Dual Locking Plate Osteosynthesis for 3- or 4-Part Proximal Humeral Fractures Combined with Multiple Fractures of the Greater Tuberosity

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Received: 7 May 2020 / Accepted: 3 October 2020 / Published online: 28 October 2020
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Abstract

Background This retrospective study was conducted to evaluate the efficacy of dual locking plate osteosynthesis for treating 3- or 4-part proximal humeral fractures combined with multiple fractures of the greater tuberosity.

Methods From January 2012 to December 2018, 19 skeletally mature patients, who suffered 3- or 4-part proximal humeral fractures combined with multiple fractures of the greater tuberosity, were treated with open reduction and internal fixation using a dual locking plate technique through a delto-pectoral approach. Indexes for evaluation included fracture healing, quality of reduction, and incidence of complications (infections, screw perforation into the glenohumeral joint, subacromial impingement, hardware failure, avascular necrosis, and loss of reduction). Shoulder function was evaluated using Constant–Murley scoring.

Results The patients were assessed at a mean time of 25.3 months after surgery. Union of fractures was radiographically confirmed for all 19 patients. The mean Constant–Murley patient score was 85.2 points, and complications were identified in two patients during follow-up evaluations.

Conclusions The method of using dual locking plate osteosynthesis through a delto-pectoral approach resulted in a satisfactory union rate, excellent fracture reduction, low complication rate and good shoulder function for patients with complex proximal humeral fractures. The method is effective for treating 3- or 4-part proximal humeral fractures combined with multiple fractures of the greater tuberosity.

Keywords Proximal humeral fracture · Internal fixation · Plating · Greater tuberosity

Abbreviations

S3 Spatial Subchondral Support
PHILOS Proximal humerus-locking compression plate
VA-LCP Variable Angle LCP

Background

Proximal humeral fracture is one of the most common types of fracture, especially in elderly people with osteoporosis. They account for approximately 6% of all fractures seen in accident and emergency departments [1–3]. It is the third most common fracture overall following hip and distal radial fracture [4–6]. Most proximal humeral fractures are undisplaced or minimally displaced [7], and can be successfully treated using conservative methods [8]. However, displaced fractures require surgical treatment.

The most frequently used classification for proximal humeral fractures is Neer classification [9–11]. Neer classification is based on the four anatomical segments of the proximal humerus (the humeral head, shaft, and greater and lesser tuberosities) and whether these segments are fractured and/or displaced. According to Neer, 3- and 4-part proximal humeral fractures are classified as comminuted displaced fractures. These account for 13–16% of all proximal humeral fractures, and always require surgical treatment [2].

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Single-plate osteosynthesis is usually recommended as the method of fixation for this type of fracture [12–15]. However, the use of a single plate is not always successful in 3- or 4-part proximal humeral fractures, especially when fractures are combined with multiple fractures of the greater tuberosity. Although surgeons may have used tension banding, screws or transosseous sutures for treating the greater tuberosity fractures, some cases need an additional plate or screw treatment if original treatments resulted in poor fixation and/or if the fracture was not reduced. In recent years, dual locking plate osteosynthesis has been used to treat these complex proximal humeral fractures, based on radiographic understanding of the fractures.

The authors applied Spatial Subchondral Support (S3) Proximal Humerus Plating Systems as the main plates to fix the proximal humeral fractures and F3 Fragment Plating Systems as secondary plates to fix the fractured greater tuberosities. This retrospective study was conducted to evaluate the radiographic and clinical outcomes. We hypothesized that satisfactory clinical and radiographic results could be achieved using this technique.

Patients and Methods

The study was approved by our institution's Committee for Research Ethics. Informed consent was obtained from all individual participants included in the study. The criteria for inclusion in the study were being aged at least 18 years and having a closed 3- or 4-part proximal humeral fracture with multiple fractures of the greater tuberosity. Exclusion criteria were other fracture patterns (non-displaced, 2-part); open fractures; old fractures; multiple injuries; fractures associated with vascular or nerve damage requiring repair; suspected pathologic fractures; and patients with failed conservative treatment. Radiographs were used to determine the locations and Neer classifications of the fractures.

From January 2012 to December 2018, 24 skeletally mature patients with 3- or 4-part proximal humeral fractures combined with multiple fractures of the greater tuberosity were treated with dual locking plate osteosynthesis (S3 and F3). Open reduction and internal fixation were conducted through a delto-pectoral approach by fellowship-trained traumatologists at the department of Orthopaedics in Shanghai Changzheng Hospital. Fractures were classified using Neer's classification system. Surgery was performed within 6 days (mean 3.8 days) of the traumatic event in all the cases.

