



Treatment of Osteopenic or Non-united Fractures of the Humerus with Structure Bone Allograft and Non-locking Plates

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Background: Treatment of osteopenic or non-united fractures of the humerus are difficult to achieve optimum mechanical stabilization before bone union. This report presents the clinical experience of structure bone allograft augmentation plus non-locking plates fixation for these complex fractures. **Patients and methods:** Twenty-four patients with osteopenic or non-united fractures of the humerus (thirteen proximal humerus and eleven humeral shaft fractures) were selected and treated with structure bone allograft augmentation and non-locking internal fixation. All patients were followed and evaluated using shoulder-joint range of motion, the American Shoulder and Elbow Surgeons (ASES) scale and radiographic examination for fracture union assessment. **Results:** The mean duration of follow-up was 45.3 months. The average time from surgery to the date of radiographic union was 3.6 months (range, 2.5–4.5 months). Twenty-three patients showed radiographically bony union. The total union rate was 95.8%. The average injured shoulder forward flexion was 120 degrees, the external rotation averaged 42 degrees and the internal rotation averaged to the 12th thoracic vertebra. The ASES score improved from an average of 37 preoperatively to 85 postoperatively. One patient had the complication of persistent non-union and loss of reduction. **Conclusions:** Structure bone allograft can be used as a strong adjuvant mechanical support for internal fixation for the weakened osteopenic humeral fractures. Through rigid fixation and good stabilization, this method can provide an effective treatment for the management of severely osteopenic or non-united fractures of the humerus.

Key words: proximal humerus, humeral shaft, fracture, osteopenic, non-union, structure bone allograft

INTRODUCTION

Osteopenic or non-united fractures of the humerus are usually difficult to treat. Optimum mechanical stabilization is important when treating these complex fractures. Loss of screw purchase is an important factor related to the failure of fixation. Inadequate screw purchase into the osteopenic cortices can result in poor fracture stabilization, mechanical failure and non-union.¹⁻⁵ To increase bone healing rate, rigid fracture stabilization must be achieved via firm bone contact and compression of the bone ends.^{3,5,6} We used a structure bone allograft to achieve rigid screw fixation with plate and to provide

improved stability to the fracture site. The use of structure bone allografts has been reported in the management of non-union or complex fractures of the humeral shaft; however, very few studies have reported their application to fractures of the proximal humerus in patients with osteoporosis.^{2-5,7} The goal of our study was to determine the clinical and radiographic outcomes of the surgical treatment of osteopenic or non-united fractures of the proximal humerus or humeral shaft after surgical treatment with non-locking plate and structure bone allograft augmentation.

PATIENTS AND METHODS

Between 2004 and 2010, 24 old age patients with osteopenic or non-united fractures of the humerus were treated using this technique. In our inclusion criteria, the patients were divided into 3 groups: group 1- osteopenic proximal humeral fracture; group 2- osteopenic proximal humeral fracture with nonunion; group 3- osteopenic humeral shaft fracture with nonunion. (Table 1) None of the patients enrolled in our study had open fractures

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Table 1 Summary of 24 patients of osteopenic or nonunited fractures of proximal humerus/humeral shaft treated with structure bone allograft and plate fixation

