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CLINICAL RESEARCH

Is Arthroscopic Technique Superior to Open Reduction Internal Fixation in the Treatment of Isolated Displaced Greater Tuberosity Fractures?

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Abstract

Background Arthroscopic double-row suture-anchor fixation and open reduction and internal fixation (ORIF) are used to treat displaced greater tuberosity fractures, but there are few data that can help guide the surgeon in choosing between these approaches.

Questions/Purposes We therefore asked: (1) Is there a difference in surgical time between arthroscopic double-row suture anchor fixation and ORIF for isolated displaced greater tuberosity fractures? (2) Are there differences in the postoperative ROM and functional scores between arthroscopic double-row suture anchor fixation and ORIF for isolated displaced greater tuberosity fractures? (3) Are there differences in complications resulting in additional operations between the two approaches?

Methods Between 2006 and 2012, we treated 79 patients surgically for displaced greater tuberosity fractures. Of those, 32 (41%) were considered eligible for our study based on inclusion criteria for isolated displaced greater tuberosity fractures with a displacement of at least 5 mm but less than 2 cm. During that time, we generally treated patients with displaced greater tuberosity fractures with a displacement greater than 1 cm or with a fragment size greater than 3×3 cm with open treatment, and patients with displaced greater tuberosity fractures with a displacement less than 1 cm or with a fragment size less than 3×3 cm with arthroscopic treatment. Fifty-three underwent open treatment based on those indications, and 26 underwent arthroscopic treatment, of whom 17 (32%) and 15 (58%) were available for followup at a mean of 34 months (range, 24–28 months). All patients with such fractures identified from our institutional database were treated by these two approaches and no other methods were used. Surgical time was defined as the time from initiation of the incision to the time when suture of the incision was finished, and was determined by an observer with a stopwatch. Patients were followed up in the outpatient department at 6, 12, and 24 weeks, and every 6 month thereafter. Radiographs showed optimal reduction immediately after surgery and at every followup. Radiographs were obtained to assess fracture healing. Patients were followed up for a mean of 34 months (range, 24–48 months). At the last followup, ROM, VAS score, and American Shoulder and Elbow Surgeons (ASES) score were used to evaluate clinical outcomes. All these data were retrieved from our institutional database through chart review. Complications were assessed through chart review by one observer other than the operating surgeon.

Results Patients who underwent arthroscopic double-row suture anchor fixation had longer surgical times than did

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that signed consent was obtained from the patients.

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patients who underwent ORIF (mean, 95.3 minutes, SD, 10.6 minutes vs mean, 61.5 minutes, SD, 7.2 minutes; mean difference, 33.9 minutes; 95% CI, 27.4–40.3 minutes; $p < 0.001$). All patients achieved bone union within 3 months. Compared with patients who had ORIF, the patients who had arthroscopic double-row suture anchor fixation had greater ranges of forward flexion (mean, 152.7°, SD, 13.3° vs mean, 137.7°, SD, 19.2°; $p = 0.017$) and abduction (mean, 146.0°, SD, 16.4° vs mean, 132.4°, SD, 20.5°; $p = 0.048$), and higher ASES score (mean, 91.8 points, SD, 4.1 points vs mean, 87.4 points, SD, 5.8 points; $p = 0.021$); however, in general, these differences were small and of questionable clinical importance. With the numbers available, there were no differences in the proportion of patients experiencing complications resulting in reoperation; secondary subacromial impingement occurred in two patients in the ORIF group and postoperative stiffness in one from the ORIF group. The two patients experiencing secondary subacromial impingement underwent reoperation to remove the implant. The patient with postoperative stiffness underwent adhesion release while receiving anesthesia, to improve the function of the shoulder. These three patients had the only reoperations.

Conclusions We found that in the hands of surgeons comfortable with both approaches, there were few important differences between arthroscopic double-row suture anchor fixation and ORIF for isolated displaced greater tuberosity fractures. Future, larger studies with consistent indications should be performed to compare these treatments; our data can help inform sample-size calculations for such studies.

Level of Evidence Level III, therapeutic study.

Introduction

It has been reported that isolated greater tuberosity fractures account for 17% to 21% of proximal humeral fractures [2, 11] and 15% to 30% of glenohumeral dislocations [11]. Even a small amount of displacement can affect shoulder function [11, 30]. Several fixation techniques using screw, tension banding, or transosseous suture have been described for reduction and internal fixation of greater tuberosity fractures [7, 9, 15]. Despite the reported satisfactory results [8, 9, 15], few techniques can provide adequate fixation of the fragments and accurate restoration of the tuberosity-head relation for comminuted fractures [3]. With further development of arthroscopy techniques, arthroscopic reduction and fixation have been used in the treatment of greater tuberosity fractures. One example is reduction of a greater tuberosity fracture using arthroscopic guidance and percutaneous screw fixation [4, 30]. Arthroscopic double-row suture anchor fixation, previously used in rotator cuff repair, has been reported for the treatment of greater tuberosity fractures [17, 19, 22, 27, 28]. This technique improves the initial repair strength and provides a tendon-bone interface better suited for biologic healing and restoration of the normal anatomy [17, 18, 20, 24].

