 cohorts for analysis. The most recent scapular anterior-posterior and axillary lateral radiographs were assessed for glenoid[16] and humeral stem loosening.[29]

As part of the standard protocol for the institution's Shoulder and Elbow Surgery Registry, patient-reported outcome measures (PROMs) were routinely collected immediately before surgery and at 3, 6, and 12 months postoperatively. Follow-up assessments were conducted at yearly intervals after the 12-month postoperative visit. Patients unable to return for routine follow-up were notified by an automated e-mail with a secure link, allowing PROMs surveys to be completed online using a Health Insurance Portability and Accountability Act–protected web-based portal.[32] PROMs used for comparing the cohorts were the Simple Shoulder Test (SST), American Shoulder and Elbow Surgeons Total (ASES), visual analog scale (VAS) for pain, and Single Assessment Numeric Evaluation (SANE).

At each visit, the patient's best effort active range of motion (ROM) was measured goniometrically and recorded in the registry. Measurements included forward elevation and external rotation.

Internal rotation was measured as the highest midline segment of the back that could be reached.[30] Overall patient satisfaction with the procedure was reported postoperatively as excellent, good, satisfactory, or unsatisfactory.

Preoperative PROMs, active ROM motion, and computed tomography–based radiographic characteristics were compared to determine whether differences existed among the 4 cohorts at the time of surgery. Postoperative outcomes recorded at the most recent follow-up were used to calculate improvement, and radiographic observations of loosening were also compared. Kaplan-Meier survival analysis was performed referencing gross glenoid loosening as an end point using MedCalc 18.10.2 software (MedCalc Software bvba, Ostend, Belgium).

Descriptive statistics, including frequencies with percentages and medians with interquartile ranges, were calculated for all variables. Patient outcomes by treatment group were compared using χ^2 tests for categorical variables. Kruskal-Wallis tests with Dunn multiple comparisons, adjusted using the Bonferroni correction, were used to compare continuous variables. Efficacy of treatment was analyzed with Wilcoxon signed rank tests to compare preoperative to postoperative changes in variables. Data analysis was performed using SPSS 23 software (IBM, Armonk, NY USA). All significant tests were 2-tailed, and $P < .05$ was used to determine whether there was a significance.

Results

Of the 226 patients with preoperative data treated with TSA using an LTO, 189 (84%) patients, 110 men (58.2%) and 79 women (41.8%), met inclusion criteria with an average follow-up of 50 months (range, 24-95 months). The mean age was 69.5 years (standard deviation, 19.2; range 32.0-88.9 years). There were 143 (75.7%) patients with union of the LTO site, 16 (8.5%) with a nondisplaced nonunion, 14 (7.40%) with a displaced nonunion, and 16 (8.5%) where the LTO could not be identified (not seen). There were no cases of refixation of any LTO nonunion.

Preoperative comparisons found no difference among the 4 cohorts with respect to baseline PROMs (Table I) and ROM (Table II). In addition, preoperative computed tomography found no difference in the Levine classification, glenoid version, or the subluxation index (Table III).

