AO X-shaped Midfoot Locking Plate to Treat Displaced Isolated Greater Tuberosity Fractures

YUN FENG CHEN, MD; WEN ZHANG, MD; Qiang Chen, MD; HAI FENG WEI, MD; LEI WANG, MD; CHANG QING ZHANG, MD

Abstract

Although various implants exist for 3- and 4-part fractures, few implants are appropriate for isolated greater tuberosity fractures. This retrospective study evaluated the efficacy of AO X-shaped midfoot locking plates (Synthes, Oberdorf, Switzerland) for greater tuberosity fractures.

Between May 2008 and September 2009, nineteen patients with displaced greater tuberosity fractures were treated with open reduction and internal fixation using AO X-shaped midfoot locking plates. Postoperatively, radiographs, functional results, and complications were evaluated. All patients were followed up for a mean 33.2 months (range, 24-42 months). Mean healing time was 9.4 weeks (range, 8-14 weeks). Mean Constant score was 90.6 ± 4.0 points (range, 77-95 points). Excellent results were obtained in 16 cases, good in 2 cases, moderate in 1 case, and poor in 0 cases. The excellent-good rate was 94.7%. No recurrence of dislocation occurred in the 11 cases with shoulder dislocation. All fractures healed without the complications of wound infection, skin numbness, subacromial impingement syndrome, nonunion, secondary displacement, and implant loosening.

The described technique is an effective, simple, and inexpensive method with a short learning curve.

The authors are from the Department of Orthopaedic Surgery, Shanghai Sixth People’s Hospital, Shanghai Jiaotong University, Shanghai, 200233, China.

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Drs Chen (Yun Feng) and Zhang (Wen) contributed equally to this work and article.

Correspondence should be addressed to: Chang Qing Zhang, MD, Department of Orthopaedic Surgery, Shanghai Sixth People’s Hospital, Shanghai Jiaotong University, 600 Y Shan Rd, Shanghai, China (zhangchangqing1962@yahoo.cn).

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Isolated greater tuberosity fractures comprise approximately 14% to 21% of proximal humeral fractures\(^1\) and 5% of all operatively treated proximal humeral fractures.\(^2\) Serving as attachment points of the rotator cuff, the greater tuberosity fragment is displaced by traction on the supraspinatus and infraspinatus. Thus, the abduction and external rotation of the shoulder is limited while the dynamic stability of the shoulder is decreased in such injuries. In the past, less attention has been paid to greater tuberosity fractures, and conservative treatment has been applied in most cases. Generally, 95% of greater tuberosity fractures are considered nondisplaced or minimally displaced and are treated without surgery.\(^3\) However, conservative treatment for displaced greater tuberosity fractures often results in shoulder dysfunction.\(^4,5\)

The Neer classification system for proximal humeral fractures describes the 4 fracture parts and provides criteria for treatment. Displacement greater than 1 cm or angulation greater than 45° is required for classification as a part and is the indication for surgery. Most authors agree that posterosuperior displacement greater than 5 mm leads to significant symptoms of subacromial impingement and should be treated with surgery.\(^2,4,5\) Park et al\(^6\) recommended displacement more than 3 mm as the surgical indication for athletes or manual workers.

For the greater tuberosity, the 3 main fixation methods are screws, tension banding, and transosseous sutures. The AO X-shaped midfoot locking plate (Synthes, Oberdorf, Switzerland) was originally designed to fix the navicular and cuniform bones of the midfoot. The authors applied this plate to greater tuberosity fractures and obtained satisfactory clinical outcomes. This retrospective study was conducted to evaluate the efficacy of the midfoot plate for greater tuberosity fractures.

**Materials and Methods**

Between May 2008 and September 2009, nineteen patients (16 men and 3 women) with isolated greater tuberosity fractures were treated with the AO X-shaped midfoot locking plate. All surgeries were performed by the same surgeon (Y.F.C.). Average patient age was 42 years (range, 25-66 years). Ten patients were left-handed and 9 were right-handed. The mechanisms of injury were vehicle trauma or motorcycle accident (n = 9), sporting trauma (n = 7), or falling from a height or on the stairs (n = 3). Average interval from injury to surgery was 3.5 days (range, 2-5 days). Preoperative imaging included true glenoid anteroposterior and trans-scapular lateral (Y view) radiographs of the shoulder, computed tomography (CT) scanning, and 3-dimensional reconstruction. In all patients, the displacement of the greater tuberosity was more than 5 mm, and 11 patients had associated anterior shoulder dislocation. The study was approved by the hospital institutional review board.