Group	Patient No.	Gender/ Age (yrs)	Side	Event	Fracture site	Neer classification	Previous treatment	Duration of nonunion (months)	Plate	Allograft strut (Type, length, location)	Bone graft / Substitutes	Union	Healing time (weeks)	Complication
1	1	F/86	R	Fall	Proximal humerus	2-part	None	NA	Buttress plate	Humeral, 7cm, endosteal	NA	NA	NA	Nonunion with loss of reduction
	2	F/83	L	Fall	Proximal humerus	2-part	None	NA	Buttress plate	Humeral, 7cm, endosteal	NA	Yes	15	None
	3	M/78	R	MVA	Proximal humerus	2-part	None	NA	Buttress plate	Fibula, 8cm, endosteal	NA	Yes	15	None
	4	F/70	L	Fall	Proximal humerus	3-part	None	NA	Buttress plate	Humeral, 7cm, endosteal	NA	Yes	16	None
	5	F/82	R	Fall	Proximal humerus	2-part	None	NA	Buttress plate	Fibula, 7cm, endosteal	NA	Yes	13	None
	6	F/71	R	MVA	Proximal humerus	2-part	None	NA	Buttress plate	Fibula, 7cm, endosteal	NA	Yes	12	None
	7	F/76	L	Fall	Proximal humerus	2-part	None	NA	Buttress plate	Humeral, 6cm, endosteal	NA	Yes	10	None
	8	M/78	R	Fall	Proximal humerus	3-part	None	NA	Buttress plate	Humeral, 7cm, endosteal	NA	Yes	14	None
	9	M/76	L	Fall	Proximal humerus	2-part	None	NA	Buttress plate	Humeral, 6cm, endosteal	NA	Yes	15	None
2	10	F/82	R	Fall	Proximal humerus	2-part	Sling	10	Buttress plate	Humeral, 6cm, endosteal	Autogenous iliac crest bone graft	Yes	14	None
	11	M/79	L	Fall	Proximal humerus	2-part	Sling	7	Buttress plate	Humeral, 8cm, endosteal	Autogenous iliac crest bone graft	Yes	14	None
	12	M/75	R	Fall	Proximal humerus	2-part	Sling	9	Buttress plate	Humeral, 6cm, endosteal	Autogenous iliac crest bone graft	Yes	14	None
	13	F/81	R	Fall	Proximal humerus	2-part	Sling	10	Buttress plate	Humeral, 6cm, endosteal	Autogenous iliac crest bone graft	Yes	15	None
3	14	M/85	L	Fall	Humeral shaft	NA	Brace	9	Dynamic compression plate	Humeral, 12cm, endosteal	Autogenous iliac crest bone graft	Yes	13	None
	15	F/87	L	Fall	Humeral shaft	NA	Brace	6	Dynamic compression plate	Humeral, 12cm, endosteal	Autogenous iliac crest bone graft	Yes	16	None
	16	M/80	R	MVA	Humeral shaft	NA	Brace	8	Dynamic compression plate	Humeral, 12cm, onlay	Autogenous iliac crest bone graft	Yes	16	None
	17	F/84	R	Fall	Humeral shaft	NA	ORIF (plate)	12	Dynamic compression plate	Humeral, 13cm, onlay	Autogenous iliac crest bone graft	Yes	14	None
	18	M/87	L	Fall	Humeral shaft	NA	Brace	9	Dynamic compression plate	Humeral, 12cm, endosteal	Autogenous iliac crest bone graft	Yes	13	None
	19	F/68	R	MVA	Humeral shaft	NA	ORIF (plate)	13	Dynamic compression plate	Humeral, 12cm, endosteal	Autogenous iliac crest bone graft	Yes	14	Transient radial nerve neuropathy
	20	F/83	L	Fall	Humeral shaft	NA	Brace	6	Dynamic compression plate	Humeral, 12cm, onlay	Autogenous iliac crest bone graft	Yes	18	None
	21	F/80	R	Fall	Humeral shaft	NA	ORIF (plate)	12	Dynamic compression plate	Humeral, 12cm, onlay	Autogenous iliac crest bone graft	Yes	14	None
	22	M/78	L	MVA	Humeral shaft	NA	ORIF (plate)	10	Dynamic compression plate	Humeral, 11cm, endosteal	Autogenous iliac crest bone graft	Yes	14	None
	23	M/82	R	MVA	Humeral shaft	NA	Brace	9	Dynamic compression plate	Humeral, 12cm, onlay	Autogenous iliac crest bone graft	Yes	16	None
	24	F/86	L	Fall	Humeral shaft	NA	Brace	8	Dynamic compression plate	Humeral, 12cm, onlay	Autogenous iliac crest bone graft	Yes	14	None

Group 1: osteopenic proximal humeral fracture; Group 2: osteopenic proximal humeral fracture with nonunion; Group 3: osteopenic humeral shaft fracture with non-union
M, male; F, female; L, left; R, right; MVA, motor vehicle accident; NA, not applicable

Table 2 Brief summary of basic data and postoperative results in three fracture groups