Table I Preoperative and postoperative patient reported outcome measures

Variables	Union (n = 143)	Nondisplaced nonunion (n = 16)	Displaced nonunion (n = 14)	Not seen (n = 16)	*P*
Age, yr	70.5 (64.5-74.6)	71.6 (66.8-76.7)	67.9 (53.5-75.9)	70.2 (65.1-76.8)	.521
Clinical follow-up, mo	49.4 (35.4-65.3)	50.5 (37.8-57.9)	52.5 (31.8-66.7)	38.3 (27.4-48.9)	.481
Simple Shoulder Test					
Preoperative	3 (1-5)	2 (1-6)	4.5 (1-6)	4 (1-6)	.822
Postoperative	11 (8-12)	10 (6-12)	7.5 (1-9)*	9 (6-11)	.003
Amount of improvement	6 (4-9)	5.5 (3-9)	2.5 (2-8)*	5.5 (2-8)	.006
SANE					
Preoperative	35 (20-50)	38 (20-50)	31 (10-70)	47.5 (19-72)	.623
Postoperative	90 (75-98)	86 (60-100)	77 (35.5-94)	85.5 (64-95.5)	.510
Amount of improvement	49 (25-70)	45 (7-67)	33 (−8 to 80)	21 (9-56)	.259
Visual analog scale function					
Preoperative	3 (2-5)	3 (2-5)	5 (2-6)	4 (3-6)	.294
Postoperative	9 (8-10)	9 (8-10)	8.5 (4-9)	8 (7-9)	.168
Amount of improvement	5 (4-7)	5.5 (2-7)	2 (0-4)†	3 (1-6)	.006
ASES total					
Preoperative	31.7 (21.7-45)	23.3 (19.2-38.8)	22.5 (14.6-35.5)	33 (21.3-39.9)	.374
Postoperative	90 (78.3-98.3)	81.7 (73.7-99.2)	62.5 (41.7-91.7)†	81.7 (71.7-94.6)	.039
Amount of improvement	53.3 (36-71.7)	60.6 (40.9-71.6)	37.5 (19.2-56.2)	53.6 (39.1-61.6)	.245
Visual analog scale pain					
Preoperative	7 (5-8)	7.5 (4.5-9)	7.5 (6-8)	7 (5-8)	.876
Postoperative	0 (0-1)	0 (0-2)	2.5 (1-5)*	0 (0-2)	.007
Amount of improvement	−6 (−8 to −4)	−7 (−8 to −4)	−4 (−6 to −1)	−5.5 (−8 to −5)	.191
Satisfaction					.103
Excellent	113 (79)	11 (69)	9 (65)	13 (81)	
Good	21 (15)	3 (19)	2 (14)	0 (0)	
Satisfied	7 (5)	1 (6)	2 (14)	2 (13)	
Unsatisfied	2 (1)	1 (6)	1 (7)	1 (6)	
Would have same procedure again	126 (88.1)	14 (87.5)	12 (85.7)	15 (93.8)	.886

SANE, Single Assessment Numeric Evaluation; *ASES*, American Shoulder and Elbow Surgeons score.
Data are presented as median (interquartile range) or as number (%).
* Significant at $P < .01$, with union as the reference category.
† Significant at $P < .05$.

Table II Preoperative and postoperative range of motion

Variable	Union (n = 143)	Nondisplaced nonunion (n = 16)	Displaced nonunion (n = 14)	Not seen (n = 16)	*P*
Active elevation, °					
Preoperative	100 (75-115)	118 (89-130)	95 (74-126)	110 (80-130)	.200
Postoperative	145 (130-155)	143 (140-150)	113 (78-145)	145 (130-160)	.841
Amount of improvement	45 (25-65)	30 (11-44)	28 (16-71)	40 (15-70)	.146
Active external rotation, °					
Preoperative	25 (0-30)	25 (13-40)	10 (0-30)	10 (0-50)	.284
Postoperative	50 (40-60)	45 (40-59)	48 (39-60)	60 (55-60)*	.022
Amount of improvement	30 (15-40)	20 (6-38)	35 (25-47)	30 (15-60)	.097
Active internal rotation, °					
Preoperative	2 (2-4)	4 (2-4)	4 (2-8)	2 (2-4)	.114
Postoperative	8 (6-8)	8 (8-10)†	6 (3.5-8)	8 (4.5-8)	.006
Amount of improvement	4 (2-6)	4 (2-6)	0 (0-4)*	4 (0-6)	.027

Data are presented as median (interquartile range).
* Significant at $P < .05$.
† Significant at $P < .01$, with displaced nonunion as the reference category.

