Preventing Varus Deformity in Senile Patients with Proximal Humerus Fractures and Poor Medial Support

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Background: We investigated the effectiveness of fibular strut allograft augmentation of proximal humerus fractures to prevent varus deformity in patients over the age of 65 years with insufficient medial support.
Methods: We analyzed the clinical and radiological outcomes of locking plate fixation with adjunct fibular strut allograft augmentation in 21 patients with proximal humeral fractures. The inclusion criteria were age (65-year-old or older); presence of severe medial comminution; inadequate medial support; and those who could participate in at least a one year follow-up. The average age was 76.4 years. We analyzed each patient's Constant score, our indicator of clinical outcome. As radiological parameters, we analyzed time-to-bone union; restoration of the medial hinge; difference between the immediately postoperative and the last follow-up humeral neck-shaft angles;; and anatomical reduction status, which was assessed using the Paavolainen method.
Results: A successful bone union was achieved in all patients at an average of 11.4 weeks. We found that the average Constant score was 74.2, showing a satisfactory outcome. The average difference in the humeral neck-shaft angles between the immediately postoperative time-point and at the final follow-up was 3.09°. According to the Paavolainen method, the anatomical reduction was rated excellent. The medial hinge was restored in 14 of 21 patients. Although we did not find evidence for osteonecrosis, we found that a single patient had a postoperative complication of screw cut-out.
Conclusions: Fibular strut allografting as an adjunct treatment of proximal humeral fractures may reduce varus deformity in patients with severe medial comminution.
(Clin Shoulder Elbow 2016;19(4):216-222)

Key Words: Proximal humerus fractures; Fibular strut allograft; Open plate fixation

Introduction

Proximal humeral fractures are one of the most common fractures amongst the elderly population. With an increasingly aging population worldwide, the prevalence of proximal humeral fractures is likewise increasing.[1] Owsley and Gorczyca[2] reported that around 36% of elderly patients who undergo plate fixation for proximal humeral fractures are associated with radiologically-determined postoperative complications. They reported that these complications were especially common in combination with 3- or 4-part proximal humeral fractures in over 60-year-old.

Since most elderly patients have poor bone quality, this predisposes them to combined comminuted fractures of the medial cortex and subsequent loss in medial support, leading them to having a higher risk of postoperative complications such as varus deformity.[3,4] In such patients, surgical interventions such as fibular strut allograft has been used.[5] In this study, we investigated the effectiveness of fibular strut augmentation as an adjunct to plating in elderly patients with proximal humeral fractures and insufficient medial support.

Methods

Subjects of Study

Between August 2010 and December 2014, we recruited patients aged 65 or over with proximal humeral fractures who for the reason of insufficient medial support had received fibular strut allograft augmentation as an adjunct to locking plate fixation. Of the total of 23 patients who fulfilled these criteria, we enrolled 21 patients who were able to participate in at least a 1-year follow-up. The average age of the patients was 76.4 years (range, 65–90 years) and the study population composed of 2 male and 19 female patients. The average follow-up period was 13.1 months (range, 12–18 months). Using dual energy X-ray absorptiometry, we measured the bone density of the patients' fractures and the spine, which according to the Lowest T-score showed an average of bone mineral density -2.9. According to the Neer classification system, we found that 16 patients had 2-part fractures and 5 patients with 3-part fractures. According to the AO classification system, we found that 7 patients had A2 fractures; 6 patients had A3 fractures; 7 patients, B2 fractures; and 1 patient, a B3 fracture.

