Anterior Traumatic Shoulder Dislocation Associated With Displaced Greater Tuberosity Fracture: The Necessity of Operative Treatment

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Objective: To evaluate the radiographic and clinical outcome, including the incidence of recurrence, in patients with displaced greater tuberosity (GT) fractures associated with a traumatic anterior shoulder dislocation.

Design: Retrospective study.

Setting: University Hospital (Level 1 trauma center).

Patients: There were 34 completely evaluated patients (19 male, 15 female) seen between 1993 and 2002 with a displaced GT fracture associated with a traumatic anterior shoulder dislocation. Average age was 52.8 years and the mean follow-up period was 4.8 years (range, 2.0 to 10 years).

Intervention: All GT fractures were internally fixed solely with heavy non-absorbable sutures and any associate rotator cuff tear was repaired at the same time. A special rehabilitation protocol was administered in all patients.

Main Outcome Measurements: Functional assessment was obtained using the parameters of the Constant score which grades outcomes as excellent, very good, good and poor.

Results: Overall, there were 25 (73.5%) excellent, 6 (17.6%) very good, 2 (5.8%) good and 1 (3.1%) poor results, and the average Constant score was 88.4 (range 45.0 to 100.0). All fractures healed radiographically, without evidence of secondary displacement, except in one patient. No case of recurrence of dislocation was noted in any patient. Partial absorption or "lysis" of the GT without significant clinical relevance was detected in 4 cases.

Conclusions: Displaced fractures of the GT after traumatic anterior shoulder dislocation may result in limitation of motion and functional disability if they are not treated promptly by surgery. Open reduction and stable fixation of the GT along with rotator cuff repair when present, allows for early passive motion of the joint, and yields excellent final results in approximately three quarters of the patients and restores their ability to return to full activities of daily living. A compliant patient is also necessary for a successful result.

Key Words: GT fracture, anterior shoulder dislocation, suture fixation

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INTRODUCTION

Isolated fractures of the greater tuberosity (GT) constitute 17% to 21% of proximal humeral fractures, and approximately 15% to 30% of them are associated with a traumatic anterior dislocation of the shoulder.[1,2] Most authors suggest nonoperative treatment in nondisplaced GT fractures after reducing the dislocation, but there is a continuous debate about the degree of displacement that requires surgery.[3,4] Recent cadaveric and clinical studies have indicated that at least 5 mm of displacement can lead to a poor functional outcome.[5–8] With displacement, the altered function of the rotator cuff tendons or direct mechanical block can lead to loss of shoulder abduction and strength.[9,10] In addition, a superior or posterior malunited GT can cause symptomatic subacromial impingement.[11]

No specific data exist about the prognosis of simultaneous anterior dislocation and the incidence of associated shoulder pathology when an operative fixation of the GT is performed in this specific group of patients.[4,12] The purpose of this study is to retrospectively evaluate the incidence of recurrence in traumatic anterior shoulder dislocations associated with GT fractures, describe the technique of GT suture fixation, and present the clinical and radiologic results in a consecutive series of 34 patients.

PATIENTS AND METHODS

We surgically treated 36 patients with a traumatic anterior dislocation of the shoulder associated with a displaced GT fracture during a 10 year period (1993–2002). The initial treatment consisted of reduction of the dislocation (by closed or open means) and fixation of the GT fracture solely with heavy nonabsorbable sutures (Ethibond No. 5; Ethicon, Edinburgh, United Kingdom). Two patients were lost to final follow-up, leaving a cohort of 19 men and 15 women, with an average age of 52.8 years (18–84 years) at injury. The average follow-up was 4.8 years (2.0–10.0 years). Fourteen patients sustained a fracture from a standing or lower-height fall; the others were

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involved in higher-energy injuries, including motor vehicle crashes (15), falls from a height greater than 2 m (3), and sports injuries (2). The dominant arm was involved in 21 cases. There were 7 (19.4%) clinically detectable neurologic deficits preoperatively, indicating a brachial plexus injury in 3, an axillary nerve compression in 2, and an isolated radial nerve deficiency in 2. Twenty-nine patients had been regularly employed before the injury: 16 had a sedentary job, and 13 performed manual work.

A standard anteroposterior view of the shoulder was obtained in all patients to confirm the clinical diagnosis of a dislocation. Before reduction, a full neurologic and vascular investigation of the entire upper extremity was performed. After sedating the patient, 1 but no more than 2 attempts to reduce the dislocation were done in the emergency department; otherwise, the patient was transferred to the operating room for reduction under general anesthesia. In the successful case, the neurovascular examination was repeated postreduction, and a special radiographic control (with an anteroposterior view in external rotation and, if it was not tolerated by the patient, an anteroposterior view in internal rotation with a 15 degree cephalic tilt, as well as an axillary view) was obtained to assess GT displacement. Computed tomography scans were performed in 11 of 36 patients for further evaluation of the degree and mainly the position of displacement (cephalic or posterior). Scanned radiographs were thereafter imported to the environment of CorelDRAW 9 program (Corel Corporation, 1998–1999), and the degree of postreduction GT displacement in the anteroposterior view in external rotation [as it was defined by a line between the inner margin of the GT fragment and the lateral margin of the biceps groove (or the lateral margin of the lesser tuberosity)] was measured in centimeters with a special measuring tool (Fig. 1A–F). The same procedure was performed for the postoperative and last follow-up radiographs. Parsons et al[13] have shown in a cadaveric study that accurate assessment of the GT displacement requires multiple views, but no one of the 4 fluoroscopic views that they performed (anteroposterior view in internal rotation and outlet view together, and then axillary view and final anteroposterior view in external rotation) was significantly more accurate than another. When 4 experienced orthopedic surgeons viewed these images sequentially, the anteroposterior view in external rotation, evaluated last, altered treatment in 9 of 48 situations. The authors concluded that the anteroposterior view in external rotation can profile the GT better and is able to demonstrate even smaller displacement. A CT scan can demonstrate further the degree of superior or posterior displacement and it does add much more information than the plain radiographs. The prereduction displacement of the GT was not measured, because it was considered greater than 10 mm by definition. According to Neer's criteria[14], all fractures had more than 1 cm displacement or more than 40 degrees of angulation and were classified as OTA/AO 11-A1.3. Patients with posterior dislocation of the shoulder were excluded from the study. All radiographs were reviewed and digitally processed by the same author (A.P.). Clinical evaluation, using the parameters of the Constant score, was performed at the last visit by 2 residents (G.K. and S.A.S.), who were independent observers of the study. The senior author (P.D.) performed all the operations.