Although numerous techniques have been used to treat displaced greater tuberosity fractures, when surgery is indicated, it has not been determined which approach is best. Specifically, to our knowledge, there has been no comparison between arthroscopic double-row suture anchor fixation and open reduction and internal fixation (ORIF).

We therefore asked: (1) Is there a difference in surgical time between arthroscopic double-row suture anchor fixation and ORIF for isolated displaced greater tuberosity fractures? (2) Are there differences in the postoperative ROM and functional scores between arthroscopic double-row suture anchor fixation and ORIF for isolated displaced greater tuberosity fractures? (3) Are there differences in complications resulting in additional operations between the two approaches?

Methods

Study Design and Setting

We performed a nonrandomized retrospective case series study after obtaining approval from our ethical review committee. Between 2006 and 2012, we treated 79 patients surgically for displaced greater tuberosity fractures. Of those, 32 (41%) were considered eligible for our study based on inclusion criteria for isolated displaced greater tuberosity fractures with a displacement of at least 5 mm but less than 2 cm and exclusion criteria for those fractures with any other concomitant injuries such as a Bankart lesion, rotator cuff tear, or superior labrum anterior and posterior (SLAP) injury. During that time, we generally treated patients with displaced greater tuberosity fractures with a displacement greater than 1 cm or with a fragment size greater than 3×3 cm with open treatment, and patients with displaced greater tuberosity fractures with a displacement less than 1 cm or with a fragment size less than 3×3 cm with arthroscopic treatment. Fifty-three patients underwent open treatment based on those indications, and 26 underwent arthroscopic treatment, of whom 17 (32%) and 15 (58%), respectively, were available for followup at a mean of 34 months (range, 24–28 months). At our institution, all such fractures were treated with these two approaches; no other approaches were used. Two surgeons performed these two approaches (ZL and LZ). Arthroscopic procedures were performed by a skilled arthroscopic sports-trained surgeon (ZL), whereas the ORIF was done by an experienced trauma surgeon (LZ). Each surgeon

performed one approach only. All devices were FDA-approved for this use. The mean followup was 33.6 months (range, 24–48 months), and none of the patients was lost to followup. At the final followup, ROM and functional scores were assessed.

Participants/Study Subjects

Radiographs and CT scans were used to make the diagnosis and define the fracture configuration of the greater tuberosity fragments. Patients with a displacement of at least 5 mm but less than 2 cm were recruited for our study. The degree of fragment displacement was defined as the distance between the inner margin of the fragment and the lateral margin of the biceps groove or the lateral margin of the lesser tuberosity on the AP radiograph and was measured with a special measuring tool. MRI was used to identify if there were any other combined injuries such as rotator cuff tear, Bankart lesion, or SLAP injury (Fig. 1). These combined injuries were further confirmed during surgery. Patients with negative findings on MRI but with associated injuries confirmed during surgery also were excluded from this study. Based on the exclusion criteria, 47 patients with associated injuries including 28 Bankart lesions, 12 rotator cuff tears, and seven SLAP injuries were excluded from the study.

Demographics and Description of Study Population

There were 23 men and nine women with a mean age of 48.3 years (range, 27–69 years). Injury mechanisms included 14 traffic accidents, seven sport injuries, and 11 falls. Twenty-six patients had isolated two-part greater tuberosity fractures, whereas the other six patients had comminuted fractures (Type II greater tuberosity fractures). The mean interval from injury to surgery was 34.9 days (range, 3–72 days) (Table 1).

Description of Experiment, Treatment, or Surgery

Arthroscopic Double-row Suture Anchor Fixation Technique

The patients received general anesthesia, and were placed in the lateral decubitus position, with longitudinal traction