We measured each patient's Constant score as our assessment of postoperative clinical outcome. And our radiological parameters were measured at five follow-up time-points: 1-, 2-, 4-, 8-, and 12-week postoperatively. We defined a successful bone union as when the fracture site was completely adjoined through callus formation, and humeral neck-shaft angles were measured according to the Paavolainen method[6] at the anteroposterior plane. We defined the humeral neck-shaft angle as the angle that forms when the angle between the line that is perpendicular to the articular surface of the fracture and the line following the humeral shaft is bisected. The humeral neck-shaft angle
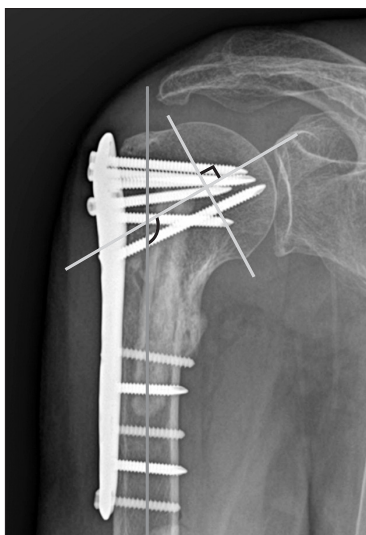

Fig. 1. Neck-shaft angle measured using the Paavolainen method.

was measured preoperatively and at the final follow-up (Fig. 1). We assessed restoration of the medial hinge according to how well the inferiomedial humeral head had been anatomically reduced,[7] and we made a comparative analysis of the clinical outcomes according to the restoration status of the medial hinge and to the humeral neck-shaft angle difference. And we also analyzed time-to-bone union and the presence of postoperative complications radiological (Table 1).

We used SPSS Statistics ver. 17.0 (SPSS Inc., Chicago, IL, USA) to perform all statistical analyses. And the nonparametric Mann-Whitney U-test was used to analyze the data. The significance threshold was set at 0.05.

Surgical Method

Elderly patients aged over 65 years with severe medial comminution and with a medial metaphyseal distance of less than 2 mm were defined as having insufficient medial support (Fig. 2, 3). We used pre-freeze–dried fibular strut allografts 6 to 8 cm in size for the adjunct augmentation. If the strut allograft was too large to be inserted into the intramedullary space, we discarded around a third of the allograft; rather than removing the allograft surface that would form an interface with the proximal humerus, we made an oblique osteotomy of the strut so that it will provide a more stable support once it is impacted into the humeral head (Fig. 4).

In all steps, we attempted to minimize vascular injury in the medial region of the fracture. We pressed the fibular strut allograft, which we extracted from a site near the fracture, into the distal intramedullary region, after which we used a hemostat or a small bone clamp to push the allograft towards the proximal fracture site as much as possible. We used a C-arm to assess whether varus deformity was satisfactorily restored and whether the fibular strut allograft made sufficient contact the fracture surface; then, the allograft was fixed temporarily using a K-wire. We positioned the plate (proximal humerus internal locking system, PHILOS; Synthes, West Chester, PA, USA) 5 to 8 mm inferior to the tip of the greater tuberosity and at the lateral greater tuberosity. In cases where varus adjustment was not enough, we used a bone clamp and mallet to displace the allograft superiorly, re-attempting a varus adjustment. The proximal screw was fixed before the distal screw (Fig. 5).

The patients were administered an immobilizing abduction brace for four postoperative weeks. They were permitted continuous passive motion from the 3rd postoperative day; passive motion within each patient's capacity from the 3rd postoperative week; and active range of motion through the full extent from the 6th postoperative week.