Group	Patient numbers	Mean age	Nonunion duration (months)	Allobone (numbers/location)	Healing (weeks)	Forward flexion / External rotation (degrees)	Union rate	Complication case
Osteopenic proximal humeral fracture	9	78	NA	9/ endosteal	13.7	118/42	8/9	1 patient with nonunion and loss of reduction
Osteopenic proximal humeral fracture with nonunion	4	79	9	4/ endosteal	14.25	115/39	4/4	None
Osteopenic humeral shaft fracture with nonunion	11	82	9.3	5/endosteal 6/onlay	14.7	127/45	11/11	1 patient with transient radial nerve neuropathy

or pathologic fractures. Fourteen females and ten males were included, with a mean age of 79.9 years (range, 68–87 years). Eighteen patients sustained fractures after falling down and six patients had fractures caused by motor vehicle accidents. Thirteen fractures were on the right side and eleven fractures were on the left side. Fifteen non-united fractures in the proximal humerus or humeral shaft were included (average duration of non-union, 9.2 months). Initially, four patients were treated with a sling and seven were treated with a functional brace. Four individuals had prior surgical intervention with failed internal fixation and non-union. The initial plain radiographs revealed severe osteopenia in nine patients and osteopenia with non-union in fifteen patients.

All patients were treated with endosteal or onlay structure bone allografts fixed with buttress or dynamic compression plates. Buttress plates were used in proximal humerus fracture, and the dynamic compression plates were used in humeral shaft fractures. Proximal humerus fracture were all fixed with endosteal structure bone allografts; and humeral shaft fracture were treated with endosteal or onlay allgraft, depending on the bone defect over the fracture sites. The grafts length was chosen mildly less than the length of fixation plate to avoid stress fracture at the site where plate and grafts ended, and to avoid extensively soft tissue striping during grafts implantation.

Postoperative management included sling support and pendulum exercise combined with gentle movement of the shoulder and elbow for the first 6 weeks. More intensive physical therapy depended on the later clinical and radiographic follow-up. All patients were followed up clinically and radiologically at 2 weeks, 6

weeks, 3 months and every 6 months interval thereafter. The radiographic bony union was defined as evidence in radiographs of bone formation, with bone trabeculae bridging across the fracture site. The shoulder functions were evaluated using the American Shoulder and Elbow Surgeons (ASES) scales preoperatively and at the 3-5 year follow-up.⁸ All patients received clinical and radiographic follow-up until fracture union or until reoperation.

RESULTS

The mean duration of follow-up was 45.3 months (range, 29-62 months). The average time from surgery to the date of radiographic union was 3.6 months (range, 2.5-4.5 months). No patients were lost during follow-up. The total union rate was 95.8%. The follow-up radiograph revealed the progressive incorporation of the allografts into the proximal humerus or humeral shaft, with obscure cortical edges for the grafts, at around 3-5 months postoperatively.

Functional outcome was measured using shoulder-joint range of motion and the ASES scale. Shoulder motion measurements were obtained at the postoperative clinical follow-up visit (2 weeks, 6 weeks, 3 months and every 6 months thereafter). The average forward flexion was 120 degrees (range, 50-180 degrees), the external rotation averaged 42 degrees (range, 15-70 degrees) and the internal rotation averaged to the 12th thoracic vertebra. The ASES score improved from an average of 37 preoperatively to 85 postoperatively. Patients with fracture union were all satisfied with the final outcome. Briefly summary of the basic data and post-operative results in 3