On admission, each patient was subjected to a standard radiologic protocol including X-rays and CT scans with 3-dimensional reconstruction. These images provided detailed information for making specific surgical decisions. Cases were assessed by different team leaders (we have five trauma teams). If the case was considered to be fit for the

“dual locking plate” technique, the patient was transferred to our team in Shanghai Changzheng Hospital. All 19 cases were operated on by our research team (Yongchuan Li, Nan Lu, Fan Zhang, Zhibin Zhou, Liangyu Zhao, and Aimin Chen).

Surgeries were performed in the beach-chair position on a radiolucent table, with side placement of an image intensifier to allow viewing of the humeral head in two planes. Surgeries were performed through a delto-pectoral approach while patients were under general anesthesia. A 12–14 cm incision was started midway between the coracoid and clavicle, and extended distally up to the deltoid insertion. The cephalic vein was identified and retracted laterally. Blunt dissection was performed through the delto-pectoral groove and the deltoid muscle was retracted to the lateral direction. This allowed access to the greater tuberosity, lesser tuberosity, the long head of the biceps muscle, and the fracture site of the proximal humerus. The long head of the biceps is an important landmark, as it indicates the location of the rotator interval space. Fractures were reduced through traction and manipulation and then provisionally stabilized with Kirschner wires. After the reduction had been confirmed by imaging, an S3 locking plate was placed approximately 3 cm distal to the tip of the greater tuberosity and just lateral to the sulcus bicipitalis. A detailed description of the fixation technique can be found in our previous study [16]. The second locking plate (F3) was positioned on the greater tuberosity fragment. After drilling and determining the correct screw length, we inserted the locking screws to fix the fragment in place. The intra-operative motion of the shoulder must be checked for impingement in all directions, especially in abduction and external rotation, to exclude subacromial impingement and to confirm reliable fixation of the proximal humerus. Intra-operative use of the C-arm image intensifier helped surgeons to accomplish reduction and verify correct screw placement to prevent intra-articular penetration. If a tear of the rotator cuff was found intra-operatively, a 2.5-mm nonabsorbable suture was used to repair it (Figs. 1, 2).

Intravenous antibiotics consisting of a first-generation cephalosporin or alternative were administered pre-operatively and for 24 h post-operatively. All patients were treated with a similar post-operative rehabilitation protocol that emphasized early passive and active motion exercises. Each patient wore a sling for the first 2 weeks following surgery. We encouraged patients to do isometric deltoid, biceps, and triceps strengthening exercises, starting on the first post-operative day. In general, passive range of motion exercises was initiated after changing the surgical dressing (on the second or third day after surgery). Active and active-assisted activities began within the second week after surgery (once sutures were removed). Pendulum exercises, anteflexion and external rotation with the arm were encouraged as tolerated. Patients continued with these actions for the first 6 weeks

Fig. 1 **a** A 63-year-old male sustained a 3-part proximal humeral fracture due to a fall from standing height. **b, c** Post-operative radiographic anteroposterior and lateral views showed an anatomic frac-

ture reduction with the use of the Spatial Subchondral Support Proximal Humerus Plating System and F3 Fragment Plating System

Fig. 2 **a** A 65-year-old male sustained a 3-part proximal humeral fracture due to a fall from height. **b, c** Post-operative radiographic anteroposterior and lateral views showed loss of fracture reduction with the use of the single Spatial Subchondral Support Proximal Humerus Plating System. **d, e** An additional F3 locking plate was

used to fix the greater tuberosity fracture in the second operation. **f, g** Post-operative radiographic anteroposterior and lateral views showed anatomic fracture reduction with the use of dual locking plate osteosynthesis

post-operatively. Then, weight training and supervised physical therapy were allowed. When their fractures were healed completely (about 3 months after surgery), patients were permitted to do further stretching and strengthening.

Data related to fracture healing, quality of reduction, and complications (infections, screw perforation into the glenohumeral joint, subacromial impingement, hardware failure, avascular necrosis, and loss of reduction) were recorded during post-operative clinical examinations and standardized X-rays (anteroposterior, lateral and axillary views) at 2, 6, 12, 26 and 52 weeks after surgery. Shoulder function was evaluated using the Constant–Murley score [17], which allocates 20 points for daily life, 15 for pain, 40 for range of motion, and 25 for strength. The highest total score is 100, indicating a healthy, asymptomatic joint, and the lowest is 0.