Operative Technique (Fig. 2)

Under general anesthesia, the patient is placed in the "beach-chair" position, with at least 60 degrees of flexion at the waist and 2 folded sheets behind the scapula to bring the shoulder girdle forward to facilitate access to the glenohumeral joint. If the dislocation remains unreduced, reduction maneuvers can be performed at this time under fluoroscopic control; this was necessary in 2 patients. Three doses of a second-generation cephalosporin are usually administered perioperatively for infection prophylaxis. The entire upper extremity is prepared and draped in a manner to allow full and unrestricted arm positioning during the procedure. The fracture area is exposed via the anterolateral transdeltoid approach (Fig. 2A), between the anterior and middle portion of the muscle. The fracture line at the tuberosity facet(s) is readily apparent because a minimal capsular rent is usually present after splitting of the deltoid muscle. Passive internal rotation of the shoulder can reveal the amount of tuberosity displacement and subsequent rotator cuff tearing. In 16 of 36 (44%) cases, a characteristic longitudinal tear in the rotator cuff that propagated through the rotator interval was present, requiring repair with nonabsorbable Ethibond No. 2 sutures (Fig. 2C); complete avulsion of the supraspinatus tendon was present in 3 cases, the infraspinatus tendon in 2 and a combined avulsion of both tendons in 1 case. All patients with avulsion of the RC tendons were younger than 43 years, and 4 of 6 were male patients. Three of them had been involved in road-traffic accidents, and 1 had signs of axillary nerve neuropraxia before reduction. As soon as the cortical edge of the tuberosity fragment is reduced in alignment with the edge of the fracture bed on the proximal humerus, 2 pairs of Ethibond No. 5 sutures are placed through the bone, in the upper and lower apex of the tuberosity fragment, and in corresponding drill holes in the humerus. The sutures are tied off in a cruciate, tension-band fashion to prevent overreduction and further comminution (Fig. 2B). Alternatively, the sutures can be placed around the GT fragment at the bone-tendon junction to avoid pulling through a comminuted or osteoporotic bone fragment. The fixation can be further secured with additional sutures placed in both the lateral and medial edges of the fragment. The deltoid flaps are reapproximated using absorbable No. 2 coated Vicryl sutures in a figure-of-8 manner. The subcutaneous tissue is closed with absorbable sutures (No. 3 Vicryl) and the skin intracutaneously (Monocryl). A Velpeau dressing converted to a simple sling on the first postoperative day secures the arm to the chest wall.

Rehabilitation Protocol (Fig. 3)

A closely monitored 3-phase rehabilitation program is administered to all patients, initially consisting of a first phase of pendulum exercises starting on the second postoperative day until the second to third postoperative week (Fig. 3A). The second phase then includes passive assisted exercises in the supine position: forward elevation is carried out with the support of the healthy arm, in which gentle traction is applied to the injured shoulder, with the patient trying to reach the edge of the bed behind his or her head from 0- to 180-degree range of motion (Fig. 3B, C). External rotation is limited to 45 degrees for the first 4 to 6 weeks and is performed also with the patient recumbent. Internal rotation and extension are done in

