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Original Article

Surgical treatment for proximal humeral fracture in elderly patients with emphasis on the use of intramedullary strut allografts

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ABSTRACT

Objective: To review the results of proximal humeral fracture in elderly patients receiving open reduction and internal fixation (ORIF), and to investigate whether use of intramedullary strut allografts leads to better outcomes.

Methods: Retrospective review of radiographs, charts, and surgical records of 90 patients, age 65 years and older, followed up for a minimum of 12 months after buttress plate fixation of a proximal humeral fracture from January 2001 to March 2011. The fractures were reduced with or without insertion of an intramedullary strut allograft during the operation. We analyzed overall results, fracture union status, and varus collapse (by determining the change in the neck-shaft angle and humeral head height) by radiography at 5 different time points: immediately and 1, 3, 6, and, 12 months postoperative.

Results: The 90 patients enrolled in the study included 24 men and 66 women. An intramedullary strut allograft was applied in 55 patients (BG group), and not applied in the remaining 35 patients (non-BG group). Overall favorable union was achieved in 72.2 % (65 of 90) of patients, with malunion in 20% (18 of 90) and nonunion in 7.8% (7 of 90). There were no significant differences between patients with satisfactory and unsatisfactory outcomes in terms of age or gender. The percentage of satisfactory outcomes was clearly higher in the BG group (92.73% vs. 40%, $p < 0.001$). Ironically, better outcomes were obtained in the severe group (Neer 3-, and 4-part fractures) than the minor group (Neer 2-part fractures) (82.98% vs. 60.47% $p = 0.017$). The degrees of loss of reduction with the use or nonuse of intramedullary strut allografts in the favorable union and malunion groups were compared. The amount of loss of reduction in the neck-shaft angle was significantly lower in the BG group than the non-BG group (2.43° vs. 11.11°, $p < 0.001$). The amount of loss of reduction in humeral head collapse was significantly lower in the BG group than the non-BG group (2.05 mm vs. 6.01 mm, $p < 0.001$).

Conclusions: Complications after treating proximal humeral fracture in the elderly are frequently encountered because of poor bone quality. When fixing the fracture with plates, adjuvant use of intramedullary strut allograft can significantly enhance the result and reduce the incidence of malunion, nonunion and varus collapse.

1. Introduction

Proximal humeral fractures account for 5% to 8% of all fractures [1–3]. It is the fourth most common fracture following hip, spine, and wrist fractures in elderly osteoporotic patients who have low-energy accidents [4]. Conservative treatment for nondisplaced or minimally displaced proximal humeral fractures is suggested and good outcomes can be achieved [5]. Caution is needed when applying nonsurgical treatment in displaced proximal humeral fractures, as unsatisfactory outcomes have been reported in up to 48% of cases, including malunion in 23%, avascular necrosis in 14%, and nonunion in 6% [6].

Surgical intervention for displaced fractures could result in better quality of life, avoiding the complications that frequently

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develop after conservative treatment [6,7]. A randomized study demonstrated that higher Neer scores and better quality of reduction would be obtained after surgical treatment than closed reduction with sling immobilization in two-, three-, and four-part proximal humeral fractures [8]. The earlier the rehabilitation intervention after stable fixation, the more successful it is in achieving full range of motion under optimal selection criteria. However, postoperative complications such as hardware failure, bone failure, nonunion, and malunion often occur in patients with poor bone quality. Prior studies revealed that loss of reduction and intra-articular screw penetration occurred in up to 29% of proximal humeral fractures with initial anatomic reduction [9]. Gardner et al felt that medial cortical support is important in treating proximal humeral fractures; in their study, the average amount of humeral head collapse was 5.8 mm without this support [10]. Bjorkenheim et al demonstrated that 26% of proximal humeral fractures in patients treated with open reduction and internal fixation (ORIF) healed with a varus deformity after one year [11].