Results

From January 2012 to December 2018, 91 patients with 3- or 4-part proximal humeral fractures were treated in our department. Among the patients, there were 24 cases combined with multiple fractures of the greater tuberosity. These cases required the dual locking plate osteosynthesis procedure. For five of these patients, follow-up data were absent due to migration, death or other reasons. The remaining 19 cases were included in the final analysis of fracture healing, quality of reduction, complications and functional outcomes. Table 1 shows the patients' demographic information. Seven of the patients were men and 12 were women, and the mean age was 58 years (range

32–77). The dominant hand for all patients was their right, and 13 of them sustained the injury on the dominant side. Thirteen patients were in the age group of > 65 years and six patients were in the age group of < 65 years.

Mean data related to the patients' (treated with dual locking plates) hospital stays, surgery and long-term recovery are presented in Table 2. Patients stayed in the hospital for an average of 12.5 days (range 7–19). Operative management took a mean total operation time (including anesthesia) of 157.0 min (range 110–190). Union of fractures was radiographically confirmed for all 19 patients. Patients also were re-assessed during follow-up visits at a mean time of 25.3 months after surgery (range 14–26).

Follow-up visits revealed one case of varus malunion (head-shaft angle of less than 120°), one case of intra-articular screw penetration, and one case of subacromial impingement. The patient in whom the fracture had malunited did not require any treatment, as the range of movements was acceptable. There was no evidence of superficial infection, avascular necrosis, loss of reduction, hardware failure, loosening of locking screws, or delayed union for any of the patients. Table 3 shows complications noted during the follow-up visits. The patients had an overall mean Constant–Murley score of 85.2 points. At final follow-up evaluations, seven patients had excellent functional outcomes, eight patients had good scores, four patients had moderate scores, and no patient had a poor result, according to their individual Constant–Murley scores.

Table 1 Patients' and fractures' demographics

Characteristic	Number
Patients	19
Mean age (range)	58 (32–77)
Gender	
Male	7
Female	12
Injury mechanism	
Body height fall	9
Road traffic accident	7
High fall	1
Struck by object	1
Work accident	1
Fracture classification (Neer's)	
Three-part	14
Four-part	5
Osteoporosis	6
Arthritis	0
Diabetes mellitus	5

Table 2 Operation and follow-up data

Characteristic	Mean
Time from injury to surgery, days	3.8
Operative time, min	157.0
Blood loss in surgery, ml	210
Hospital stay, days	12.5
Follow-up, months	25.3
Union rate, <i>n</i> (%)	19 (100%)

Table 3 Complications during the follow-up

Complications	Number
Superficial infection	0
Screw perforation	1
Subacromial impingement	1
Hardware failure	0
Avascular necrosis	0
Loss of reduction	0

Discussion

Most complex proximal humeral fractures are caused by high-impact injury, and fully understanding these fractures is the basis for successful treatment. In the past, less attention was paid to greater tuberosity fractures, and conservative treatment was applied in most isolated greater tuberosity fractures, which often resulted in shoulder dysfunction [18, 19]. By more frequent use of CT scans and careful review of CT images, some researchers have realized the importance of the greater tuberosity for proper shoulder function. However, their studies have focused mainly on isolated greater tuberosity fractures [20–23]. The current study focuses on 3- or 4-part proximal humeral fractures with multiple fractures of the greater tuberosity. The greater tuberosity fragment is often displaced by traction of the supraspinatus and infraspinatus, which serve as attachment points of the rotator cuff. In most cases, fragments were pulled into the anterior direction by the supraspinatus and into the posterior direction by the infraspinatus and teres minor, when 3- or 4-part proximal humeral fracture occurred. A single-plate osteosynthesis or plate osteosynthesis combined with greater tuberosity fixation using implements such as tension banding, screws or transosseous sutures is usually recommended as the definitive fixation technique for this kind of fracture. However, some cases require an additional plate or screw treatment to resolve poor fixation or loss of reduction. The previous technique may be unsuitable to fix large areas of the greater tuberosity [16] (Fig. 2a–c). In recent years, we have used a novel dual locking plate osteosynthesis technique to treat these complex proximal humeral fractures through a delto-pectoral approach. Our method strengthens the fixation and prevents further displacement of the greater tuberosity. No cases of lost reduction were noted during follow-up visits with the 19 patients. This is the first report in English literature of using this fixation method for complex proximal humeral fractures with multiple fractures of the greater tuberosity.