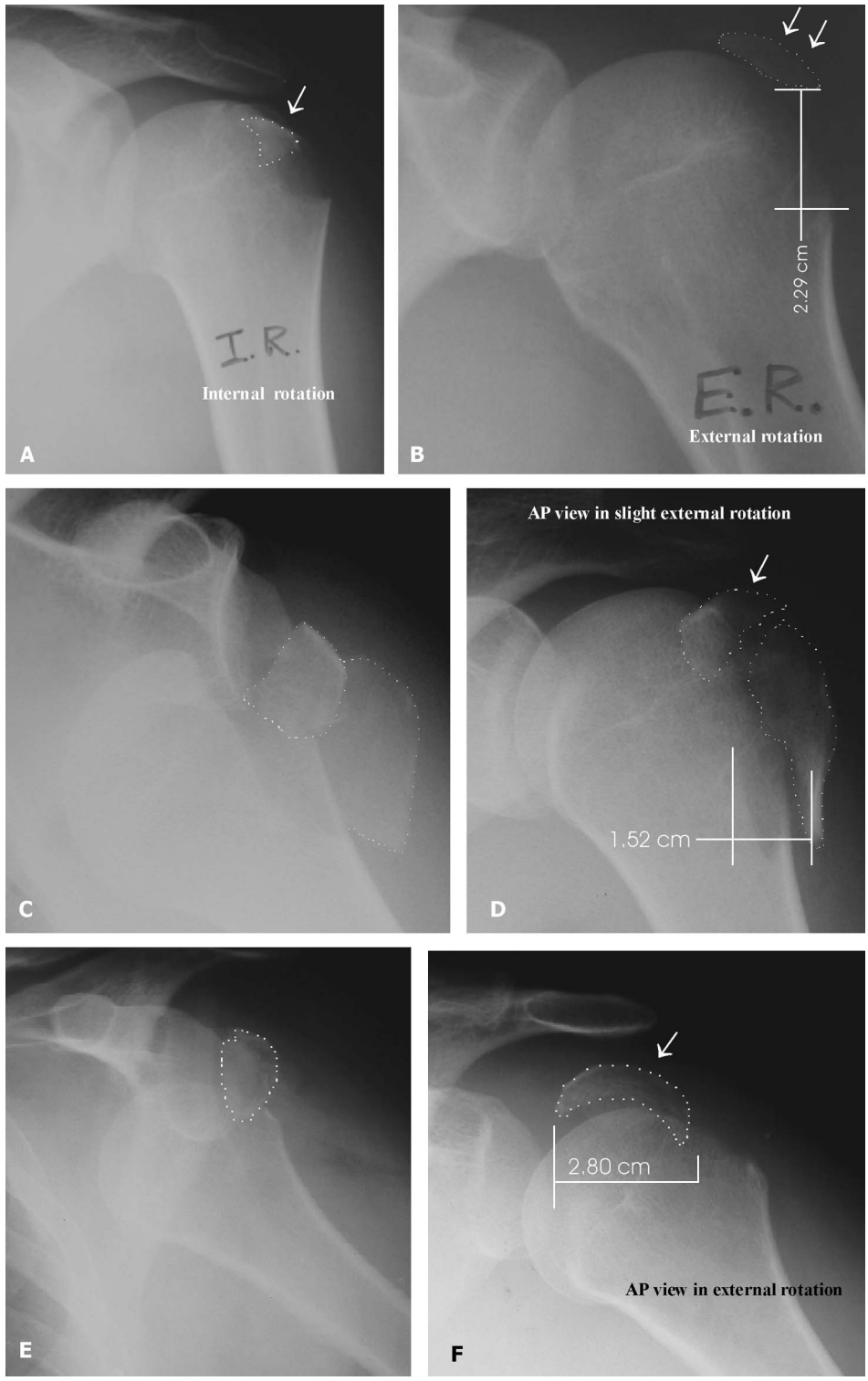

FIGURE 1. A, The displacement of GT fragment is not demonstrated in the initial postreduction anteroposterior view of the shoulder in internal (I.R.) rotation. B, anteroposterior view of the same patient in external (E.R.) rotation that shows 2.3 cm superior displacement of the GT fragment. C, Anterior dislocation of the shoulder in a 23-year-old patient with multifragmentation of the GT. D, Postreduction radiograph in the same patient; the amount of lateral GT displacement (1.52 cm) can be measured with accuracy with the CorelDRAW9 program (Corel Corporation, USA) program. E, Anterior dislocation of the shoulder with associated GT fracture in a 35-year-old athlete. F, Postreduction radiograph of the same patient shows 2.80 cm superior displacement of the GT (caused by retraction from the avulsed supraspinatus tendon).

the standing position with the aid of a stick (Fig. 3D, E). As the progress to union is completed, a third phase of active exercises using gradually increased weights (starting from 1 kg) is administered until the 12th postoperative week (Fig. 3F, G). If the patient is capable of forward elevation using 2 to 3 kg of weight in the supine position, active dynamic shoulder motion and strengthening exercises are administered in the standing position until the sixth postoperative month. Preservation of shoulder motion and strength is maintained for another 2 to 3 months with stretching and strengthening exercises. The patient is followed up every week for the first 2 postoperative months and is instructed and guided by us. We believe that

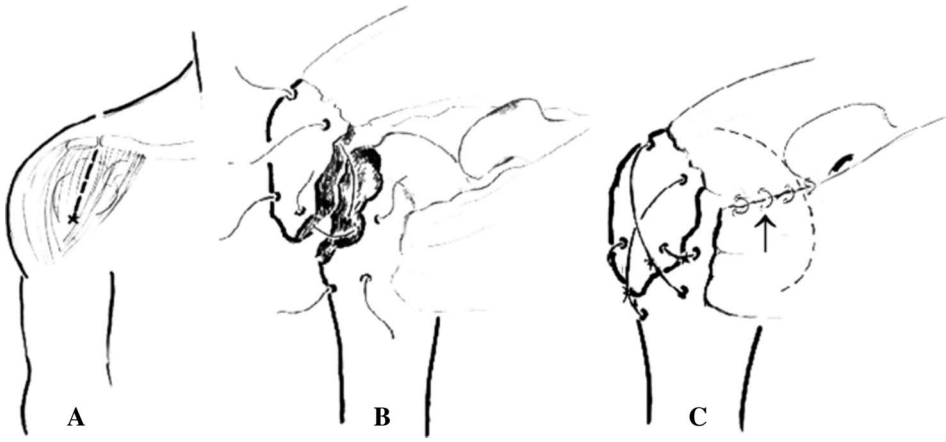

FIGURE 2. Schematic representation of our surgical technique. A, The anterolateral transdeltoid approach. B, Passage of the sutures (Ethibond No. 5) through the GT fragment (both medially and laterally) and through corresponding drill holes into the humeral head. In cases of comminution, the sutures can be passed near the musculotendinous junction. C, The GT fragment is reduced and fixed to its anatomical position in a cruciate manner (figure-8 technique). Additional sutures can be applied near the cortical edge for extra stability. The tear in the rotator interval is closed with nonabsorbable (Ethibond No. 2) sutures (black arrow).

a simple prescription of physiotherapy does not help the patient as much as this frequent monitoring that is closely supervised by the patient's surgeon.

RESULTS

The mean duration of surgery was 47 minutes (range, 38–74 minutes) and the average duration of hospital stay 3 days (range, 2 to 6 days). The time from injury to surgery ranged between 1 and 3 days. No intraoperative or early postoperative complications or cases of superficial or deep infection were observed. All patients with preoperative neurologic deficits had complete return of their neuropraxias within 3 to 5 months in all cases except the one patient with a severe brachial plexus injury. This patient was referred to a special center for this problem after fracture healing was completed.

Clinical Outcome

There was no case of recurrent dislocation of the shoulder. The average Constant-Murley score of the affected shoulder was 88.4 points (range, 40.0 to 100.0 points), whereas the functional score, unadjusted for age or sex as a percentage of the unaffected shoulder, was 93.2%. The average active elevation in a standing position was 170 degrees (150–180 degrees), the average external rotation between 55 degrees and 75 degrees, and the mean internal rotation with respect to the posterior spine segment reached by the thumb at least to the T10 spinous process. All patients were satisfied with the result, having no pain with vigorous activities, and all were able to resume previous levels of daily and recreational activities. One patient had symptoms of impingement syndrome, probably because of subacromial bursitis, but that was successfully treated with 2 subacromial steroid injections. All 21 patients who had been regularly employed before the injury in a sedentary job returned to their full work duties within 7 months of the surgery. Of the 16 patients who had been regularly employed in a manual job before the injury, 14 returned to their previous work duties. Only 2 patients had restriction of shoulder motion, mainly of abduction and external rotation: the one patient with the brachial plexus palsy and a 69-year-old woman with severely compromised shoulder function because of osteoarthritis of the shoulder joint before the injury.