Table III Preoperative computed tomography and postoperative radiographic findings

Variable	Union (n = 143)	Nondisplaced nonunion (n = 16)	Displaced nonunion (n = 14)	Not seen (n = 16)	*P*
Levine class					.712
Concentric	104 (72.7)	11 (68.8)	9 (64.3)	10 (62.5)	
Eccentric	39 (27.3)	5 (31.2)	5 (35.7)	6 (37.5)	
Glenoid version	−9.8 (−17.8 to −4.3)	−8.4 (−20.6 to −5.9)	−6.8 (−11.8 to −3.2)	−9.9 (−13.8 to −8.2)	.395
Subluxation index, %	52.1 (46.7-57.8)	54.2 (47.1-56.8)	48.6 (44.3-58.6)	52.0 (47.2-59.6)	.929
Post-op radiographic follow-up, mo	29.4 (12.1-49.3)	18.0 (3.7-38.1)*	53.8 (35.6-63.2)	25.7 (12-37)	.011
Glenoid loosening					
Any loosening	20 (14)	3 (18.8)	4 (28.6)	1 (6.3)	.362
Gross loosening	4 (2.8)	0 (0)†	3 (21.4)‡	0 (0)†	.036

Data are presented as number (%) or as median (interquartile range).
* Significant at $P < .01$, with displaced nonunion as the reference category.
† Significant at $P < .05$.
‡ Significant at $P < .01$, with union as the reference category.

Overall efficacy of TSA among the 4 cohorts is summarized in Table IV. All cohorts experienced statistically significant preoperative to postoperative improvements in PROMs and ROM, with few exceptions. Patients in the displaced nonunion cohort had no significant preoperative to postoperative improvement in SANE score (Table IV) or active internal rotation (Tables II and IV).

Postoperative PROM comparisons identified significant differences among the cohorts' postoperative SST ($P = .003$), ASES Total ($P = .006$), VAS pain ($P = .007$), and VAS function improvement ($P = .039$; Table I). Postoperative active external rotation ($P = .22$), active internal rotation ($P = .006$), and improvement in internal rotation ($P = .027$) were significantly different among the cohorts (Table II). The nondisplaced nonunion patients did not show differences in PROMs or ROM compared with those with union.

Subgroup comparisons found patients in the displaced nonunion cohort had lower postoperative SST scores ($P < .01$), lower overall SST improvement ($P < .05$), lower postoperative ASES scores ($P < .01$), lower overall improvement in VAS function ($P < .05$), and higher postoperative VAS pain scores ($P < .01$) compared with the union cohort. Although PROMs were lower among patients with a displaced nonunion, 85.7% of the patients reported they would have the same procedure again, with only 1 patient with an unsatisfied outcome (Table I). The nondisplaced nonunion patients did not show differences in postoperative PROMs or ROM compared with those with union.

Postoperative radiographic findings are reported in Table III. Although there were no differences in the incidence of radiolucent glenoid lines, glenoid gross loosening occurred significantly more often in patients with a displaced nonunion

Table IV Efficacy of treatment

Assessment	Pre-op score	Post-op score	*P*
	Median (IQR)	Median (IQR)	
Simple Shoulder Test			
Union	3 (1-5)	11 (8-12)	<.001
Nondisplaced nonunion	2 (1-6)	10 (6-12)	<.001
Displaced nonunion	4.5 (1-6)	7.5 (1-9)	.001
Not seen	4 (1-6)	9 (6-11)	<.001
SANE			
Union	35 (20-50)	90 (75-98)	<.001
Nondisplaced nonunion	38 (20-50)	86 (60-100)	<.001
Displaced nonunion	31 (10-70)	77 (35.5-94)	.114
Not seen	47.5 (19-72)	85.5 (64-95.5)	.005
Visual analog scale function			
Union	3 (2-5)	9 (8-10)	<.001
Nondisplaced nonunion	3 (2-5)	9 (8-10)	<.001
Displaced nonunion	5 (2-6)	8.5 (4-9)	.020
Not seen	4 (3-6)	8 (7-9)	.006
ASES total			
Union	31.7 (21.7-45)	90 (78.3-98.3)	<.001
Nondisplaced nonunion	23.3 (19.2-38.8)	81.7 (73.7-99.2)	.001
Displaced nonunion	22.5 (14.6-35.5)	62.5 (41.7-91.7)	.001
Not seen	33 (21.3-39.9)	81.7 (71.7-94.6)	.001
Visual analog scale pain			
Union	7 (5-8)	0 (0-1)	<.001
Nondisplaced nonunion	7.5 (4.5-9)	0 (0-2)	.001
Displaced nonunion	7.5 (6-8)	2.5 (1-5)	.005
Not seen	7 (5-8)	0 (0-2)	.001
Active elevation			
Union	100 (75-115)	145 (130-155)	<.001
Nondisplaced nonunion	118 (89-130)	143 (140-150)	<.001
Displaced nonunion	95 (74-126)	113 (78-145)	.022
Not seen	110 (80-130)	145 (130-160)	.004
Active external rotation			
Union	25 (0-30)	50 (40-60)	<.001
Nondisplaced nonunion	25 (13-40)	45 (40-59)	.003
Displaced nonunion	10 (0-30)	48 (39-60)	.013
Not seen	10 (0-50)	60 (55-60)	.001
Active internal rotation			
Union	2 (2-4)	8 (6-8)	<.001
Nondisplaced nonunion	4 (2-4)	8 (8-10)	<.001
Displaced nonunion	4 (2-8)	6 (3.5-8)	.279
Not seen	2 (2-4)	8 (4.5-8)	.008