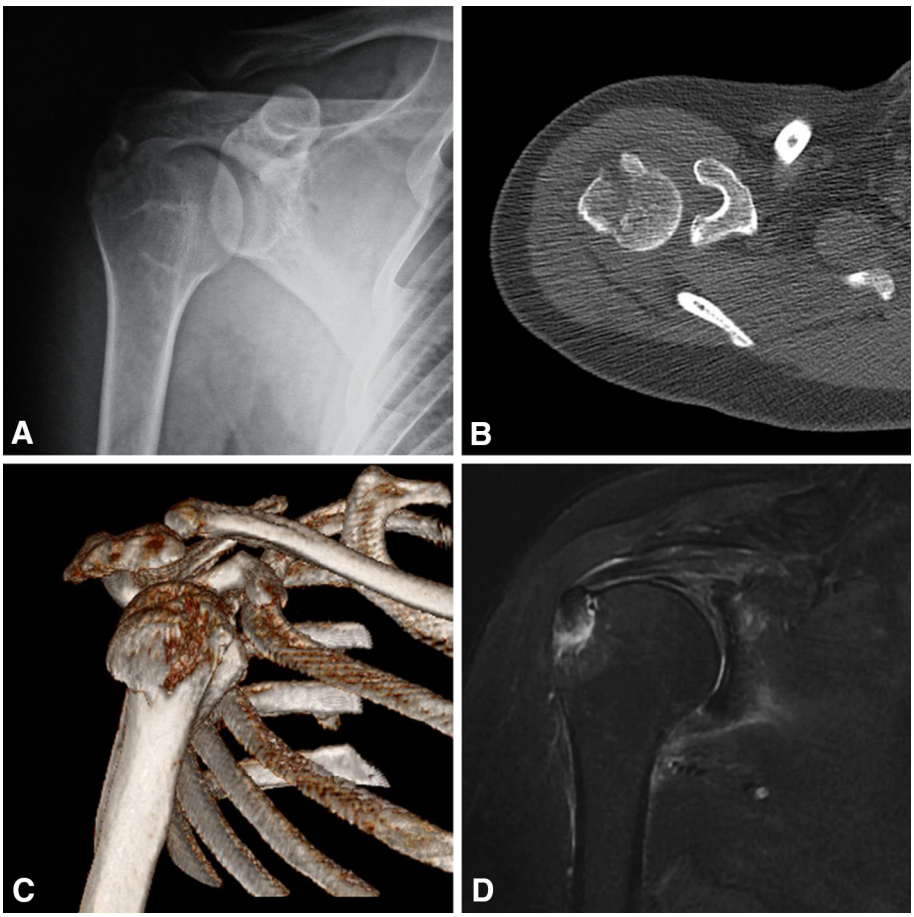

Fig. 1A–D Preoperative imaging examinations were used to evaluate the fracture. (**A**) A radiograph showed a displaced greater tuberosity fracture. (**B**) CT and (**C**) three-dimensional CT scans confirmed the configuration of the greater tuberosity fragment. (**D**) An MR image showed a displaced greater tuberosity fracture with no concomitant injuries, including rotator cuff tear.

Table 1. Comparison of the key patient demographics between groups

Item	ADSF	ORIF	p value
Gender (M/F)	10/5	13/4	0.699
Age (years)	45.8 ± 11.7 (27–65)	50.5 ± 12.4 (31–69)	0.283
Injury mechanisms (traffic accident/sport/fall)	8/3/4	6/4/7	0.569
Classification (two-part/comminuted)	12/3	14/3	> 1.000
Interval from injury to surgery (days)	33.1 ± 20.9 (3–72)	36.4 ± 17.2 (5–60)	0.631
Followup (months)	31.7 ± 6.2 (24–42)	35.2 ± 8.5 (24–48)	0.206

Data expressed as mean ± SD and range; ADSF = arthroscopic double-row suture anchor fixation; ORIF = open reduction internal fixation.