Radiographic Outcome

Solid union was arbitrarily defined when the patient reported no shoulder pain or only mild activity-related discomfort and no radiolucent lines were present on the most recent radiographs in contrast to the preoperative ones. The mean postreduction displacement of the GT was 1.6 cm (range, 1.3–2.9 cm), whereas both postoperative and last follow-up displacement were below 3 mm (Fig. 4). As stated previously, all these measurements were performed using only the anteroposterior view in external rotation. All fractures were united within 7 to 11 weeks. No cases of nonunion, heterotopic ossification, or secondary displacement were noted, except in one case with slight (4 mm) superior displacement. Absorption of the cortical margin of the GT was detected in 4 cases, 3 to 4 months postoperatively, without serious functional compromise of the shoulder (Fig. 5). In 2 cases, there was an associated osteochondral defect of the humeral head near the articular margin; intraoperatively, there was severe impaction of the articular surface in the first patient and a small osteochondral fragment, which was removed, in the other. This injury is considered by some authors[15] as a Hill-Sacks lesion equivalent at the area of the GT that can some times impede reduction of the dislocation, although we have not noticed that in any other case in our series. Symptoms of subacromial impingement were identified early in the last case, but the patient did not wish to have an acromioplasty. No other patient required revision surgery during the given follow-up period.

DISCUSSION

The GT is an important component of the subacromial gliding mechanism and serves as the insertion for the rotator cuff tendons, which are the dynamic stabilizers and controllers of the shoulder. As a result, shoulder function may be impaired if there is inappropriate management of a GT fracture associated with an anterior dislocation.

The overall incidence of GT fracture as part of an anterior dislocation of the shoulder in a series of 544 displaced

FIGURE 3. Various stages of our individualized rehabilitation protocol. A, Pendulum exercises. B, Passive assisted forward elevation in the supine position with the aid of the healthy arm. C, Passive assisted forward elevation with the aid of a stick. D, Passive assisted extension in the standing position using a stick. E, Passive assisted internal rotation in the standing position with the aid of the healthy arm. F, Active external rotation in the supine position using 1 kg weight. G, Active forward elevation in the supine position using 1 kg weight. Active exercises in the standing position (against gravity) are performed only if the patient is capable of lifting 2–3 kg in the supine position.

fractures of the proximal humerus that underwent operative treatment in our clinic between 1993 and 2002 was 6.6%. Isolated GT fractures without shoulder dislocation occurred in 49 (9%) patients. In general, 2 groups of patients can be distinguished: young men (n = 19; average age, 44.7 years) who were involved in traffic accidents or other high-energy injuries and old women (n = 15; average age, 62.3 years) who had a simple fall from their height. Twelve of the 19 men (63.1%) were younger than 45 years. The higher incidence of this uncommon injury in younger patients must be taken into consideration to expedite return to work.

The mechanism of a GT fracture is usually described as an avulsion fracture of the rotator cuff that occurs as a shearing against the glenoid rim in extreme rotation, which then hits the GT as it moves towards the acromion.[4,16,17] Barhs et al[18] studied 103 patients with GT fractures during a 16 year period. Of the 59 patients with a GT fracture as part of an anterior shoulder dislocation, 24 had an undisplaced fracture in the anteroposterior view, 9 had less than 1 cm of displacement, and only 7 had more than 1 cm of displacement in the superior direction. Surprisingly, 19 of these patients (35%) showed an inferior displacement of the GT fragment. The authors suggested that impingement of the GT against the acromion might be the real mechanism of injury in cases with inferior displacement of the GT as part of an anterior dislocation of the shoulder. In contrast to our study, they noticed more than 1 cm of GT displacement (either superior or inferior) in 29 of 59 (42.3%) of their cases with anterior dislocation of the shoulder, but the degree of displacement was measured mainly in the axillary view. The authors concluded that the common Hill-Sachs lesion in anterior shoulder dislocations presents itself in its completed form as a GT fracture.

Nonoperative treatment of GT fractures has led to different outcomes. Neer[14] suggested that patients who have closed treatment of fractures that are displaced less than 1.0 cm and who have early functional rehabilitation can have a satisfactory outcome. Olivier et al[19] demonstrated unsatisfactory results in 31% of their patients treated nonoperatively. Young and Wallace[20] reported that patients with fracture-dislocations progressed more slowly, experienced more pain, and needed longer courses of physiotherapy with closed treatment. Although the authors reported good or satisfactory outcome in 94% of their patients, they treated a population with a mean age of 66 years, followed up for only 6 months, and they