One method to enhance the outcome is the use of an intramedullary strut allograft. Chao et al stated that the fixation strength of different methods for fracture fixation is affected significantly by alteration of cortical and trabecular bone structures and material properties [12]. Generally, screws placed into cortical bone have better resistance to pullout than those placed into adjacent trabecular bone [13]. Intramedullary strut allografts have been widely applied in fracture treatments. However, there is a lack of large research studies on the effect of strut allografts in proximal humeral fractures.

The aim of the study was to review the results of proximal humeral fracture in elderly patients receiving ORIF, and to investigate if applying intramedullary strut allografts leads to better outcomes. We hypothesized that intramedullary strut allograft augmentation could provide stable fixation of fracture fragments and prevent humeral head varus collapse.

2. Material and methods

2.1. Patients

From January 2001 to March 2011, 116 patients, age 65 years and older, were admitted to Buddhist Tzu Chi General Hospital, Hualien, Taiwan because of displaced proximal humeral fracture and received ORIF. Their radiographs, charts and surgical records were reviewed. Patients were excluded if they had a Neer 2-part greater tuberosity fracture ($n = 3$), pathologic fracture ($n = 1$), lack of regular follow-up, incomplete surgical records, or any loss of radiographs ($n = 22$) during the follow-up period. In total, 90 patients were recruited into our study, and 55 patients among them were treated with intramedullary strut allografts. The use or nonuse of strut allografts was judged by operators based on bone quality, fracture nature, and comminutions. A strut allograft was often applied to assist fixation in complex proximal humeral fractures.

2.2. Operative procedure

Under general anesthesia, all patients were placed in a beach-chair position and a standard deltopectoral approach was applied. After deep dissection, the fracture site was exposed and reduced for fixation with a buttress plate and screws. If used, an intramedullary strut allograft with an optimal diameter and length was selected. It was inserted into the intramedullary canal distal to fracture site and then driven back to the proximal humeral bone (Fig. 1). Postoperatively, the arm was protected with a sling. Intramedullary strut allograft insertion was visible on postoperative radiographs.

The strut allografts, being part of radial shaft, ulnar shaft, humeral shaft, tibial shaft, fibular shaft, and femoral shaft, were taken from cadaveric donors. These strut allografts were stored in the freezer, at temperatures between −60 °C and −80 °C, until use. All allografts were free of blood-conducted diseases such as human immunodeficiency virus, hepatitis B virus, hepatitis C virus, and syphilis.

2.3. Radiologic analysis and outcome evaluation

The fracture type was defined as Neer 2-part, 3-part, or 4-part according to Neer classification on the preoperative radiography. Fracture union status was analyzed at 5 different time points: immediately and 1, 3, 6, and 12 months postoperative by checking shoulder internal and external rotation radiography (Fig. 1). Union was determined as appearance of bridging callus and disappearance of fracture lines on radiography. According to the United States Food and Drug Administration, a nonunion is considered to be established when a minimum of 9 months has elapsed since injury,