Inclusion criteria were isolated greater tuberosity fractures with or without anterior shoulder dislocation with displacement of the greater tuberosity greater than 5 mm. Exclusion criteria included a previous shoulder joint surgery or surgery associated with shoulder disease, other proximal humerus fractures in addition to the greater tuberosity fracture, a fragment no less than 1.5 cm in width, a greater tuberosity fracture with posterior shoulder dislocation, systemic or local infection, and a lack of patient informed consent.

**Surgical Technique**

Surgery was performed with the patient under a brachial plexus block or general anesthesia. A folded sheet was placed under the shoulder to elevate it. A superior deltoid splitting approach was used. A skin incision was made extending less than 5 cm lateral to the acromion. The deltoid fibers were split at the junction of the anterior and middle deltoid. Care was taken to avoid splitting the deltoid more than 4 to 5 cm lateral to the acromion to prevent injury to the axillary nerve. Richardson retractors were used to retract the deltoid and expose the greater tuberosity fragment. The periosteum and any hematoma were removed from the fracture site. The fragment was reduced using a forceps and fixed using 1.5-mm Kirschner wires. After satisfactory reduction was confirmed by intraoperative radiographs, an AO X-shaped midfoot locking plate was applied to fix the fragment and locking screws were inserted. Intraoperative radiographs were obtained and the affected shoulder was moved in all directions to exclude subacromial impingement and confirm reliable fixation of the greater tuberosity. If a tear of the rotator cuff was found intraoperatively, a 2.5-mm nonabsorbable suture (Ethibond; Ethicon, Inc, Eppendorf, Germany) was used for repair.

Antibiotics and analgesics were routinely administered postoperatively. For the first 3 weeks, all patients were kept in a neck-wrist sling, and gentle passive pendulum exercises were instituted. Adduction and internal rotation was limited. After 3 weeks, the sling was removed, and painless passive motion exercises of the shoulder were started. Patients were encouraged to participate in activities of daily living, such as washing their face, brushing their teeth, and combing their hair. At 6 weeks, painless active motion exercises of the shoulder were started. At 12 weeks, strengthening exercises were allowed.

Postoperatively, patients were followed up in the outpatient clinic at 1, 3, and 6 months and every 6 months thereafter. Anteroposterior and lateral radiographs were obtained to evaluate radiographic results after surgical treatment. The Constant score and complications, including shoulder dislocation, skin numbness, axillary nerve injury, loss of reduction, and implant loosening, were recorded.

**Results**

Of the 19 patients studied, 11 had greater tuberosity fractures associated with anterior shoulder dislocation (Figure 1). A rotator cuff tear was found in 1 of these 11 patients; 8 patients had no dislo-
cation. Of these 8, four had a rotator cuff tear. Mean operative time was 40 ± 13.5 minutes, mean blood loss was 48.2 ± 5.2 mL, and mean length of hospital stay was 6 ± 1.3 days.

All 19 patients were followed up at a mean 33.2 months (range, 24-42 months). All primary incisions healed in all patients. Average fracture healing time was 9.4 weeks (range, 8-14 weeks). None of the 11 patients with anterior dislocation of the shoulder had recurrence of the dislocation. No complications occurred, including local skin numbness, deltoid atrophy, deltoid paralysis, subacromial impingement, nonunion, loss of reduction, or implant loosening (Figure 2). At the last follow-up, average Constant score was 90.6 ± 4.0 points. Results were excellent in 16 (84.2%) patients, good in 2 (10.5%), moderate in 1 (5.3%), and poor in 0. The excellent-and-good rate was 94.7%.

Average shoulder range of motion was 155° of forward elevation (range, 140°-170°) and 150° of abduction (range, 130°-160°). The external rotation score ranged from 6 points (hand on top of head with elbow forward) to 10 points (full elevation with hand on top of head). The internal rotation score ranged from 6 points (end of the thumb to L3 or waist) to 10 points (end of the thumb to T7 or interscapular) (Figure 3).

**DISCUSSION**

The greater tuberosity serves as the attachment to the rotator cuff. Limitation of motion and disability are attributed to malfunction of the rotator cuff and to impingement caused by superior and posterior displacement of the greater tuberosity. The current literature recommends surgical fixation for fractures with more than 5 mm of displacement in the general population or more than 3 mm of displacement in active patients with frequent overhead activity.

The ideal surgical treatment of isolated greater tuberosity fractures remains controversial. Although a variety of implants for 3- and 4-part fractures exist, few are specifically designed for isolated greater tuberosity fractures.