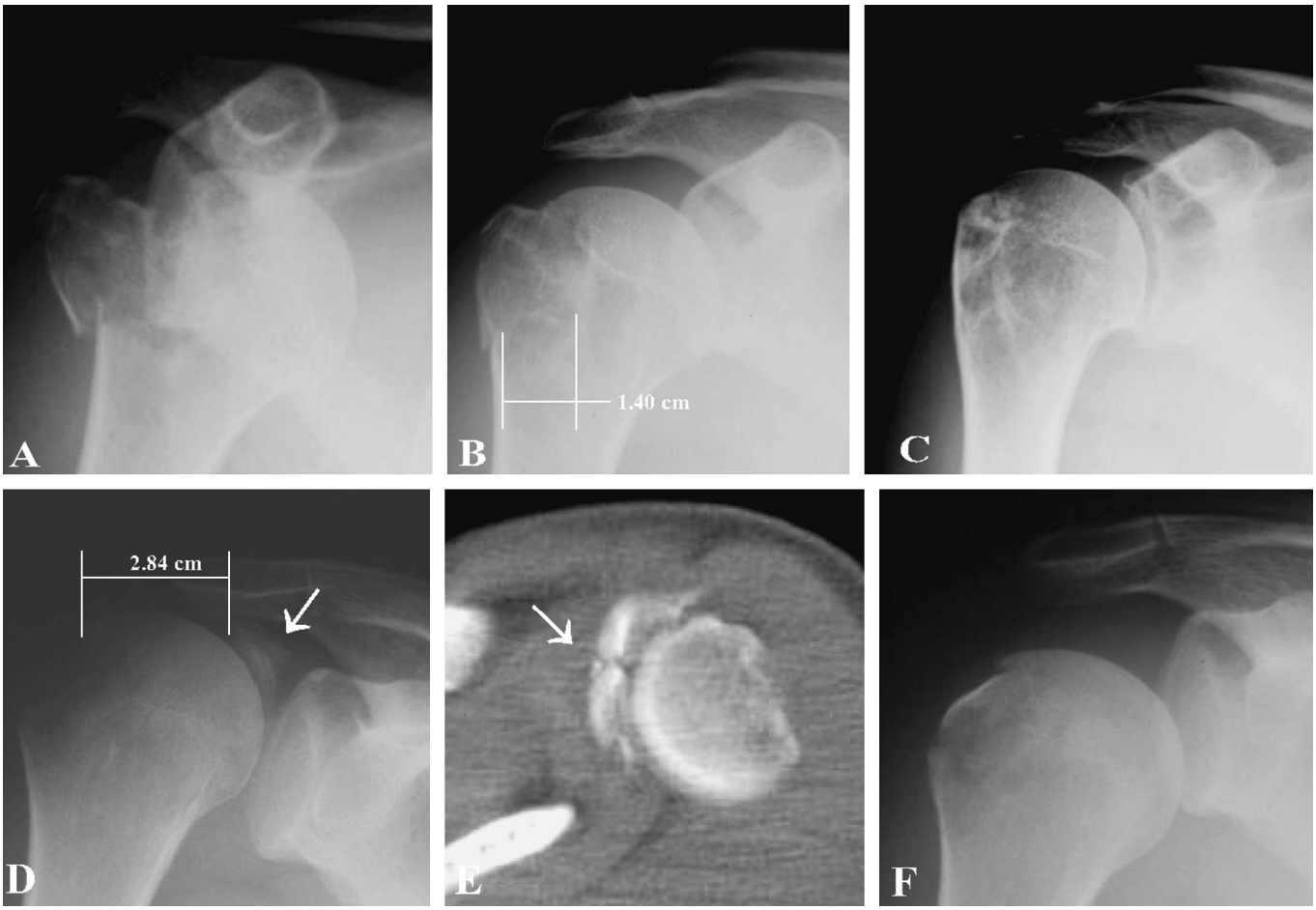

FIGURE 4. A, Anterior shoulder dislocation associated with a GT fracture in a 32-year-old patient. B, Postreduction GT displacement is measured at 1.4 cm in the standard anteroposterior view. C, Solid union and excellent clinical outcome (Constant score 100) 5.5 years postoperatively. D, Another patient with avulsion and retraction of the GT fragment after reduction of the dislocation (arrow). The postreduction displacement is measured at 2.84 cm. E, CT scan demonstrates the degree of fragmentation and a hidden, posteriorly displaced, GT fragment (arrow). F, Reduction and fixation was achieved with sutures; both the supraspinatus and infraspinatus tendons were avulsed from their facets.

considered active abduction up to 60 degrees as the minimum functional requirement of the shoulder in this age group. Explanations for poor results after nonoperative treatment of fractures of the GT include loss of shoulder elevation and painful motion. Platzer et al[3] in a recent article identified poor correlation between degree of displacement in minimally displaced fractures of the GT after nonoperative management and final shoulder function. Twenty-six (19.3%) of these patients had a GT fracture associated with an anterior traumatic dislocation of the shoulder, but according to the authors, the final outcome was similar to that of patients with GT fractures without dislocation. About 71% of the invited patients (411/546) did not attend the last follow-up, a fact that was explained by the authors as perhaps a factor in the excellent results that were achieved. Patients with a displacement of 3 mm or less had equal results, whereas patients with a superior displacement of more than 3 mm experienced slightly worse results compared to those with less displacement. The authors supported surgical stabilization in athletes or active patients engaged in overhead activity who have a displacement of more than 3 mm to prevent further displacement and secondary impairment of shoulder function. However, their study was not a prospective trial and did not include a control group.

The rationale for surgical intervention is prevention of nonunion and impingement of the GT beneath the acromion and mechanical blockage of abduction of the shoulder by a superiorly displaced tuberosity or obstruction of external rotation because of posterior GT displacement.[10,21] Recently, many surgeons have expanded their surgical indications. Bigliani et al,[5] Craig,[8] and Iannotti and Sidor[7] endorse surgical fixation of fractures that are displaced by 0.5 cm or more to minimize dysfunction and to decrease the incidence of impingement and loss of forward elevation. According to Park T et al,[22] surgical treatment should be considered for athletes or persons engaged in heavy labor with smaller displacements (3 mm). Flatow et al[21] reported an average abduction of 170 degrees, with mild or no pain in 12 patients treated surgically for displaced fractures, whereas Park M et al[23] reported good to excellent results in 13 patients with GT fractures who were treated operatively. Recently, arthroscopic