IQR, interquartile range; *SANE*, Single Assessment Numeric Evaluation; *ASES*, American Shoulder and Elbow Surgeons score.

(3 patients [21.4%]) compared with all other groups ($P < .05$). Kaplan-Meier survival analysis referencing gross glenoid loosening as an end point identified a mean survival of 93 months (95% confidence interval, 87.5-98.4; Fig. 1). There were no cases of loose humeral stems.

Three patients were treated with revision. One patient with a displaced LTO nonunion did not improve clinically and was converted to a reverse shoulder arthroplasty 1 year later (Figs. 2 and 3). One patient developed a late postoperative infection at 5 years and was treated with a 2-stage revision to a reverse shoulder arthroplasty. The other developed a massive rotator cuff tear of the supraspinatus and infraspinatus 5 years after surgery and was revised to a reverse shoulder arthroplasty. No additional revisions were performed in patients with less than 2 years of follow-up who were not included in the study cohorts.

Discussion

To our knowledge, this is the first study to document and compare clinical outcomes of various degrees of LTO healing

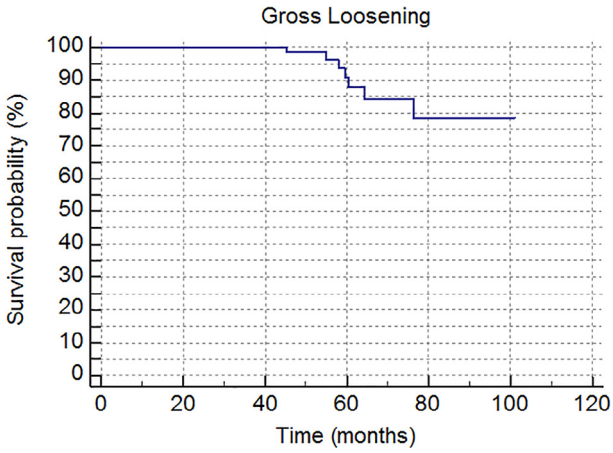

Figure 1 Kaplan-Meier survival curve referencing gross glenoid loosening.

after anatomic TSA. The results demonstrate patients with a displaced LTO nonunion have a greater rate of glenoid gross loosening, higher pain scores, and lower function outcomes scores. However, at an average of 50 months of follow-up, they maintain high levels of patient satisfaction and desire to have the surgery again, with improvements that exceed what has been suggested as a substantial clinical improvement.[26,27] Patients with nondisplaced LTO nonunions did not demonstrate differences in pain, outcome, motion, or radiographic loosening compared with those with LTO unions, suggesting that a nondisplaced nonunion does not affect outcomes of TSA.

One may not have expected to observe the improvements seen with LTO displaced nonunions. Significant improvements in all PROMs and ROM (except SANE and active internal rotation) were observed. These improvements are paralleled by the 87.5% of this cohort that would have the procedure again and the absence of patient satisfaction differences compared with the other cohorts. Using the minimal clinically important difference (MCID) thresholds defined by Simovitch et al,[26,27] the displaced nonunion cohort met and exceeded MCID for SST (>1.5, ±0.3), ASES (>13.6, ±2.3), VAS pain (>1.6, ±0.3), active forward flexion (>12, ±4), and active external rotation (>3, ±0.3). In addition, the displaced nonunion cohort met and exceeded substantial clinical benefit for ASES (>31.5, ±2) and active external rotation (>11.7, ±1.9).