Results

We achieved a successful bone union in all patients, and

Table 1. Demographic Data of Patients

Patient No.	Sex	Age (yr)	Cause	F/U (mo)	AO type	Neer class	BMD (T-score)	Union (wk)	Pre NSA (°)	Post NSA (°)	Last NSA (°)	Hinge restoration	Foreward elevation (°)	Abduction (°)	External rotation (°)	Internal rotation (°)	Constant score
1	F	82	TA	12	B2	3	-2.5	12	122	135	135	O	100	100	60	T12	70
2	F	85	TA	13	A2	2	-3.9	12	92	130	122	x	110	100	45	L2	60
3	F	82	SD	12	A2	2	-2.5	16	92	135	120	x	120	110	55	T7	64
4	F	90	SD	12	A3	2	-2.8	14	132	140	140	O	160	120	40	T9	86
5	F	78	SD	14	A2	2	-2.3	8	115	130	128	O	125	110	60	T12	77
6	F	77	SD	15	A2	2	-3.1	8	115	130	125	x	110	100	45	L2	70
7	F	76	SD	12	B2	3	-2.4	12	127	132	130	x	120	115	40	T7	74
8	M	68	TA	12	A3	2	-2.4	10	125	125	125	O	165	130	40	T9	84
9	F	65	TA	16	B2	2	-2.4	8	120	130	130	O	140	120	30	L4	80
10	F	68	SD	12	B3	2	-3.1	12	130	135	130	O	150	150	55	T7	86
11	M	73	SD	14	B2	3	-2.7	16	135	130	135	O	140	140	40	T9	81
12	F	75	SD	15	A3	2	-3.5	10	130	130	122	x	100	100	40	L2	62
13	F	82	SD	12	A2	2	-3	8	110	130	130	O	160	140	55	L4	88
14	F	85	SD	12	A2	2	-2.5	12	110	135	130	O	125	125	40	T7	70
15	F	83	SD	12	A3	2	-3.5	16	125	140	135	O	150	150	60	T9	78
16	F	83	SD	12	B2	3	-3.3	12	123	125	135	O	130	110	45	T12	74
17	F	72	TA	13	B2	3	-2.5	12	60	130	125	x	110	100	50	T9	60
18	F	70	SD	18	A2	2	-4.6	8	70	130	120	O	130	130	60	T7	78
19	F	74	SD	12	A3	2	-2.5	12	115	125	125	O	125	100	45	T9	74
20	F	68	SD	15	B2	2	-2.9	10	75	125	120	x	110	105	45	T9	62
21	F	75	SD	12	A3	2	-2.9	12	90	125	120	O	130	130	50	T12	80

F/U: follow-up, BMD: bone mineral density, NSA: neck-shaft angle, F: female, M: male, TA: out-car traffic accident, SD: slipdown.
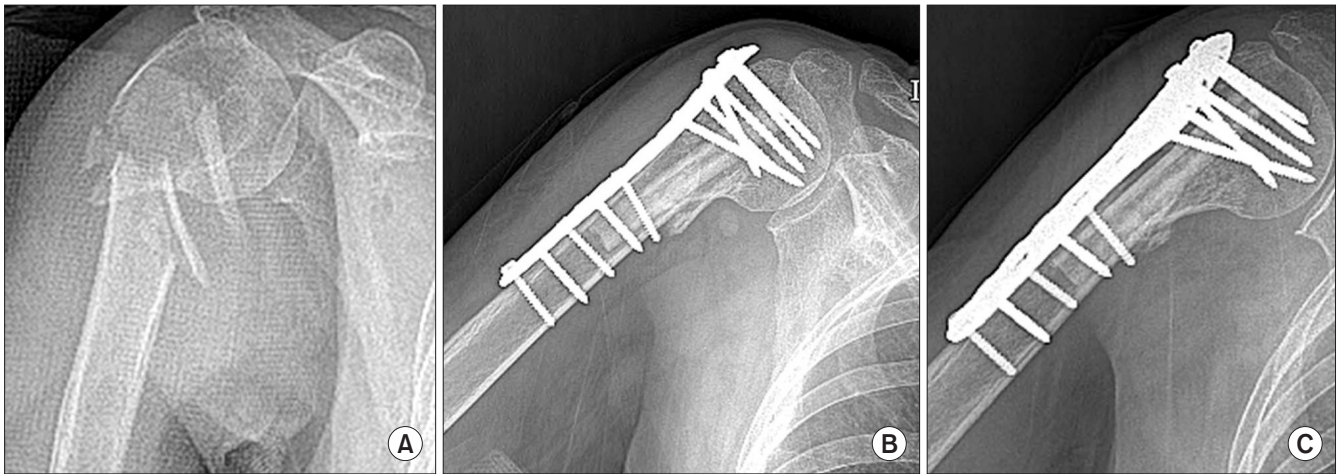
Fig. 2. Radiographs of an 80-year-old female patient treated with locking plate fixation using an anatomical plate and screws show varus angulation and comminution of the fracture fragments preoperatively (A), a successful clinical outcome postoperatively (B), and at the final follow-up (C).
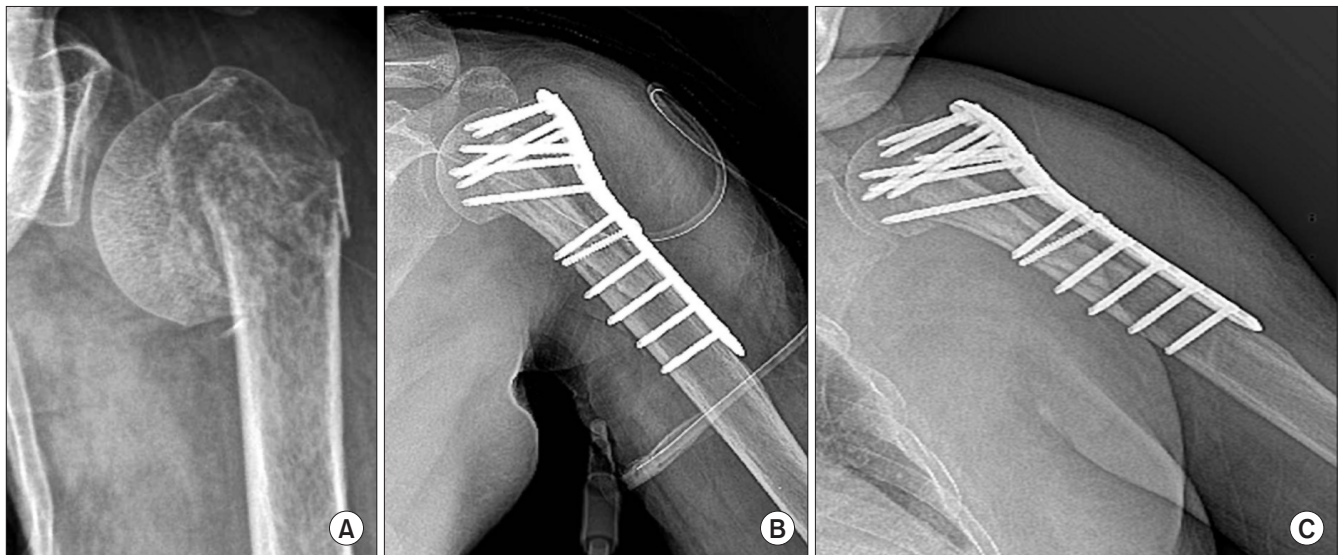