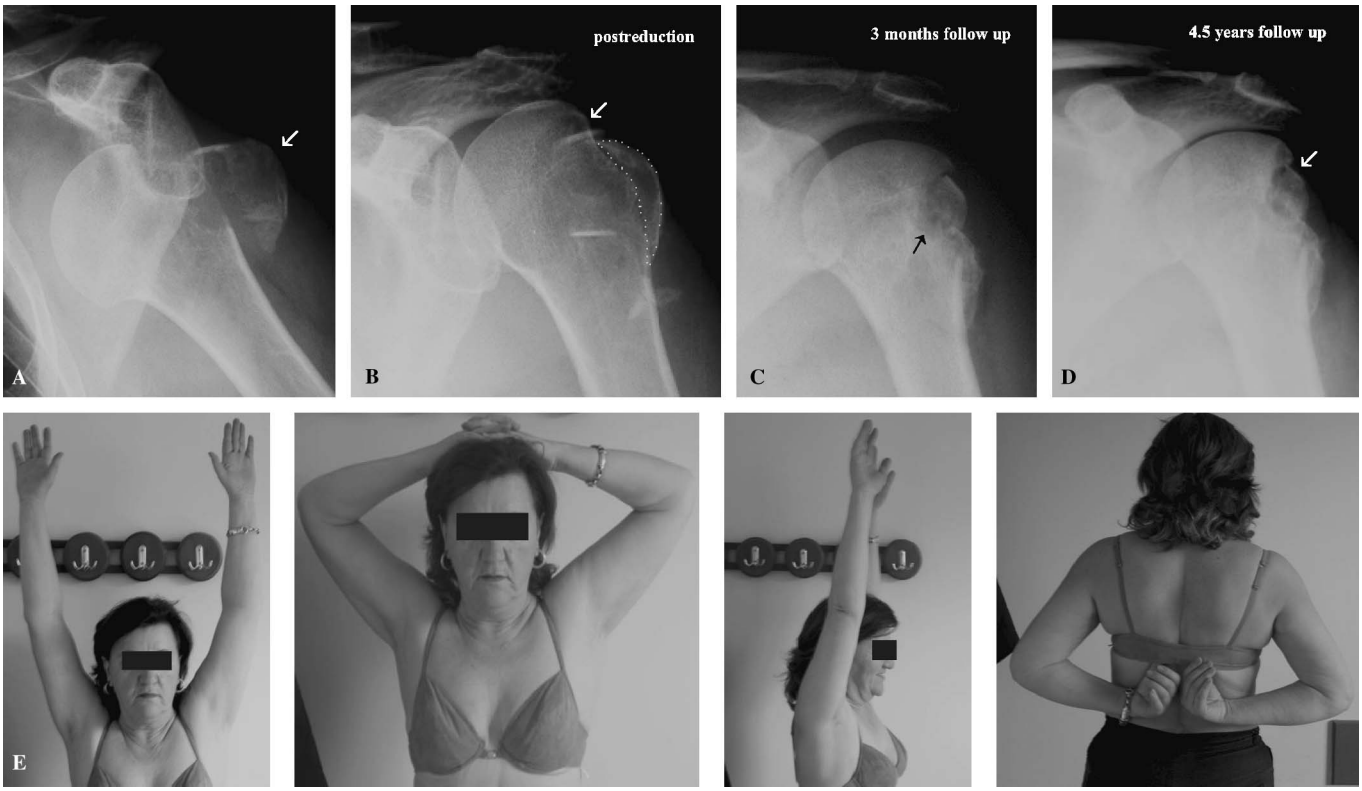

FIGURE 5. A, Anterior dislocation of the shoulder with associated GT fragment (arrow) in a 53-year-old woman. B, Postreduction radiograph shows GT displacement (arrow). C, Follow-up radiograph at 3 months shows anatomical reduction of the GT (arrow). D, Radiograph at final follow-up (4.5 years postoperatively) demonstrates partial absorption of the cortical margin of the tuberosity (arrow). E, Despite this radiologic finding, the clinical outcome was excellent (Constant score 98) after 4.5 years of follow-up.

stabilization of minimally displaced GT fractures and associated soft-tissue lesions has been reported,[24] with excellent functional results. Furthermore, Kim and Ha[25] reported that 23 patients for whom a displaced fracture of the GT had been initially treated nonoperatively for at least 6 months had significant improvement 2 years after arthroscopic reduction of the tuberosity and subacromial decompression. Although these data are limited, they indicate good functional rehabilitation after open reduction and internal fixation of GT displacement. On the contrary, poor results of shoulder prosthetic replacement for displaced fractures of the proximal humerus have been correlated with GT abnormalities. Boileau et al[26] reported unsatisfactory results in 28 of 66 patients who underwent hemiarthroplasty for displaced fractures of the proximal humerus; initial malposition or secondary GT displacement was detected in 33 (50%) patients and was correlated with an unsatisfactory outcome, consisting of stiffness and persistent pain. Frankle et al[27] performed a biomechanical study in cadaveric shoulders, stimulating a 4 part fracture that was repaired with hemiarthroplasty. The GT was fixed in either an anatomic or nonanatomic position; nonanatomic reconstruction led to a significant impairment in external rotation kinematics and up to an 8-fold increase in torque requirements.

No specific data exist concerning the surgical management of GT fractures associated with traumatic anterior dislocation of the shoulder. Our experience the last 10 years with nonoperative treatment of these injuries has shown a high percentage of complications attributed to secondary tuberosity displacement and subsequent rotator cuff tearing. We have already operated on 17 neglected cases [5 from our area and 12 referrals from other centers with GT displacement and associated anterior dislocation of the shoulder that were treated nonoperatively with sling immobilization and subsequent physiotherapy (Fig. 6)]. During surgical exploration, 12 (70.5%) of these patients had moderate or large rotator cuff tears. Our decision to internally fix the GT in its anatomic position is based on the nature of injury and not the degree of postreduction displacement. The rule of 10 mm or 5 mm, in our opinion, cannot be applied in cases of dislocation, because the displacement extends to 20 mm on average before reduction in the majority of cases. An accurate measurement of this displacement is difficult because the humeral head is in a locked position and the patient is not able to externally rotate his shoulder. The associated tears of rotator cuff tendons, noted in 44% of our cases, indicate that the force of impaction is absorbed mainly by the tuberosity and the incorporated tendons, without any serious stretching of the capsule. This is perhaps one of the reasons that a recurrent dislocation of the shoulder is not common after such injuries. Robinson et al[28] performed a 3 year, prospective, observational, cohort study in 538 consecutive patients with a first-time anterior dislocation and found that 17 (3.2%) patients sustained an early redislocation within the first week after the original dislocation. None of these patients had an associated GT fracture. Patients