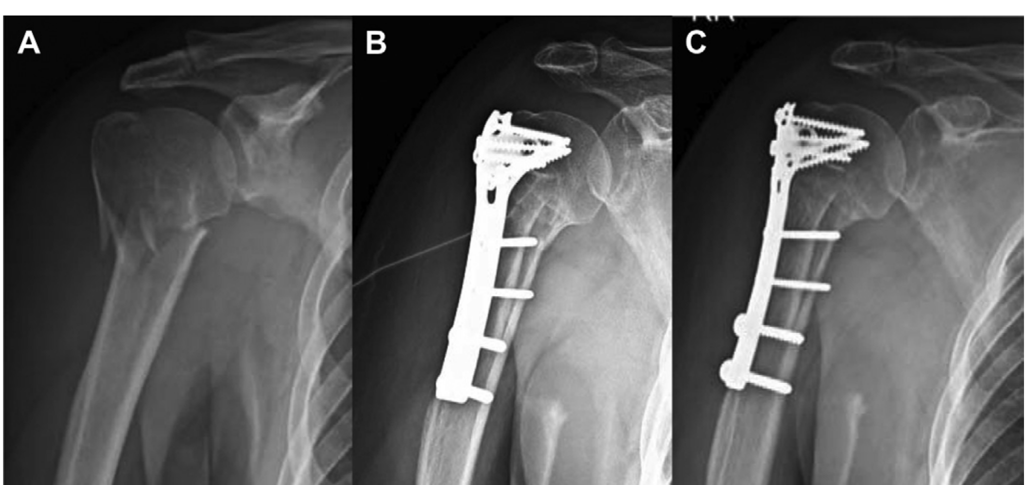

Fig. 1. A 69-year-old woman sustained a proximal humeral fracture after low energy trauma. (A) The radiographs demonstrate a Neer 3-part proximal humeral fracture. (B) Radiograph immediately after open reduction and internal fixation with a buttress plate and screws. An intramedullary strut allograft was applied. (C) The fracture status on the 6-month postoperative radiograph shows no loss of reduction and the intramedullary strut allograft is visible.

and the fracture site shows no visible healing signs progressive for a minimum of 3 months. In our study, patients who received revision surgery when symptomatic varus collapse developed due to hardware loosening were also regarded as having nonunion.

During the healing process, variable degrees of loss of reduction can occur, which may result in malunion. While a favorable union was categorized into the satisfactory outcome, malunion was regarded as an unsatisfactory result as nonunion. The neck-shaft angle and humeral head height were measured on the radiography to evaluate these changes. The neck-shaft angle was determined at different time points in a shoulder external rotation view to determine changes in varus deformity. It was calculated by measuring the angle at which a line drawn on the central axis of the humeral shaft intersects with a line perpendicular to the orientation of the anatomic neck of the humerus in the shoulder external rotation view [14] (Fig. 2). Humeral head height was also checked in the shoulder external rotation view at different time points, and the progression of collapse was monitored. The humeral head height was interpreted as the distance between the top of plate and the top of the humeral head using the axis of the humeral shaft as the reference [14] (Fig. 2). Three measurements done by the same doctor were recorded and averaged for analysis. Malunion was defined as a neck-shaft angle $<120°$ or $>150°$ [15], and a favorable union was considered a neck-shaft angle between 120° and 150°.

2.4. Statistical analysis

Data were expressed as either case numbers or mean ± standard deviation. Student *t* test was applied to compare the means of continuous variables. Categorical variables were analyzed using the Chi-square or Fisher's exact test. Statistical significance was defined as $p < 0.05$. All statistical analyses were performed with SPSS, version 13.0 (SPSS Inc., Chicago, IL, USA).

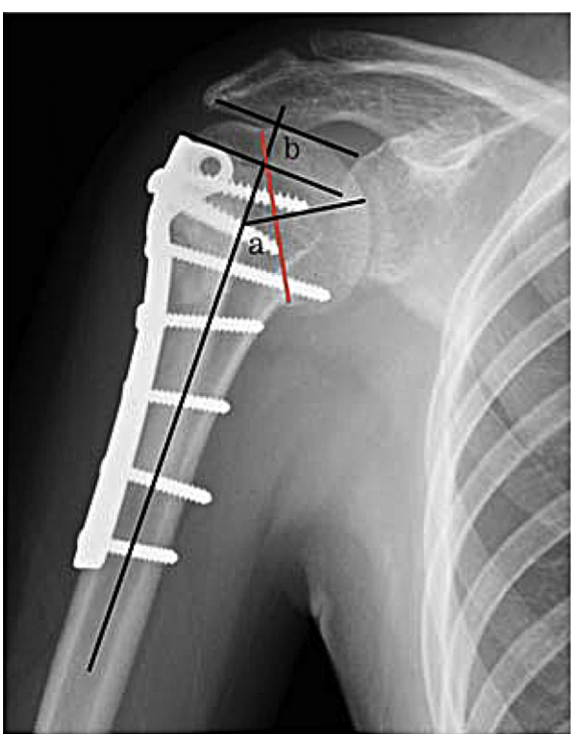

Fig. 2. The neck-shaft angle (a) is calculated by measuring the angle at which a line drawn on the central axis of the humeral shaft intersects with a line perpendicular to the orientation of the anatomic neck of the humerus in the shoulder external rotation view. The humeral head height (b) is interpreted as the distance between the top of plate and the top of the humeral head using the axis of the humeral shaft as the reference.