Common techniques used for open reduction and internal fixation of greater tuberosity fractures are tension banding, screws, and transosseous sutures. However, none of these techniques have been established as a gold standard, and moreover, these techniques may lead to several problems [19, 23]. It is difficult to replace and retain the fragile parts at their origin, when the tuberosity is displaced and multiple fractures occur. Simple screwing may lead to further damage to the fragments and screws with washers can lead to secondary subacromial impingement [24, 25]. Moreover, isolated screw fixation of these fractures has been described as infeasible if the fragment is comminuted and should, therefore, be used with caution

due to the risk of further fracture or subsequent displacement [19]. The tension-banding technique may be inappropriate for patients with osteoporosis, given the risk of iatrogenic fracture of the surgical neck [24]. In contrast, transosseous sutures are widely used to treat proximal humeral fractures because they fix the fragment at the tendon–bone interface, minimize the risk of metal allergy, and need no removal of implant. A long-term follow-up study by Dimakopoulos et al. [25] showed 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 [19].

A few recent studies have used plates to treat greater tuberosity fractures [20, 26]. Chen et al. [20] treated displaced isolated greater tuberosity fractures with open reduction and internal fixation using an AO x-shaped midfoot locking plate in 19 patients. The mean Constant–Murley score was 90.6 points and all fractures healed without any complications of wound infection, numbness, subacromial impingement syndrome, nonunion, secondary displacement, or implant loosening. Schöffl et al. [26] used a small Bamberg plate cut from a calcaneus plate to perform an osteosynthesis procedure on patients with multiple greater tuberosity fractures. Excellent postoperative outcomes were achieved, with no complications and no secondary losses of reduction. The Constant–Murley scores more than 6 months post-operatively reflected the excellent functional results in all cases. Choi et al. [27] described a new dual-plate fixation technique to treat comminuted proximal humeral fractures that were similar to the cases presented in our study. However, there were several significant differences between our studies. The first difference was that we used a Spatial Subchondral Support Proximal Humerus Plating System and F3 Fragment Plating System for comminuted proximal humeral fractures, while a proximal humerus-locking compression plate (PHILOS) and a Variable Angle LCP (VA-LCP) Distal Radius System were applied in the study by Choi et al. Second, the VA-LCP distal radius plate used by Choi et al. was to prevent nonunion, varus collapse of the neck-shaft portion and anterior–posterior angulation of the humeral head. In comparison, the F3 locking plate used in our study had the added functionality of providing fixation for multiple fractures of the greater tuberosity. Thirdly, the VA-LCP distal radius plate was harder to be shaped and more extensive soft tissue stripping was needed to fix the plate. In addition, we have treated a series of patients and obtained satisfactory clinical outcomes, whereas their study only provides a technical introduction.

The F3 fragment plating system is a collection of titanium alloy locking plates, which allows in situ contouring, and it is, therefore, suited to smaller bones in the distal extremities, particularly the foot and ankle. We applied this implant

to greater tuberosities with multiple fractures in conjunction with S3 Proximal Humerus Plating Systems for treating complex proximal humeral fractures. This small locking plate (F3) covers a larger fracture area and may potentially provide more reliable stability than screws, tension banding, or transosseous sutures, especially in cases of comminuted or osteoporotic fractures. Although previous studies have reported good results from using locking plates for 3- or 4-part proximal humeral fractures [12–15] or isolated greater tuberosity fractures [20, 26], ours is the first report on using two locking plates to treat 3- or 4-part proximal humeral fractures combined with multiple fractures of the greater tuberosity. Based on Constant–Murley scores and incidence of post-operative complications, our method provided better clinical results compared to other reported methods for treating complex proximal humeral fractures.

The limitations of the present study are that: (1) the sample size was small because of the rarity of the injury; (2) a control group was not included to demonstrate the advantages of this procedure over other fixation techniques; and (3) the average follow-up time was after only 25.3 months, which is a relatively short evaluation period and most cases of post-traumatic arthritis would not have developed yet. A larger sample size with a control group and extended follow-up evaluations are recommended for future studies to strengthen their validity.

Conclusion

A dual locking plate osteosynthesis technique was performed through a delto-pectoral approach to treat 19 cases of complex proximal humeral fractures, resulting in a satisfactory union rate, excellent fracture reduction, low complication rate and good shoulder function for patients. It was demonstrated to be an effective method for treating 3- or 4-part proximal humeral fractures with multiple fractures of the greater tuberosity.

Author contributions AC and LZ designed the study; YL, ZZ, FZ, LZ and AC did the operation; YL, NL, FZ, and ZZ collected the data; YL, NL, FZ, and ZZ analyzed the data; YL, NL, FZ, ZZ, LZ and AC wrote the paper; YL, NL, FZ, and AC revised the manuscript.

Funding This research has no funding source.

Compliance with Ethical Standards

Conflict of interest There are no conflicts of interests.

Ethical standard statement This article does not contain any studies with human or animal subjects performed by the any of the authors.

Ethical approval The research has been approved by The Ethics Committee of Shanghai Changzheng Hospital and consented by all participants.

Informed consent The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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