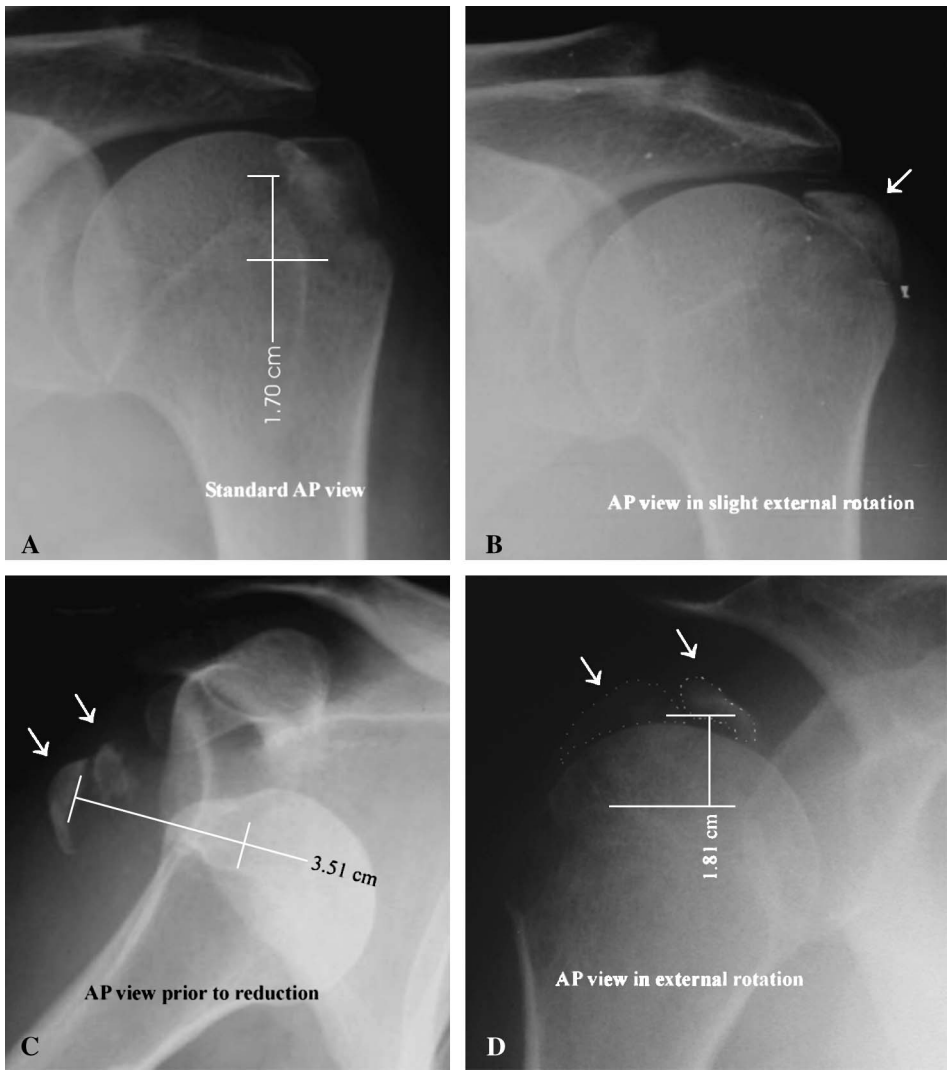

Figure 6. A, Postreduction radiograph in a 26-year-old patient who was involved in a road traffic crash. A, There is a 1.7-cm superior displacement of the GT, but the patient was treated nonoperatively in another hospital with sling immobilization for 5 weeks and subsequent physiotherapy. B, Three months after the injury, the patient was referred to us, having all the hallmarks of subacromial impingement syndrome and 55 points on the Constant score. Radiograph in slight external rotation showed a malunited GT fragment with posterosuperior displacement (arrow). During surgery, a tear in the supraspinatus tendon was identified. The GT fragment was excised and the supraspinatus tendon was repaired with nonabsorbable sutures. Five years postoperatively, the patient had a Constant score of 85. C, Another example in a 54-year-old heavy laborer who sustained an anterior dislocation of his shoulder after a fall from 4 m high. Radiograph shows multifragmentation of the GT fragment and 3.51 cm initial displacement before reduction (arrows). The patient was treated with sling immobilization in another hospital but sought medical attention in our hospital 7 weeks after the injury because he was unable to abduct his arm more than 40 degrees (Constant score, 44 points). Radiograph of his shoulder showed 1.81 cm superior GT displacement. During surgical exploration, a 2 cm tear of the supraspinatus tendon was found and repaired. Functional outcome was satisfactory 3.4 years postsurgery, with a Constant score of 93.

at increased risk of redislocation include those who sustained the original dislocation as the result of a high-energy injury (relative risk, 13.7), those in whom a large rotator cuff tear occurred in conjunction with the dislocation (relative risk, 29.8), and those in whom the original dislocation was associated with a fracture of the glenoid rim (relative risk, 7.0) or fracture of both the glenoid rim and the GT (relative risk, 33.5). With respect to the high incidence of RC tears, Wohlwend et al[29] performed sonographic examinations of both shoulders in 77 asymptomatic individuals (154 shoulders) aged between 30 and 80 years and found irregularities of the GT in 36 (90%) of 40 shoulders with a rotator cuff tear. In contrast, the GT was irregular in only 12 (11%) of 114 shoulders without a rotator cuff tear. After age was accounted for, a statistically significant association was found ($P < 0.001$) between rotator cuff status and GT status. Therefore, it is reasonable to expect similar irregularities in the rotator cuff tendons when the GT is not anatomically fixed in its position after a traumatic anterior shoulder dislocation.

We believe that the anatomic fixation of the tuberosity and subsequent rotator cuff repair prevents secondary displacement and degenerative tearing, especially in older patients, while contributing to restitution of shoulder muscle balance. In a cadaveric study,[6] for example, the necessary abduction force of the deltoid was significantly increased by 16% and 27% by superior displacements of 0.5 cm and 1 cm of the GT, respectively, whereas combined superior and posterior displacement of 1 cm gave an increase in necessary abduction force of 29%.

The strengths of this study include its philosophy about the necessity of operative reconstruction of the GT and associated rotator cuff tears, the specialized and closely supervised rehabilitation program, the thorough evaluation of the patients in medium to long follow-up, and the fact that all patients were operated on by a single surgeon. However, some limitations

exist: First, the precise assessment of this specialized physiotherapy regimen relative to outcome is difficult to measure. Second, we prefer heavy nonabsorbable sutures for fixation of this simple fracture because they provide adequate stabilization with minimal soft-tissue damage. Whether this technique or others are best for GT stabilization is not known. However, we do use the same technique for other types of displaced proximal humeral fractures (2-part surgical neck, 3-part GT, 4 part valgus impacted) in our department.[30–32] We believe that metal fixation (screws, tension band wiring) can lead to further comminution of the fragments, migration, and poor fixation, especially in osteoporotic bone. Furthermore there is no need for hardware removal if metal is not used and damage to the rotator cuff is minimized in those cases of metal loosening, breakage, or migration. However, arthroscopic-assisted screw-fixation techniques might be an attractive alternative.[33] Third, the number of our patients is small, but considering the rarity of injury and the lack of documented similar studies, we believe that this is one of the larger series of patients that has been reported to date. Finally, there is always a need for a control group, but we believe that the randomization of treatment in this injury to a nonoperative and surgical therapy group is not acceptable, as partially evidenced by our previous discussion of subsequent surgery in those patients who failed nonoperative treatment. As always, a multicenter investigation may help to compare the benefits of each treatment.

Despite these limitations, we recommend operative fixation of the GT fracture associated with a traumatic anterior dislocation of the shoulder. Anatomic reconstruction of the GT and subsequent rotator cuff repair allow for early passive motion of the joint; the subsequent avoidance of tendon retraction, malunion, and secondary GT displacement yields a predictable and satisfactory medium- to long-term outcome.