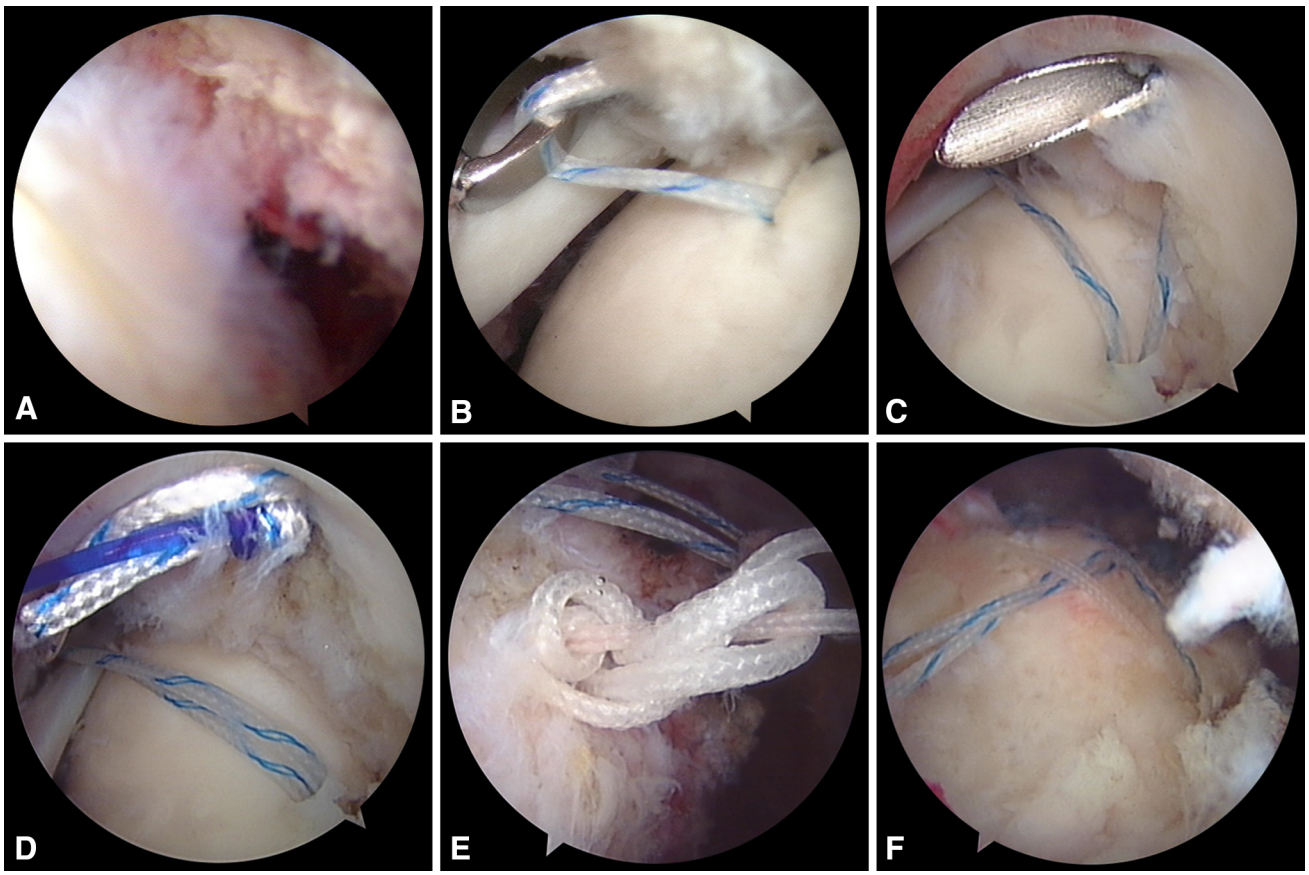

Fig. 2A–F The schema of arthroscopic double-row suture anchor fixation is shown. (**A**) A displaced greater tuberosity fragment was detected under arthroscopy. (**B**) A medial-row anchor was inserted at the articular margin of the humeral head and its strands were retrieved from the joint through the anterior portal using a suture grasper. (**C**) An 18-gauge spinal needle was used to confirm the exact location. (**D**) The strands of the medial-row anchor were shuttled through the intact cuff with a prolene suture. (**E**) The strands of the medial-row anchors were tied with a sliding knot in the subacromial space under direct observation. (**F**) The suture bridge was created for greater tuberosity fracture fixation.

of the affected limb. A routine arthroscopic examination of the intraarticular joint was performed through the posterior portal. Blood clots and hemarthrosis were débrided by a shaver through the anterior portal to facilitate better observation. After that the displaced greater tuberosity fragment attached to the supraspinatus was detected (Fig. 2A), débridement was performed on the undersurface of the fragment and the crater of the fracture site. Subsequently, a metallic suture anchor (TWINFIX™ Ti; Smith & Nephew Endoscopy, Andover, MA, USA) was inserted at the articular margin of the humeral head through an intact cuff, serving as a medial-row anchor. All strands of

the anchor then were retrieved from the joint through the anterior portal using a suture grasper (Fig. 2B). The exact location was confirmed using an 18-gauge spinal needle (Fig. 2C), through which a No. 0 prolene suture was passed to deliver the strands through the intact cuff respectively (Fig. 2D). An additional suture anchor was placed at the medial margin of the fracture site and its strands were shuttled through the intact cuff in the same fashion. Subsequently, the arthroscope was moved to the subacromial space. The strands of the medial-row anchors were tied with a sliding knot under direct observation (Fig. 2E). After confirmation of the fracture site, a pilot hole for the Footprint® anchor (Smith & Nephew Endoscopy, Andover, MA, USA) was created approximately 5 to 10 mm distal to the lateral margin of the greater tuberosity fragment so as to prevent cortex cracking and anchor loosening. Then two strands from each medial-row anchor were threaded through the eyelet of a 4.5-mm Footprint® anchor. With the help of a probe to accomplish fracture reduction, the Footprint® anchor was advanced completely in the pilot hole as a lateral-row anchor. A second Footprint® anchor was inserted approximately 10 mm posterior to the first one, using the same protocol to create the suture bridge (Fig. 2F). The procedure must be performed with extreme caution to avoid axillary nerve injury. After fixation, the stability of reduction was checked from the glenohumeral joint and subacromial space during joint motion. Acromioplasty was performed if there was any sign of impingement syndrome caused by a curved or hooked acromion. Radiographs were performed immediately after surgery to evaluate the adequacy of fracture reduction.

ORIF Technique

The patients received general anesthesia and were placed in a beach chair position. The surgery was performed through a deltopectoral approach. The hematoma and scar tissue were cleared to expose the edge of the fragment and the bony bed of the fracture site. A heavy braided suture was placed in the rotator cuff as a traction suture, through which the greater tuberosity fragment was reduced and secured to the bony bed (Fig. 3A). Subsequently, a locking