Fig. 3. Radiographs of a 76-year-old female patient after plate fixation using an anatomical plate and screw show angulation of the fractured fragments preoperatively (A), successful clinical outcomes postoperatively (B), and at the final follow-up (C).

the average time to bone union was 11.4 weeks (range, 8–16 weeks). Our indicator of clinical outcome, the Constant score was on average 74.2 points (range, 60–88 points) at the 1-year postoperative follow-up, showing a good clinical outcome associated with the fibular graft augmentation.

Anatomical reduction was carried out according to the Paavolainen method, and in all the final follow-up humeral neck-shaft angle was excellent (range, 120°–140°). The average preoperative humeral neck-shaft angle was 110.14° (range, 60°–135°), the average immediately postoperative humeral neck-shaft angle was 130.80° (range, 125°–140°); and the average final follow-up humeral neck-shaft angle was 127.71° (range, 120°–140°). Thus, we found that the difference between the immediately postoperative and the final follow-up values was 3.09°.

The average forward elevation, abduction, external rotation, and internal rotation was 129.04°, 118.33°, 38.33°, and T10–T11, respectively.

After treatment, we found that 14 of 21 patients (66.7%) had a successful medial hinge restoration. Those with medial hinge restoration showed an average Constant score of 79 points, and those without had a significantly lower Constant score of 64.57 points ($p=0.000$). Preoperatively, we found that the patients in the successful medial hinge restoration group had had a lower average preoperative humeral neck-shaft angle (115.85°), and thus a less severe varus deformity, than patients whose medial hinge did not restore (98.71°). Yet this difference was not statistically significant ($p=0.224$). However, we observed a statistically significant difference at the final follow-up with respect to the av-

erage humeral neck-shaft angle: the patients in the former group had a significantly higher average humeral neck-shaft angle than those of the latter group (129.86° vs. 123.43°; *p*=0.025). For the range of motion, patients with successful medial hinge restoration showed postoperative abduction, external rotation, and internal rotation of 137.86°, 125.35°, and 49.64°, respectively. The respective values for patients without successful medial restoration were 111.42°, 104.28°, and 45.71°, respectively; the two groups significantly differed in terms of only abduction and external rotation (Table 2). We found that the type of fracture did not influence the success and failure of medial hinge restoration.