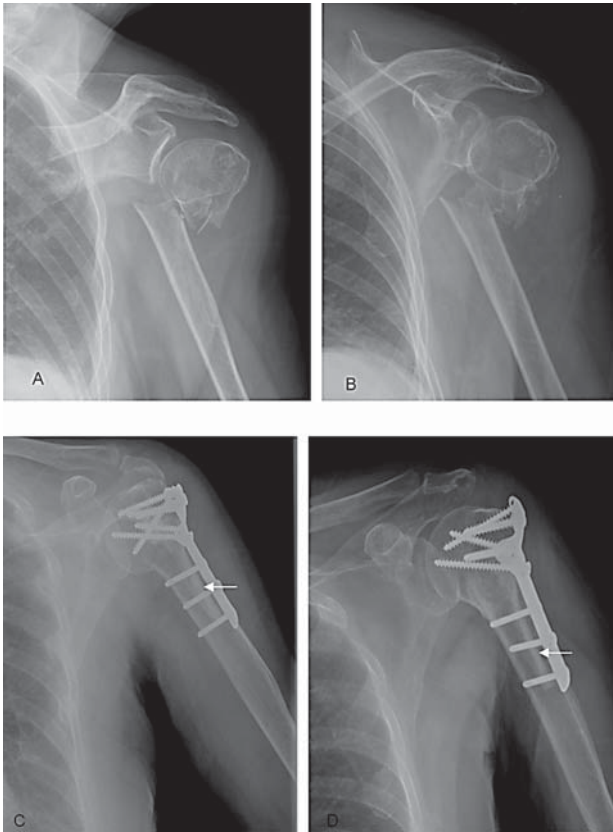


Fig. 1 An 85-year-old female with fracture of the proximal humerus with angulation (a and b) classified in group 1 treatment with endosteal strut bone graft and buttress plate, bone union 15 weeks post operatively (c and d).

different fracture groups were described in table 2. And the image results in these 3 groups were demonstrated separately in figure 1-3.

In group 1, there was one failure associated with loss of reduction and non-union at the 5-month postoperative follow-up. (Fig. 4) Severe osteoporosis was noted in the subsequent radiographs. This patient received further management with shoulder hemiarthroplasty due to persisted nonunion of proximal humerus fracture. No complication was noted in group 2. In group 3, one patient presented with transient radial nerve neuropathy after surgery, which was caused by iatrogenic injury while performing non-union site exposure. The symptom improved 6 months after the operation, with complete nerve function recovery 1 year after the operation. No further operation was performed. There were no postoperative infections, malunions or allograft fractures noted in these 3 groups.

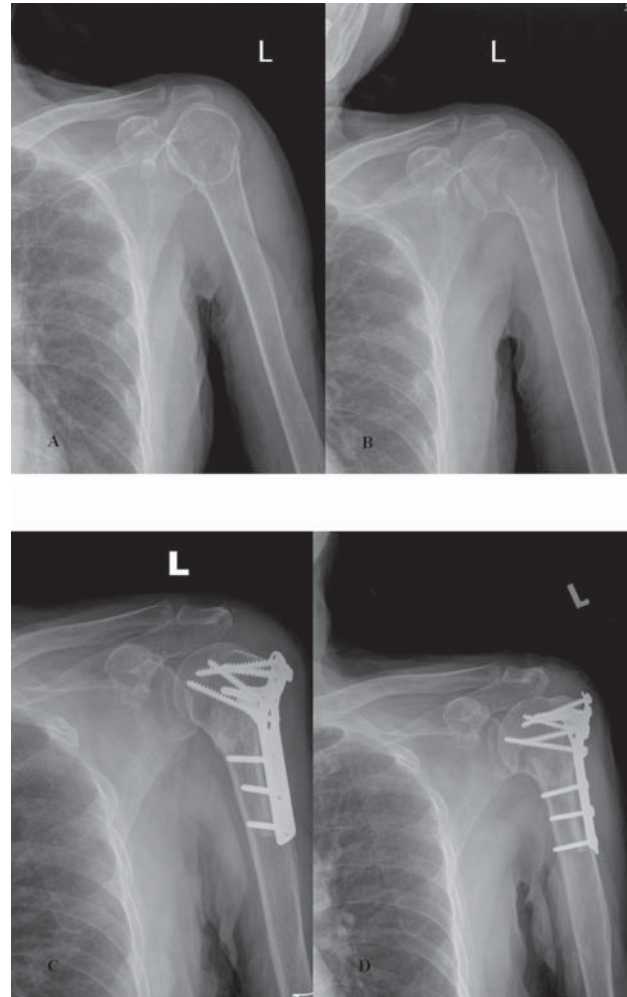


Fig. 2 A 79-year-old female with fracture of proximal humerus (a) after falling down injury was found fracture site displaced (b) during follow-up (classified in group 2). Endosteal strut bone graft and buttress plate was applied with good bony union after 14 weeks follow-up.