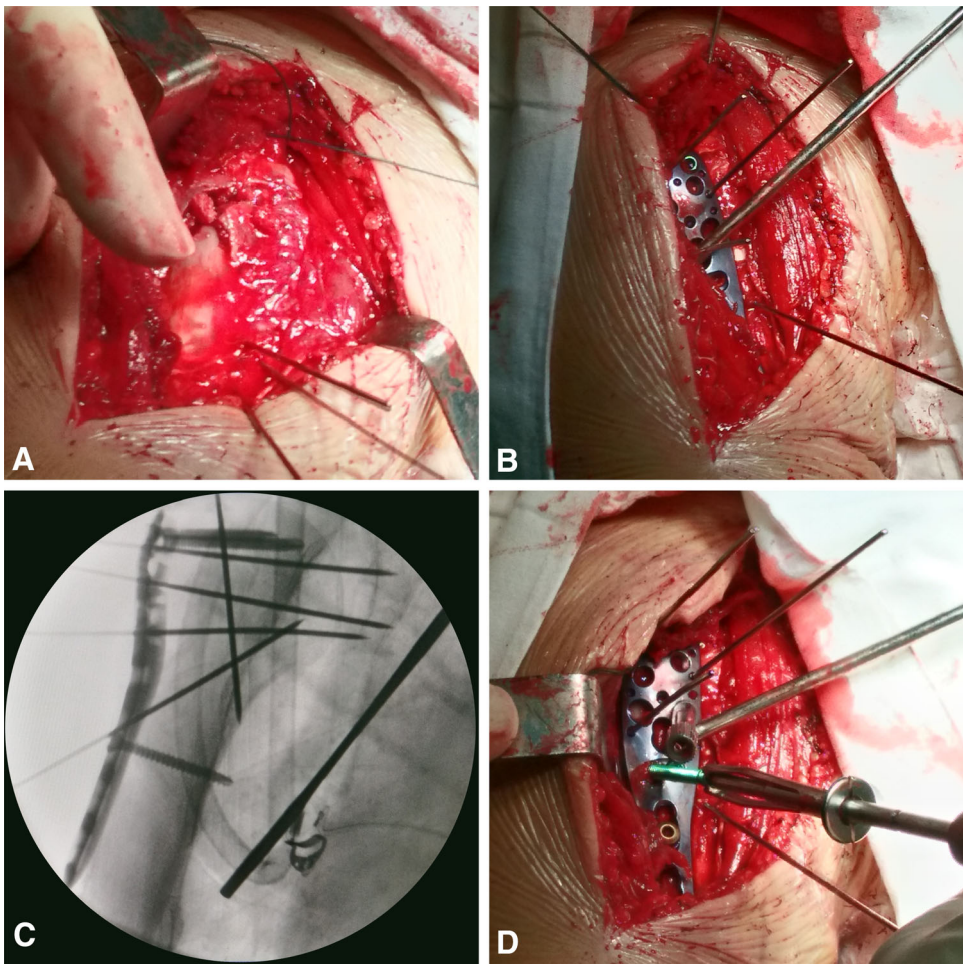

Fig. 3A–D For open reduction and internal fixation, (**A**) the fragment edge was exposed and a heavy braided suture was placed in the rotator cuff as traction suture. (**B**) A locking plate was placed at the lateral aspect of the humeral shaft, and K-wires were inserted for temporary fixation of the plate. (**C**) An intraoperative radiograph showed a satisfactory reduction. (**D**) Locking screws were inserted for permanent fixation of the plate.

plate (PHILOS; Synthes, Stratec Medical Ltd, Mezzovico, Switzerland) was applied to the lateral aspect of the humeral shaft just lateral to the bicipital groove and right beneath the tip of the greater tuberosity. Then K-wires were inserted for temporary fixation of the plate (Fig. 3B). After satisfactory reduction was confirmed by intraoperative radiographs (Fig. 3C), locking screws were inserted for permanent fixation (Fig. 3D). The proximal locking screws were placed unicortically through an external guide and confined in the humeral head, confirmed by intraoperative radiographs, whereas the distal locking screws were placed bicortically. As for comminuted fractures or fractures with relatively small fragment size, it was difficult to maintain fracture stability only by plate fixation alone because of the natural traction force the rotator cuff imposed on the fracture fragment. In these instances, supplemental suture fixation was performed by tying the previously placed braided suture to the plate through the suture eyelets to counter this force of the rotator cuff and prevent further displacement postoperatively. The operative shoulder was moved in all directions to confirm reliable fixation of the greater tuberosity fracture. Immediate postoperative radiographs were used to assess the fracture reduction.

Aftercare

The postoperative rehabilitation protocols were similar for patients in the arthroscopic double-row suture anchor fixation and ORIF groups. For the first 3 weeks postoperatively, the shoulder was supported with a sling. Pendulum exercises were initiated from the second postoperative day. Passive forward flexion and abduction were allowed and progressed gradually after 1 week. Simultaneously, adduction and internal rotation were limited. Three weeks later, the sling was removed, and patients were encouraged to start painless passive ROM exercises. At 6 weeks, active ROM exercises of the shoulder were performed as tolerated without pain. Progressive strengthening exercises with a resistance band were permitted when radiographs showed apparent evidence of fracture healing, which commonly occurred 3 months after surgery.

Variables, Outcome Measures, Data Sources, and Bias

Surgical times were recorded during the perioperative period. Surgical time was defined as the time from initiation of the incision to the time when suture of the incision was finished, and was determined by an observer with a stopwatch. Radiographs were obtained immediately after surgery to evaluate the adequacy of fracture reduction, which was determined by measuring the degree of residual displacement. Patients were followed up in the outpatient department at 6, 12, and 24 weeks, and every 6 months thereafter. Owing to the relatively higher cost, CT scans were not used as a regular examination during postoperative followup. Instead, AP and lateral radiographs were taken at every followup to assess fracture healing and no special image views were used. Radiographs of a fracture showing successive bony callus in the fracture gap and disappearance of the visible fracture line could be determined to have healed. Although it was more difficult to determine union on radiographs, especially when hardware was present, successive bony callus always could be obvious enough to detect if the fracture healed well. Fracture healing was assessed by an observer (HZ) not involved in patient care. At the final followup, ROM including forward flexion, abduction, and external rotation at the neutral position were measured with a goniometer, whereas internal rotation was determined through the vertebral-level method [13]. VAS score and American Shoulder and Elbow Surgeons (ASES) score [1] were assessed by one observer (JZ) independent from the treating team through a questionnaire. All these data were retrieved from our institutional database through chart review. The ASES score consists of a patient-self-assessed section and an examiner-assessed section. The former is divided in pain, instability, and activities of daily living. The latter contains ROM (passive and active), signs, strength, and instability. Complications were assessed through chart review by one observer (JL) other than the operating surgeon. Subacromial impingement was diagnosed according to the symptoms (pain, and limitation of ROM), physical signs (pain arc, positive Neer test, and positive Hawkins test), and radiographic findings. The anchor location on radiographs was used to detect whether anchor pullout existed. Alteration of the anchor location suggested there might be anchor pullout.