3. Results

A total 90 patients, including 24 men (26.7%) and 66 women (73.3%) were enrolled in our study. The average age was 74.2 years, and patients had follow-up for 18 months. There were 43 patients (47.8%) with a Neer 2-part fracture, 46 (51.1%) with a Neer 3-part fracture, and one (1.1%) with a Neer 4-part fracture. An intramedullary strut allograft was applied in 55 patients, the bone graft group (BG group), and the remaining patients constituted the nonbone graft group (non-BG group). The satisfactory (favorable union) rate was 72.2% (65/90) and unsatisfactory (including 7 nonunion and 18 malunion) rate was 27.8%.

A comparison of satisfactory and unsatisfactory outcomes is presented in Table 1. No statistically significant differences were found between these two groups in terms of age and gender. The percentage of satisfactory outcomes was clearly higher in the BG group (92.7% vs. 40.0 %, $p < 0.001$). Ironically, better outcomes were obtained in the severe group (Neer 3-, and 4-part fractures) than the minor group (Neer 2-part fractures; 83.0% vs. 60.5% $p = 0.017$).

A comparison of follow-up data including neck-shaft angle and humeral head height between the BG group and non-BG group is presented in Table 2. The amount of loss of reduction in the neck-shaft angle was also significantly lower in the BG group than the non-BG group (2.43° vs. 11.11°, $p < 0.001$). In addition, the amount of loss of reduction in humeral head collapse was also significantly lower in the BG group than non-BG group (2.05 mm vs. 6.01 mm, $p < 0.001$).

4. Discussion

The use of intramedullary strut allograft augmentation can result in good outcomes. In our study, the overall favorable union rate was 72.2%, while the malunion and nonunion rate was 27.8%, similar to other studies [11]. It is difficult to gain satisfactory outcomes in treatment with ORIF in proximal fractures in the elderly. In particular, the rate of satisfactory result in the BG group was up to 92.7%, which was much higher than in other studies, but in the non-BG group, it was only 40.0%. Consequently, intervention with an intramedullary strut allograft can enhance the favorable union rate in elderly and osteoporotic fractures.

Some authors mentioned that patients with complex fractures could achieve a better quality of life with operative treatment [4,7].

Table 1
Characteristics of proximal humeral fracture patients with satisfactory and unsatisfactory outcome.

	Satisfactory outcome ($n = 65$)	Unsatisfactory outcome ($n = 25$)	p
Age (y)	74.11 ± 6.41	74.44 ± 6.67	0.828
Gender			0.214
Male	15	9	
Female	50	16	
Fracture type			0.017*
Minor (Neer 2-part)	26	17	
(BG group)	(13)	(1)	
(Non-BG group)	(13)	(16)	
Severe (Neer 3- and 4-part)	39	8	
(BG group)	(38)	(3)	
(Non-BG group)	(1)	(5)	
Use of strut allograft			<0.001*
BG group	51	4	
Non-BG group	14	21	

Data are presented as n or mean ± standard deviation; *$p < 0.05$ was considered statistically significant after test.

Table 2
Comparison of follow-up data between BG and non-BG groups.

Follow-up item	n	Immediate post-op	At union	Amount of loss of reduction at union	p
Neck-shaft angle (°)					
BG group	54	133.31 ± 3.30	130.52 ± 4.53	2.43 ± 2.49	<0.001*
Non-BG group	29	132.73 ± 2.75	121.18 ± 4.45	11.11 ± 3.17	
Humeral head height (mm)					
BG group	54	9.44 ± 3.48	7.39 ± 3.68	2.05 ± 0.85	<0.001*
Non-BG group	29	12.35 ± 2.29	6.34 ± 2.32	6.01 ± 1.29	

Data are presented as n or mean ± standard deviation; * $p < 0.05$ was considered statistically significant after test; the *p* column denotes the equivalence test result of change amount between BG and non-BG groups.