DISCUSSION

Patients with osteopenia or non-union of the humeral shaft and proximal humerus are difficult to treat, as they may be at a greater risk for insecure plate fixation because of systemic osteoporosis or local disused osteoporosis with bone loss.^{7,9-10} The main concern with plate fixation is poor screw purchase or loosening in these osteopenic-related fractures.^{3,11} Inadequate screw purchase may result in mechanically unstable fracture fixation, fixation failure and fracture non-union.^{5,12-16}

Reduction and fixation must be stable enough to

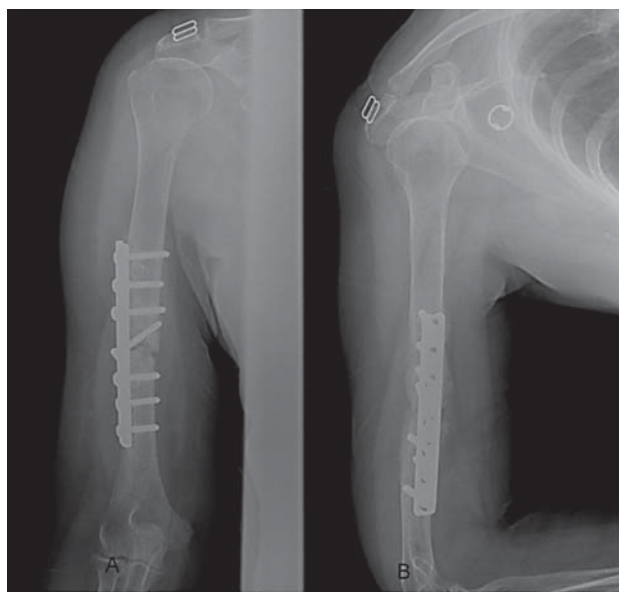


Fig. 3 The radiograph showing fracture of the humeral shaft treated with dynamic plate fixation with persistent atrophic non-union in an 80-year-old female (classified in group 3) (a and b). Onlay structure bone allograft and a dynamic compression plate were applied for rigid stabilisation; good bony healing was achieved (arrow), with maintenance of reduction after 14 weeks of follow-up (c). Allograft bone struts were incorporated with a humeral shaft after 12 months of follow-up (d).

achieve early shoulder motion and a good functional outcome. Many single fixation methods, such as either using a dynamic compression plate or locking plate technology for fractures of the proximal humerus, are

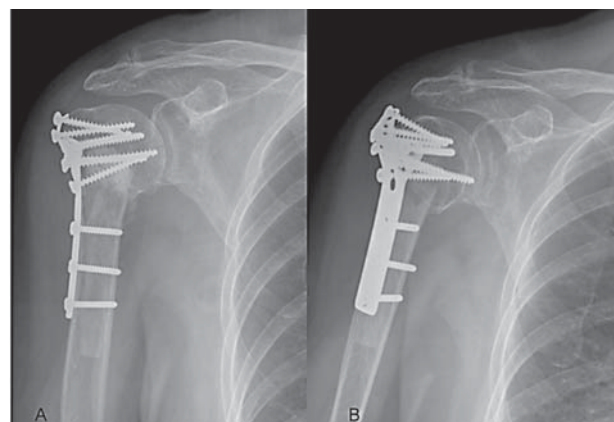


Fig. 4 The initial postoperative radiograph showed acceptable alignment after fixation with endosteal allograft bone struts and a buttress plate (a). Radiograph at 4 months postoperative showed a failure of fixation with collapse of fracture site, resulting in varus deformity (b).

not always successful for these osteopenic or non-union fractures.^{17,18} The success of traditional plates and screws applied for the treatment of proximal humerus and humeral shaft fractures depends on the friction between the plate and the bone. However, in osteopenic bone, this construct is prone to failure because of poor mechanical bone strength, bone resorption underneath the plate and high rotational forces. In addition, the screws may not achieve sufficient purchase in the osteopenic bone.