Statistical Analysis, Study Size

Statistical analysis was performed with SPSS software (Version 13.0; SPSS Inc, Chicago, IL, USA). Data were expressed as mean ± SD. The paired t test was used to compare the postoperative clinical results, including ROM and functional scores. Independent-samples t test was used to compare the quantitative data between the arthroscopic double-row suture anchor fixation and ORIF groups, whereas the qualitative data of the two groups were compared using the chi-square test. Statistical significance was set at a probability less than 0.05. No significant differences were found between the two groups according to the demographics (Table 1), suggesting the comparability of two groups.

Table 2. Comparison of ROM and functional scores between the two groups

Variable	Group		p value
	ADSF	ORIF	
Operation time (minutes)	95.3 ± 10.6 (80–120)	61.5 ± 7.2 (50–75)	< 0.001
Followup ROM			
Forward flexion (degrees)	152.7 ± 13.3 (130–170)	137.7 ± 19.2 (100–170)	0.017
Abduction (degrees)	146.0 ± 16.4 (120–170)	132.4 ± 20.5 (90–170)	0.048
External rotation (degrees)	30.7 ± 14.9 (10–60)	33.5 ± 16.2 (10–60)	0.608
Internal rotation	L1 (L4 to T7)	L2 (L5 to T7)	0.432
Followup score			
VAS	0.8 ± 0.9 (0–3)	0.9 ± 1.2 (0–4)	0.834
ASES	91.8 ± 4.1 (85–100)	87.4 ± 5.8 (80–100)	0.021

Data expressed as mean ± SD and range; ADSF = arthroscopic double-row suture anchor fixation; ORIF = open reduction internal fixation.

Results

Patients who underwent arthroscopic double-row suture anchor fixation had longer surgical times than did patients who underwent ORIF (mean, 95.3 minutes, SD, 10.6 minutes vs mean, 61.5 minutes, SD, 7.2 minutes; mean difference, 33.9 minutes; 95% CI, 27.4–40.3 minutes; $p < 0.001$). Primary incision healing was achieved in all the patients.

Compared with patients who had ORIF, the patients who had arthroscopic double-row suture anchor fixation had slightly better ROM and ASES scores. Forward flexion (mean, 152.7°, SD, 13.3° vs mean, 137.7°, SD, 19.2°; mean difference, 15.0°; 95% CI, 2.9°–27.1°; $p = 0.017$) abduction (mean, 146.0°, SD, 16.4° vs mean, 132.4°, SD, 20.5°; mean difference, 13.6°; 95% CI, 0.1°–27.2°; $p = 0.048$), and ASES score (mean, 91.8 points, SD, 4.1 points vs mean, 87.4 points, SD, 5.8 points; mean difference, 4.4 points; 95% CI, 0.7–8.0 points; $p = 0.021$) favored the arthroscopy group; however, in general, these differences were small and of questionable clinical importance (Table 2). Anatomic fracture reduction was seen on radiographs for all patients immediately after surgery and at every followup; bone union was achieved in 12 weeks (Fig. 4).

With the numbers available, there were no differences in the proportion of patients experiencing complications resulting in reoperation; secondary subacromial impingement occurred in two patients in the ORIF group and postoperative stiffness in one from the ORIF group. The two patients experiencing secondary subacromial impingement underwent reoperations to remove the implant, and symptoms of impingement were relieved after removal of the implant. The patient with postoperative stiffness received manipulation while under anesthesia to achieve adhesion release and improve function of the shoulder. These three patients, all from the ORIF group, were the only ones who underwent reoperations in this series. None of the patients in either group experienced complications, including neurovascular injury, nonunion or malunion, pullout of the suture anchor, and intraarticular screw penetration during followup.

Discussion

Isolated greater tuberosity fractures are rare and generally considered alongside proximal humeral fractures or as a concomitant injury resulting from anterior glenohumeral dislocation [21]. Previously, most greater tuberosity fractures were treated conservatively, which often led to shoulder dysfunction in patients with displaced greater tuberosity fractures [12, 25]. Platzer et al. [25], in a comparative study, recommended that greater tuberosity fractures with displacement greater than 5 mm be treated operatively. The results of ORIF described previously are favorable [9, 12]. However, because of the biomechanical advantage of double-row suture anchor fixation [31], this technique has been used in open and arthroscopic fixation of greater tuberosity fractures to restore the bone-tendon transition area accurately [3, 17, 19, 22, 27, 28]. Even with various surgical techniques available, it is difficult for surgeons to choose which to use, since, to our knowledge, no studies have directly compared these approaches. We found that in the hands of surgeons comfortable with both approaches, there were few important differences between these two techniques for isolated displaced greater tuberosity fractures. Both treatments resulted in reliable healing, and although there were some differences in ROM and ASES scores favoring arthroscopic treatment, these