However, a malunion rate of 50%, and even up to 83% in fractures of more than two parts, has been reported [7], along with a 54% nonunion rate and an 18% infection rate [16]. Several studies demonstrated rates of satisfactory outcomes ranging from 22% to 64% using different internal fixation techniques in the elderly [17–20], which is similar to our findings of high rates of nonunion and malunion (60%) in the non-BG group.

Intramedullary strut allograft augmentation of proximal humeral fractures in the elderly offers better outcomes in several ways. It assists with cortical bone for better resistance against screw pullout, provides medial support, and reaches volumetric reduction. Hence this mechanism adds mechanical stability, gains stronger holding power between bone and traditional screw-plate devices, diminishes humeral head varus collapse, and lowers the incidence of malunion.

Varus collapse and deformity often develop after ORIF in proximal humeral fractures. In the current study, the mean loss of reduction in the neck-shaft angle was 5.85°, but that in the BG group was 2.43°, which was markedly lower than in the non-BG group (11.11°, $p < 0.001$). Overall, the mean humeral head height was 3.44 mm, while that in the BG group was 2.05 mm, much lower than that in the non-BG group (6.01 mm, $p < 0.001$; Table 2). Varus deformities from 2.2° to 36°, and collapses between 1.2 mm and 13.6 mm have been reported in the different methods of treatment of proximal humeral fractures [10,21]. Excellent results were achieved in our BG group. Therefore, intramedullary strut allograft augmentation could lower nonunion and malunion rates.

The total satisfactory rate was 72.2% (65 out of 90). The satisfactory rate in the BG group was 92.7% (51 out of 55), notably higher than 40.0% (14 out of 35) in the non-BG group. In addition, the satisfactory rate in the severe group was 83.0% (39 out of 47), higher than 60.5% (26 out of 43) in the minor group, which could be associated with the use of intramedullary strut allograft. More operations (87.2%, 41 out of 47) in the severe group used strut allograft but only 32.6% (14 out of 43) in the minor group had this adjunct procedure. Thus, it can be concluded intramedullary strut allograft application could improve the satisfactory rate.

The process of deciding how to deal with proximal humeral fractures is very complicated. There are several contributing factors, such as age, activity level, underlying disease, fracture type, bone quality, and implant characteristics. There is no absolute indication for surgery. The purpose of surgical intervention is to improve functional outcomes and daily activity, and reduce the risk of complications associated with conservative treatment, such as symptomatic nonunion or malunion. As a result, intramedullary strut allograft is strongly recommended if ORIF is indicated.

Prior studies considered that the diaphyseal cortex in the elderly is thin in comminuted fractures, with a high complication rate if treated with traditional plates [22]. A locking plate can be used in these patients, although the outcomes vary greatly. Also, several authors have recommended intramedullary strut allograft augmentation with locking plate fixation [9, 23–27]. Good outcomes have been achieved with intramedullary strut allograft augmentation in traditional plates, which could be advocated as another choice of treatment.

There are several limitations in the current study. First, this is a retrospective study that only evaluated radiological outcomes of surgery. The functional outcomes, such as the American Shoulder and Elbow Surgeons score was not included. Second, relevant patient data on lifestyle such as smoking, alcohol, premorbid activity level, and comorbidities that may influence bone healing, were not collected. Third, there may have been an intrarate reliability error when measuring the radiologic neck-shaft angle and humeral head height, although the mean of 3 measurements was used for analysis to minimize this problem. Finally, there are no standard selection procedures for choosing allograft origins, lengths, and diameters correlated with the size of the humeral canal, which may add variability to the outcome assessment.

5. Conclusions

Complications after treating proximal humeral fracture in the elderly are frequently encountered because of poor bone quality. When fixing the fracture with plates, adjuvant use of intramedullary strut allograft can significantly enhance the result and reduce the incidence of malunion, non-union, and varus collapse.

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