Subscapularis dysfunction has frequently been observed, with reported rates as high as 60% after anatomic TSA.[6,7,19,20] Several studies have clinically documented the manifestation of this dysfunction, with loss of internal rotation,[12,19,20] abnormal lift-off or belly-press tests, and loss of functional activities like the ability to tuck in one's shirt or fasten a bra.[31] Nonetheless, physical examination findings have proven to be unreliable and demonstrate poor predictive value for subscapularis integrity and pathology when referenced to ultrasound findings of subscapularis integrity.[12,19]

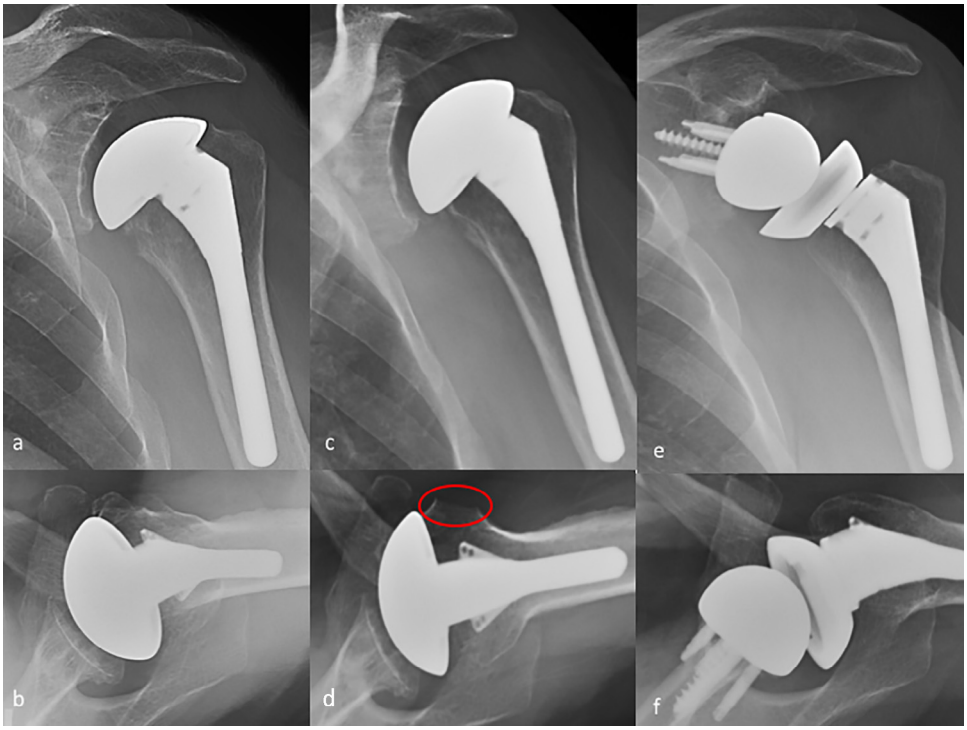

Figure 2 Illustrative case of a patient who sustained a lesser tuberosity osteotomy (LTO) displaced nonunion requiring revision. Reduced LTO is demonstrated on initial **(a)** anteroposterior and **(b)** axillary lateral radiographs. **(c** and **d)** Radiographs at the 6-week follow-up assessment demonstrate displacement of the LTO. **(e** and **f)** Follow-up radiographs at 1 year after the revision using a platform conversion to a reverse shoulder arthroplasty. The *red* ○ identifies the missing LTO.