Regular techniques for open reduction and internal fixation of greater tuberosity fractures are tension banding, screws, and transosseous sutures. These techniques have several problems. Braunstein et al reported that, among these fixations, tension banding and 2 cancellous screws provide better mechanical stability for isolated fractures of the greater tuberosity. However, screws may lead to further harm of the fragments, and screws with washers can lead to secondary subacromial impingement. The larger the implant, the greater the chance of impingement. Although the figure-eight tension banding technique may be inappropriate for patients with osteoporosis, tension banding carries the risk of iatrogenic fracture of the surgical neck because the stress raises at 1 to 2 cm above the insertion site of the anchor screw. Transosseous sutures are widely used to treat proximal humerus fractures because they fix the fragment at the tendon-bone interface, minimize the risk of metal allergy, and need no removal of internal fixation. Long-term follow-up studies show satisfactory clinical results with transosseous sutures. However, when the greater tuberosity fragment is comminuted, suture fixation may further decrease stability when sutures tear out of the tissue around the loop.

The AO X-shaped midfoot locking plate, as its name implies, was originally designed for midfoot fractures. The current authors applied the low-profile implant to greater tuberosity fractures. The X-shaped plate is angle-stable and covers a larger fracture area than screws, tension banding, or transosseous sutures. Thus, the fence structure may provide more reliable stability, especially for comminuted fractures.
or osteoporotic fractures. The X-shaped plate is a low-profile implant that fits smoothly to the tuberosity area and has the potential to avoid hardware-related problems. In addition, the locking system distributes the pressure over a relatively larger area than screws in tension banding, which may be a potential theoretical advantage for the fragment's blood supply.

In the current study, the AO X-shaped midfoot locking plate provided reliable stability, and satisfactory functional results were obtained. Average Constant score was 90.6±4.0 points at last follow-up, and the excellent-and-good rate was 94.7%. All fractures healed within 8 to 14 weeks. Complications such as deltoid atrophy, subacromial impingement, nonunion, loss of reduction, or implant loosening did not occur.

Despite the fact that isolated greater tuberosity fractures are well recognized, few published follow-up data exist regarding the surgical treatment of displaced fractures. Chun et al. reviewed the results of 141 two-part proximal humeral fractures; 24 were greater tuberosity fractures. They treated 10 of the greater tuberosity fractures with open reduction and internal fixation and 8 with screws. On the basis of Neer’s criteria, the results of the 11 patients assessed at a mean follow-up of 5.1 years were 1 excellent, 7 good, and 3 fair. The authors did not specify whether these were the result of operative or nonoperative treatment.

Dimakopoulos et al. evaluated the long-term functional and radiographic results of transosseous suture fixation in a series of selected displaced fractures of the proximal part of the humerus in 188 patients. Fifty-six (34%) patients had 2-part fractures of the greater tuberosity. All fractures were fixed with transosseous nonabsorbable sutures. All 2-part fractures involving the greater tuberosity showed bony union within 4 months. At final follow-up, mean Constant score was 91 points. The clinical and radiographic results of this transosseous suture technique were satisfactory. Gruson et al. reported that besides the fracture type, a multitude of patient-related factors also contribute to the choice of fixation. Even if the above-described suture fixation techniques have good results, they can be difficult if the tuberosity is multiple fractured and suturing would further diminish the fragment stability.

Patients in the current study showed outcomes similar to those in the studies of Dimakopoulos et al. and Szyszkiowitz et al. However, these studies also included surgical neck, anatomic neck, and lesser tuberosity fractures, which are more complex and may have fewer good results than isolated greater tuberosity fractures.

Recently, Schöffl et al. treated greater tuberosity fractures using a small Bamberg plate cut from a calcaneus plate. Ten patients with displaced fractures of the greater tuberosity were treated surgically with open reduction and internal fixation using the self-made Bamberg plate. No intraoperative complications occurred, and all fractures healed without complication. Secondary loss of reduction did not occur. The Constant score more than 6 months postoperatively proved the excellent functional results in all cases (mean, 94.2; range, 91-98). Their clinical results were slightly better than those in the current study, although Schöffl et al. presented a small number of cases. The Bamberg
plate performs a function similar to the AO X-shaped midfoot locking plate, but the latter is easier to manipulate because it matches the natural shape of the greater tuberosity and does not need to be pre-contoured and cut.

The current study has some limitations. A small number of patients were included in the research. A control group was not included to demonstrate the advantages of this procedure over other fixation techniques, and further biomechanical tests are required to verify the effectiveness of the implant. Long-term follow-up is also needed to assess the complication rates of this surgical technique.

**Conclusion**

The AO X-shaped midfoot locking plate provides reliable stability, especially for comminuted or osteoporotic fractures. Satisfactory functional results were obtained in the current study. Complications such as subacromial impingement, loss of reduction, and deltoid paralysis did not occur. This technique is inexpensive and has a short learning curve. Despite the need for further mechanical and comparative studies relative to other implants for greater tuberosity fractures, the current method shows promise. This procedure may ultimately lead to the development of a multifunctional anatomic plate designed for use in isolated greater tuberosity fractures.

**References**