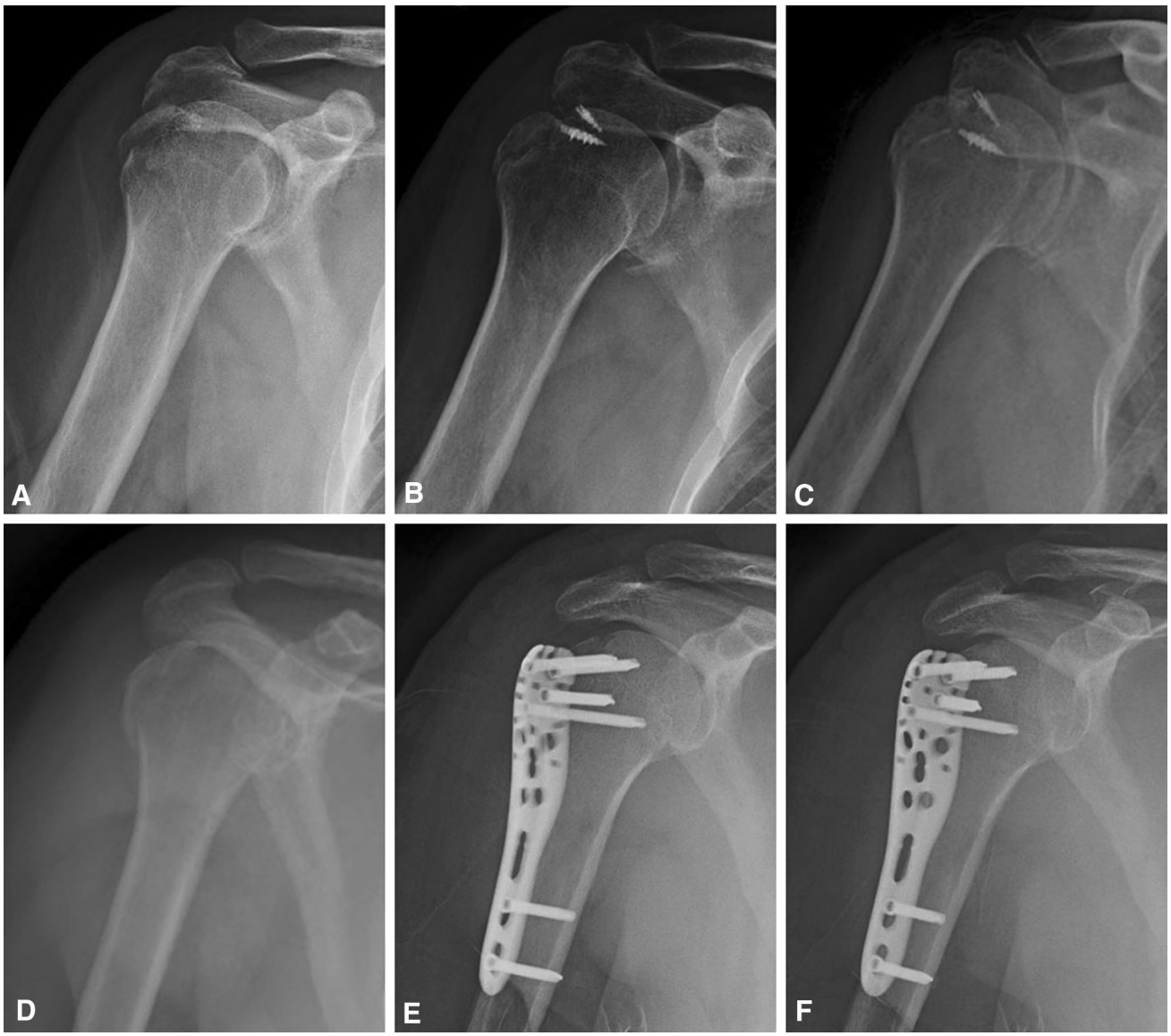

Fig. 4A–F (**A**) A preoperative radiograph showed a displaced greater tuberosity fracture in a patient from the arthroscopic double-row suture anchor fixation group. (**B**) The immediate postoperative radiograph showed accurate fracture reduction, and (**C**) a radiograph showed bony union at 12 weeks postoperatively. (**D**) A preoperative radiograph showed a displaced greater tuberosity fracture in a patient from the ORIF group. (**E**) The immediate postoperative radiograph showed accurate fracture reduction and (**F**) at 12 weeks postoperatively, a radiograph showed bony union.

differences were small and of questionable clinical importance.

This study has some limitations. First, it was a nonrandomized retrospective series and some selection bias might arise from unblinded surgeons and patients. Future studies with consistent indications should be performed to minimize the bias and improve the comparability of different groups. Second, because of the low incidence of isolated greater tuberosity fractures, the number of patients enrolled in the study was too small to detect large differences between the two groups and the possibility for Type II error exists, ie, that there was a difference in the outcomes of the approaches but that we did not have sufficient numbers to detect one. Third, all procedures were performed by two surgeons (ZL and LZ) from different subspecialties, and this might introduce potential surgeon-related confounding factors. Fourth, the ROM differences might have been susceptible to observer bias and in any case were fairly small. Analysis of intraobserver reliability might help to minimize the observer bias. Fifth, our differences in the followup scores were below the minimum clinically important difference for those measurements. Future larger studies might be favorable to detect large differences between the two groups. Sixth, the open approach used