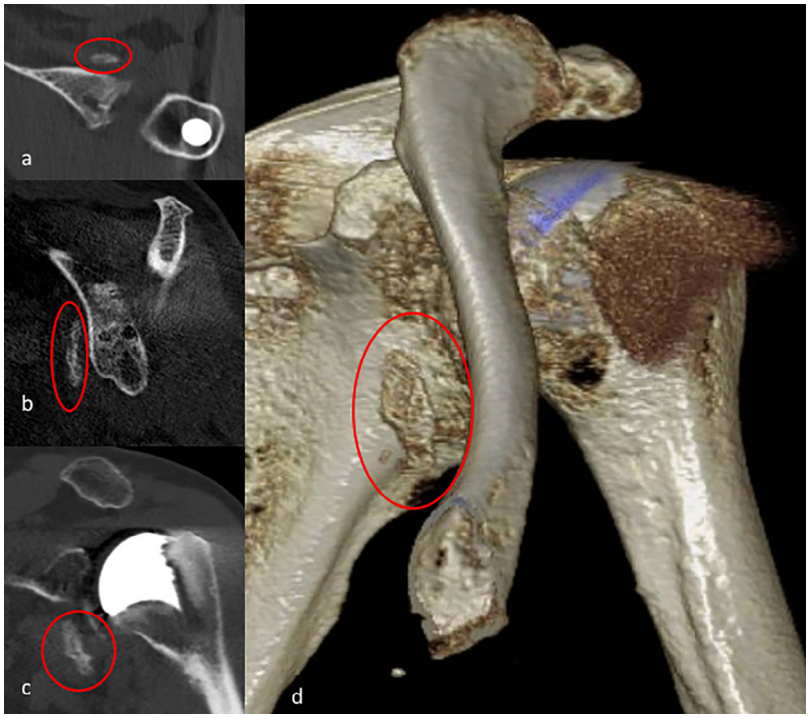

Figure 3 Computed tomography scan performed 10 months after primary TSA demonstrates lesser tuberosity osteotomy (LTO) displaced nonunion of patient described in Fig. 2. Retraction of the LTO to the level of the glenoid is demonstrated in **(a)** axial, **(b)** sagittal, **(c)** coronal, and **(d)** 3-dimensional reconstructions. The *red* ○ identifies the LTO.

Armstrong et al[1] reported high rates of eletromyographic evidence of subscapularis chronic denervation and reinnervation after anatomic TSA in the setting of significant clinical improvements in functional outcomes. Certainly, in the case of a displaced nonunited LTO, one would suspect subscapularis dysfunction as noted by the lack of improvement in internal rotation among this cohort. However, the reports described above support the observations found in this study, because high rates of functional improvement were observed in the setting of nonunited LTO.

The popularity of LTO in anatomic TSA is likely based on several studies that support improved mechanical strength of the subscapularis repair as well as high rates of LTO healing. In 2001, Gerber et al[10] described the LTO as a way to improve subscapularis integrity, function, and clinical outcomes and prevent anterior destabilization after anatomic TSA. In 2005, Gerber et al[11] published the initial outcomes of 39 shoulders treated with LTO and found a 100% visible healing rate at the osteotomy site via x-ray imaging and computed tomography. Ponce et al[21] reported that LTO provided significantly less cyclic loading displacement and significantly greater maximum load to failure compared with a transosseous and soft tissue repair.[21]

LTO techniques have compared favorably to subscapularis tenotomy techniques. Krishnan et el[14] demonstrated that LTO fixation was mechanically superior to subscapularis tenotomy, with LTO healing rates of 97%.[14] Similar results were demonstrated by Scalise et at,[23] who found that LTO resulted in anatomic healing in all patients, with superior outcomes and improved ultrasound appearance compared with tenotomy. Jandhyala et al[13] was able to demonstrate superior strength improvements on the graded belly-press test when comparing osteotomy to tenotomy. A recent systematic review and evaluation of 20 studies (1420 shoulders) comparing LTO and tenotomy found similar complication rates and fewer revisions (10.0% vs. 16.2%) after tenotomy compared with LTO.[2]

LTO has also been compared to the subscapularis peel technique. In 2011, Lapner et al[15] published a prospective comparison of LTO and subscapularis peel. They observed no differences in overall strength or clinical outcomes. This was in contrast to Shafritz et at[3,15,24] who, using a similar comparison, reported that the peel technique was associated with significantly worse postoperative clinical subscapularis function compared with LTO. A systematic review in 2018 by Choate et al[4] noted that when data from all studies are compared, the weighted mean healing rate for LTO (93.1%) is significantly better than that of the tenotomy (75.7%) and peel (84.1%) techniques. The 8.47% nonunion rate observed in this series is consistent with the findings of this systematic review.