Evidence from recent studies shows that locking plates placed from the lateral position for fixation may also not prevent loss of reduction reliably. Bjorkenheim et al. reported a review of 72 patients treated with locking plates for a proximal humeral fracture and revealed that 26% of them healed with a varus deformity and found an incidence of 11% loss of fixation.¹⁹ Fragen et al. reported 166 patients with proximal humeral fractures treated with locking plates and revealed a failure rate of the locking screw construct of 22%.²⁰ Agudelo et al. found a 13.7% loss of fixation in 153 patients treated with locking plates.²¹

Structure bone allografts have been used as a successful treatment option for periprosthetic femoral fractures.²²⁻²⁷ They act as biological plates combined with internal fixation devices to stabilise the fractures. Structure bone allograft may also be incorporated to increase the bone stock of the fracture sites.^{5,25,28-32} Their use has also been described in the case of humeral periprosthetic fractures, hip revisions and femoral/humeral complex

non-unions.^{2,3,5,7,27,33,34} Several studies used structure bone allograft to treat osteopenic humeral shaft non-union. Hornicek *et al.* presented 10 humeral shaft non-unions treated with compression plates and structure bone allografts.² Their results showed a union rate of 100%. Nine cases revealed bony union at 3 months post-operatively and one exception achieved bone union at 6 months after surgery. Van Houwelingen *et al.* treated six patients with non-union of the humeral shaft with compression plates, structure bone allografts and autogenous bone grafting.⁵ All fracture bone unions were achieved at an average of 3.4 months after operation.

Very few studies have reported on the usage of structure bone allograft for the treatment of osteopenic proximal humeral fractures. Gardner *et al.* treated seven cases with proximal humerus fracture using allografts and locking plates and achieved excellent results, with a union rate of 100%.¹⁷ Badman *et al.* treated 18 cases of proximal humeral non-unions using locking plates and structure bone allografts.¹ There was one loss of fixation. Seventeen patients achieved bony union, with an average bone union time of 5.4 months. Their results showed a union rate of 94%. These studies all showed that structure bone allograft provide added bone stock to enhance fixation and improve bony union.

Despite their similarities, there remain some differences between our study and previous studies. We used non-locking plate fixation in conjunction with structure bone allograft for the management of these fractures. In this study, 24 patients (thirteen proximal humerus and eleven humeral shaft fractures) were treated with endosteal or onlay structure bone allograft and non-locking plate fixation. Twenty-three patients exhibited good bony union; however, one patient showed persistent non-union and loss of reduction during follow-up. The cause of the loss of reduction may have been an operative technique error due to the short length of the allograft inserted into the proximal part of the fracture site, which resulted in inadequate mechanical support and unstable fixation of the proximal fragment, and finally led to the failure of fixation (Fig. 4).

The general results of our study was a union rate of 95.8%. Structure bone allografts may be used as strong biological plates in combination with internal fixation devices to stabilise these osteopenic fractures. They provided adequate mechanical stability, enhanced fracture healing and increased bone stock. These results provided an effective treatment for the management of osteopenic and non-union fractures of the proximal humerus and humeral shaft.

The major drawbacks of the use of structure bone allografts are limited supply in our country, the need for substantially greater soft-tissue stripping, disease transmission and risk of infection. The greater soft-tissue stripping may disrupt the surrounding blood supply to the fracture fragments and interfere with the biological aspects of healing; however, clinically, this approach did not show a significant impact on bony union.^{2,4,7} Except its potential drawback of infection, the intraoperative risk factors, such as more extensive soft-tissue dissection, increased blood loss and prolonged operation time, should also be taken into consideration.

CONCLUSION

The management of fractures of the proximal humerus and humeral shaft nonunion has shown persistent evolution. The development of locking plates provided more stable fixation for these fractures. However, recent studies showed that the use of locking plates or other internal fixators alone might also not provide adequate stability for severe osteopenic and non-union fractures. The combination of internal fixators with structure bone allograft can provide a cheaper and alternative treatment to stabilize osteopenic and non-union fracture sites via a very secure fixation in our country. The rigid stabilization allows reliable bony union of the fracture site with early return to function.

DISCLOSURE

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