may have resulted in more problems than otherwise expected; the use of a plate like that for a small fragment is not a standard approach and numerous methods of open reduction are used to treat these fractures. Future studies should compare other standard approaches to avoid several postoperative complications described in the current study. Seventh, the expertise needed for the arthroscopic repair may limit its use in the treatment for displaced greater tuberosity fractures, as a well-performed open technique always is better than a poorly performed arthroscopic technique. Eighth, the lack of information regarding osteoporosis assessment may lead to a potential disproportion of patients who are elderly and who have osteoporosis in one group or another. Ninth, this series includes patients with several chronic fractures primarily owing to misdiagnosis or inappropriate conservative treatment before presenting to us. The inclusion of acute and chronic fractures may add heterogeneity to the patient group. Nevertheless, removing the chronic fractures would further decrease the sample size of this study, which may correspondingly increase the possibility for Type II error. The absence of separate patient satisfaction data is also a potential weakness.

The operation time of the arthroscopic double-row suture anchor fixation was longer than that of ORIF, suggesting that it technically is more demanding. This is in accordance with previous studies which indicated that arthroscopic double-row suture anchor fixation needed a longer surgical time and a high learning curve linked to the shoulder arthroscopic technique [19, 23, 28]. In our opinion, this difference in surgical time is important because a longer surgical time may correspondingly increase potential risk of the surgery. Some authors have reported that it is not technically possible for arthroscopic double-row suture anchor fixation to reduce and fix severely displaced fracture fragments adequately, and therefore an open procedure is preferred [3, 19]. Additionally, arthroscopic double-row suture anchor fixation may damage the rotator cuff, as the medial anchors are inserted through the intact cuff attached to the greater tuberosity fragment [17, 19]. As for ORIF, several alternative surgical techniques are available for use such as a tension band which may have fewer differences compared with the arthroscopic technique, however, it was reported in a biomechanical study that a locking plate provides superior fixation of a greater tuberosity fracture compared with tension bands [10]. We used the locking plate because we thought it would improve fracture healing by distributing its pressure over a larger area [5, 6, 26, 32]. Although there are several surgical approaches available for this technique, we chose the classic deltopectoral approach to facilitate observation and manipulation and to minimize the risk of axillary nerve injury [26].

We observed reliable fracture healing without malunion on radiographs, and improvement of ROM and functional scores in both groups, suggesting that in experienced hands, either technique can be effective. The small differences in ROM and ASES scores are unlikely to be clinically important. Our results are consistent with those of previous studies in ROM and functional scores [5, 6, 16, 19, 26]. However, as previous literature indicated that the minimum clinically important difference for the ASES score was between 12 and 17 points [29], the mean difference of 4.4 points between the two groups in this study was small and of questionable clinical importance.

The occurrence of subacromial impingement in two patients from the ORIF group may be attributable to use of the locking plate, which is known to cause secondary impingement [5, 32]. The larger the implant, the greater the chance of impingement [6, 14]. Placement of the plate might influence this, as the more proximal the plate, the more likely that impingement will occur. However, for avulsion fractures with small fragments, the recommended placement of a locking plate described in the technique guide could not fix the fragment firmly. Instead, the locking plate was placed in a relatively high position to better secure the fragments, which might have contributed to the impingement and need for plate removal. This might not be seen with other types of open fixation. Symptoms were relieved after removal of the implant, but this resulted in a second operation for these two patients. Fixation with tension-band wiring might have avoided this complication. However, tension-band wiring also has some limitations. It is less likely to provide adequate fixation of the fragments and accurate restoration of the tuberosity-head relation for comminuted fractures. Additionally, the necessity for tunnel drilling in fixation with tension-band wiring may result in other complications, especially in osteoporotic bone. Postoperative stiffness occurred in one patient in the ORIF group who had a comminuted fracture. Although not seen in the arthroscopic double-row suture anchor fixation group in our study, postoperative stiffness was reported in another study when using arthroscopic double-row suture anchor fixation technique [19]. In addition to the degree of comminution, it also may be related to the difficulty in complying with the rehabilitation protocols for elderly patients, and with extensive scar formation after the surgery [16]. For most elderly patients, the relatively poor compliance with the rehabilitation protocol may be partly attributable to their relatively lower demand for postoperative ROM and their decreased activity level. Adhesion release with the patient under anesthesia was performed to alleviate the postoperative stiffness and improve the function of the shoulder.

We showed that arthroscopic double-row suture anchor fixation can provide a satisfactory clinical result for

treatment of isolated displaced greater tuberosity fractures. The results are similar to those for an open technique using a locking plate. We also observed some minor advantages to the arthroscopic approach. Fracture configuration including fragment size, degree of displacement, and comminution should be considered when choosing an appropriate surgical technique for greater tuberosity fractures. We believe that the arthroscopic repair using double-row suture anchor fixation is at least comparable while offering some advantages to open fixation, but it requires an experienced arthroscopic surgeon. Larger, randomized controlled studies comparing other arthroscopic techniques with open techniques, such as suture anchor fixation which avoids use of a plate, are needed to determine which treatment is associated with less morbidity and more consistent outcomes. This study should provide the rationale and our data can help inform sample-size calculations for such studies.

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