In terms the postoperative complications, we did not observe any medial support loss, fibular fractures, or severe varus deformity, resulting from unsuccessful plating. Nor did we observe any incidents of osteonecrosis. Even though one patient pre-sented with a screw cutout because a successful bone union was apparent we kept a vigilant eye throughout the follow-up: the patient later presented with a satisfactory Constant score of 60 points.

Discussion

Proximal humeral fractures compose 10% of all fractures amongst elderly patients over 60 years, and with an aging population its prevalence is increasing.[1] Various treatment methods exist for proximal humeral fractures such as suture fixation, percutaneous K-wire fixation, plate fixation, intramedullary nailing, and arthroplasty. But for elderly patients who commonly have concomitant osteoporosis it is difficult to attain a satisfactory fixation on account of their poor bone quality, meaning that the
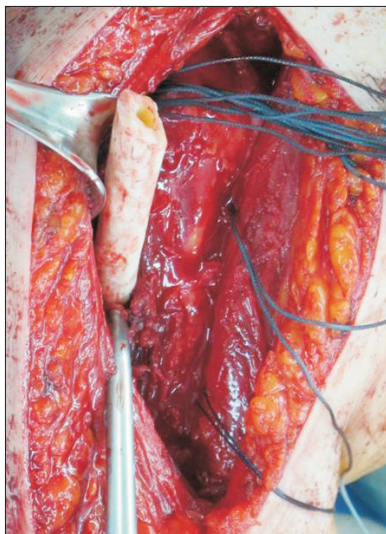

Fig. 4. Oblique cut-out of a fibular strut allograft.

Table 2. Results of the Medial Hinge Restoration*

Variable	Medial hinge restoration (+)	Medial hinge restoration (-)	*p*-value
Age (yr)	76.85	76.42	0.971
BMD (T-score)	-2.89	-2.97	0.636
Union (wk)	11.43	11.42	0.971
Pre NSA (°)	115.85	98.71	0.224
Post NSA (°)	131.07	130.29	0.931
Last NSA (°)	129.86	123.43	0.025
Forward elevation (°)	137.86	111.42	0.001
Abduction (°)	125.35	104.28	0.006
External rotation (°)	49.64	45.71	0.535
Internal rotation	T10–T11	T10–T11	0.971
Constant score	79	64.57	0.000

BMD: bone mineral density, NSA: neck-shaft angle.
*Mann-Whitney U-test.

Fig. 5. Image intensification shows the anatomical reduction of the proximal humerus fracture (A); the inserted fibular allograft (B); and the anatomical plate fixated using a screw (C).

gold standard of treatment is yet to exist for these subset of patients.[8]

Solberg et al.[9] suggested that in patients older than 55 years the presence or absence of early varus deformity and the length of the fracture at the medial metaphyseal region are important factors concerning treatment prognosis. Thus, we followed the method of intramedullary fibular allograft augmentation proposed by Gardner et al.[10] in elderly patients with a distance between the medial comminution fracture and the medial interosseous fragment of less than 2 mm, because we thought that this may prevent re-establishment of medial support.

In a human cadaver study where the outcomes after locking plates and intramedullary fibular allografting were compared to outcomes after locking plates alone, it was found that employing an additional adjunct treatment provided stronger fixation.[11,12] Hettrich et al.[13] looked at the clinical outcomes after fibular allograft and locking plate in patients over 70 year olds with proximal humeral and concomitant medial comminution fractures. They found that the difference between the intraoperative and the final follow-up humeral neck-shaft angles was only 2.2° (135.4° vs. 133.2°), showing good clinical outcomes. This humeral neck-shaft angle difference in our study was 3.09°. This comes to show that even with the addition of fibular strut grafts a stable fracture reduction that is maintained through to the final follow-up via medial support can be attained whilst preserving the proximal humerus length.