REFERENCES

1. Rowe CR. Prognosis in dislocations of the shoulder. *J Bone Joint Surg Am*. 1956;38:957–977.
2. Lind T, Kroner K, Jensen J. The epidemiology of fractures of the proximal humerus. *Arch Orthop Trauma Surg*. 1989;108:285–287.
3. Platzer P, Kutscha-Lissberg F, Lehr S, et al. The influence of displacement on shoulder function in patients with minimally displaced fractures of the greater tuberosity. *Injury.* 2005;36:1185–1189.
4. Green A, Izzi J Jr. Isolated fractures of the greater tuberosity of the proximal humerus. *J Shoulder Elbow Surg*. 2003;12:641–649.
5. Bigliani LU, Flatow EL, Pollock RG. Fractures of the proximal humerus. In: Harryman DT, Matsen FA, Rockwood CA, et al, eds. *The Shoulder: Vol. 1*. 2nd ed. Philadelphia, Pa: WB Saunders; 1998:337–390.
6. Bono CM, Renard R, Levine RG, et al. Effect of displacement of fractures of the greater tuberosity on the mechanics of the shoulder. *J Bone Joint Surg Br*. 2001;83:1056–1062.
7. Iannotti J, Sidor M. Malunions of the proximal humerus. In: Warner J, Iannotti J, Gerber C, eds. *Complex and Revision Problems in Shoulder Surgery.* Philadelphia, Pa: Lippincott-Raven; 1997:245–264.
8. Craig E. Open reduction and internal fixation of greater tuberosity fractures, malunions and nonunions. In: Craig E, ed. *Master Techniques in Orthopaedic Surgery: The Shoulder*. New York, NY: Raven Press; 1995: 289–307.
9. Stevens J. The action of the short rotator on the normal abduction of the arm, with a consideration of their action in some cases of subacromial bursitis and allied conditions. *Am J Med Sci*. 1909;138:870–884.
10. Neviaser J. Complicated fractures and dislocations about the shoulder joint. *J Bone Joint Surg Am*. 1962;44-A:984–988.
11. Connor PM, Flatow EL. Complications of internal fixation of proximal humeral fractures. *Instru Course Lect*. 1997;46:25–37.
12. Handoll HHG, Almaiyah MA, Rangan A. Surgical versus non-surgical treatment for acute anterior shoulder dislocation (review). *Cochrane Database Syst Rev.* 2004;25:CD004962.
13. Parsons BO, Klepps SJ, Miller S, et al. Reliability and reproducibility of radiographs of greater tuberosity displacement: a cadaveric study. *J Bone Joint Surg Am*. 2005;87:58–65.
14. Neer CS 2nd. Displaced proximal humeral fractures. I. Classification and evaluation. *J Bone Joint Surg Am.* 1970;53-A:1077–89.
15. Davies MB, Rajasekhar C, Bhamra CS. Irreducible anterior shoulder dislocation: the greater tuberosity Hill-Sachs lesion. *Injury.* 2000;31:470–471.
16. Patten RM, Mack LA, Wang KY, et al. Nondisplaced fractures of the greater tuberosity of the humerus: sonographic detection. *Radiology.* 1992;182:201–204.
17. Jakob RP, Kristiansen T, Mayo et al. Classifications and aspects of treatment of fractures of the proximal humerus. In: Bateman JE, Welsh RP, eds. *Surgery of the Shoulder.* Philadelphia, Pa: Mosby; 1988:330–343.
18. Bahrs C, Lingenfelter E, Fisher F, Walters EM, Schnabel M. Mechanism and Morphology of the greater tuberosity fragment. *J Soulder Elbow Surg.* 2006;15:140–147.
19. Olivier H, Duparc J, Romain F. Fractures of the greater tuberosity of the humerus. *Orthop Trans*. 1986;10:223.
20. Young T, Wallace W. Conservative treatment of fractures and fracture-dislocation of the upper end of the humerus. *J Bone Joint Surg Br.* 1985; 67-B:373–377.
21. Flatow E, Cuomo F, Maday M, et al. Open reduction and internal fixation of two-part displaced fractures of the greater tuberosity of the proximal part of the humerus. *J Bone Joint Surg Am*. 1991;73-A:1213–1218.
22. Park T, Choi I, Kim Y, et al. A new suggestion for the treatment of minimally displaced fractures of the greater tuberosity of the proximal humerus. *Bull Hosp Jt Dis*. 1997;56:171–176.
23. Park M, Murthi A, Roth N, et al. Two-part and three-part fractures of the proximal humerus treated with suture fixation. *J Orthop Trauma*. 2003;17: 319–325.
24. Taverna E, Sansone V, Battistella F. Arthroscopic treatment for greater tuberosity fractures: rationale and surgical technique. *Arthroscopy.* 2004; 20:53–57.
25. Kim SH, Ha KI. Arthroscopic treatment of symptomatic shoulders with minimally displaced greater tuberosity fracture. *Arthroscopy.* 2000;16: 695–700.
26. Boileau P, Krishnan SG, Tinsi L, et al. Tuberosity malposition and migration: reasons for poor outcomes after hemiarthroplasty for displaced fractures of the proximal humerus. *J Shoulder Elbow Surg*. 2002;11: 401–412.
27. Frankle MA, Greenwald DP, Markee BA, et al. Biomechanical effects of malposition of tuberosity fragments on the humeral prosthetic reconstruction for four-part proximal humeral fractures. *J Shoulder Elbow Surg*. 2001;10:321–326.
28. Robinson CM, Kelly M, Wakefield AE. Redislocation of the shoulder during the first six weeks after a primary anterior dislocation: risk factors and results of treatment. *J Bone Joint Surg Am*. 2002;84:1552–1559.
29. Wohlwend JR, van Holsbeeck M, Craig J, et al. The association between irregular greater tuberosities and rotator cuff tears: a sonographic study. *Am J Roentgenol*. 1998;171:229–233.
30. Panagopoulos A, Dimakopoulos P, Tyllianakis M, et al. Valgus impacted proximal humeral fractures and their blood supply after transosseous suturing. *Int Orthop*. 2004;28:333–337.
31. Dimakopoulos P, Panagopoulos A, Papadopoulos AX, et al. Reconstruction of 4 part "valgus impacted" fractures of the humeral head. *J Bone Joint Surg*. 2004;86-B(Suppl III):308.
32. Dimakopoulos P, Panagopoulos A, Papadopoulos AX, et al. Management of acute 2-, 3- and 4-part fractures of the proximal humerus with transosseous suturing fixation: surgical technique and midterm outcome in 197 cases. Presented at: 19th Congress of ESSSE/SECEC; 21–24 September 2005; Rome, Italy.
33. Carrera EF, Matsumoto MH, Netto NA, et al. Fixation of greater tuberosity fractures. *Arthroscopy.* 2004;20:109–111.