Interestingly, LTO failure was rarely described before 2011. Ponce et el[21] reported 1 of 26 LTO patients experienced osteotomy site rupture. Later, Levy et al[18] published a report characterizing the radiographic appearance LTO nonunions, noting that a displaced LTO site failure is best identified on true anterior-posterior radiograph and is often missed on axillary lateral radiographs. Small et al[28] expanded on this, and

in 2014 published the first large-scale study that reported LTO healing rates and defined the integrity of the LTO site as not seen, bony union, nondisplaced nonunion, and displaced nonunion. This provided further assistance in evaluating and monitoring the healing of the osteotomy site but lacked an associated clinical correlation. Subsequently, Denard et al[5] provided clinical outcomes associated with healed vs. nonhealed osteotomy sites, reporting ASES scores were significantly greater when the LTO healed. Shi et al[25] reported a case series of 5 patients (3% [162 total]) that highlighted displaced nonunion LTO failure. Their report described LTO nonunion displacement as an under-reported complication associated with significant morbidity, lower average postoperative subjective shoulder scores, lower patient satisfaction, and limited surgical intervention.

In light of the suspicion that LTO healing after TSA can be variable, this study examined and reported clinical outcomes associated with each variation in LTO healing based on the radiographic characteristics described by Small et al.[28] This study demonstrated no difference in clinical outcomes between patients with LTO unions, nondisplaced nonunions, and those that could not be seen on radiographs. Although patients with a displaced nonunion demonstrated worse pain and functional outcome scores, there was no difference in overall patient satisfaction, and 85.7% of patients with a displaced nonunion reported a desire to have the same procedure again. Nearly every PROM and ROM metric (excluding SANE and active internal rotation) improved significantly from baseline, thus demonstrating a high level of efficacy, despite displacement and nonunion of the LTO site. Finally, patients met and exceeded the MCID for the SST, ASES, VAS pain, active forward flexion, active external rotation, and substantial clinical benefit for ASES and active external rotation. Based on the findings of this study, we believe that although a displaced nonunion osteotomy site can represent a potential failure, significant morbidity, patient dissatisfaction, and desire for surgical revision are not always associated. In fact, we found patients were satisfied with their substantial improvement from baseline in nearly all metrics. While the debate over which subscapularis takedown technique continues, we believe in and continue to use LTO in our practice.

Strengths of this study relate to the large series of 189 patients with an average follow-up of 2 years and high inclusion rate of 84%. This allowed for optimal observation in identifying LTO healing and postoperative complications. In addition, as a single-surgeon series, minimal variability in surgical technique, implant use, and a postoperative rehabilitation protocol helped to control important confounding variables that may influence LTO healing.

Despite these strengths, our study does have limitations. With an average follow-up of 52.5 months for displaced nonunion patients, there is a possibility that higher revision rates may develop over time. With glenoid loosening being the primary concern, the ability to perform successful revisions may be compromised by glenoid bone loss in these patients. In addition, the TSA humeral stem used in this series did not facilitate LTO repair. Modern stems may facilitate LTO healing with innovative features to support LTO repairs. This may affect LTO healing.

In addition, the LTO in 16 patients could not be identified on postoperative radiographs. This may relate to the small nature of the fleck osteotomy, resorption of the osteotomy, or unidentified displacement. If these represented displaced tuberosities, the results of the study may have been altered.

Finally, the LTO repair technique used has not been mechanically tested. Although this technique may be mechanically inferior to other repair techniques, the rate of displaced nonunion was not different than what has been reported in systematic reviews of LTO healing.

Conclusion

At midterm follow-up, patients with a displaced nonunion LTO site have lower functional scores, higher pain scores, and greater risk of gross glenoid loosening. Despite these findings, substantial clinical improvements are observed with high rates of patient satisfaction. Those with nondisplaced LTO nonunions have similar outcomes as patients with LTO union.

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