In their comparative study, Gardner et al.[4] found that, after treatment of proximal humeral fractures, patients with medial support showed an average 1.2-mm loss in humeral length, whereas those without medial support, a 5.8-mm loss. We found that the 14 patients who showed successful medial hinge restoration showed satisfactory clinical outcomes, and their humeral neck-shaft angles at the final follow-up were significantly better than the other 7 patients whose medial hinge did not restore. In the latter cases, we observed that varus deformity began within 2 and 4 weeks of the treatment. It seems that those who have severe varus deformity preoperatively have less change of anticipating a successful medial hinge restoration. However, further studies are required to confirm this association between preoperative varus deformity and treatment outcome. Still, our results suggest that fibular allograft augmentation does not always guarantee a successful medial hinge restoration and other steps must be carried out to ascertain as much medial support as possible, thereby ensuring a more favorable prognosis postoperatively.

Likewise, Neviaser et al.[14] have reported good clinical outcomes after fibular grafting, generally using 6- to 8-cm fibula allografts. They suggested that with fibular graft augmentation it was vital to form a natural medial arch and that a sturdy fixation can be attained by tailoring the placement of graft to each fracture. They also used temporary K-wire fixation to adjust

the fibular allograft if necessary. Using cadaveric specimens, Chow et al.[15] used 8-cm long allografts from the fibular shaft cut into around 5-cm constructs, which were fixated onto the distal fracture site. We also chose to use 8-cm fibular allografts, which were inserted in a manner that provides the most medial support and then were temporarily fixed. Then, the plate was permanently fixed on the lateral humerus, the distal end of which was also temporarily stabilized beforehand, with screws on the proximal and distal ends. Saltzman et al.[16] used a saw and burr to shape the fibular allograft so it fits the intramedullary area, whereas Matassi et al.[17] stabilized the graft with screws after medially impacting the graft first during fibular insertion. For the authors, in incidences where the intramedullary area of the distal humerus could not accommodate the fibular graft, we ostetomized the bone obliquely to the width; the oblique cut was made so that the fibular graft and proximal surface area of contact could be maximized.

The prevalence of osteonecrosis in patients with proximal humeral fractures has been reported to range from 2.2% to 8%.[18,19] In their study, Neviaser et al.[14] reported that none of the 36 patients who were treated with fibular grafts presented with complete osteonecrosis. They proposed that by carrying out a fibular graft transfer, they were able to prevent reduction loss and, thus, osteonecrosis, notwithstanding the poor bone quality and the medial comminution by structurally enhancing the biomechanics of the humerus. Although our study requires greater statistical power to conclude for certain that the prevalence of osteonecrosis was decreased as a result the treatment, several pre-existing reports have already shown that the prevalence of osteonecrosis after fibular graft augmentation is low.[16]

One of the study's limitations is that, as a retrospective study, the findings may have been influenced by selection bias. Although we did not see a difference with respect to the distribution of Neer classification of the medial comminution fractures, since we did not make an analysis of the severity of fractures among patients, we may have included in our fibular allograft augmentation group those whose fractures are not severe enough to justify them having received this treatment. Thus, a prospective analysis may be required to assess the long-term outcomes of the intervention. Second, the total number of cases numbered only 21; therefore, it is difficult to anticipate a statistically significant difference based on whether a medial hinge restoration has been achieved. Third, because the study design consisted of a relatively short follow-up, the manifestation of long-term complications, such as osteonecrosis, later on cannot be out-ruled. Lastly, the study requires a more detailed analysis of why the medial hinge could not be restored in some patients. Still, in spite of the small study population and these limitations, compared to other studies that have reported the outcomes of fibular strut allografts, ours is notable in that we were able to achieve good clinical outcomes, especially given that our study

population consisted of only elderly patients.

Conclusion

In sum, in case of insufficient medial support amongst elderly patients with proximal humeral fractures, fibular strut graft augmentation as an adjunct to plate fixation may facilitate an anatomical reduction and reduce varus deformity.

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