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The elderly have similar outcomes compared to younger patients after ORIF with locking plate for comminuted proximal humerus fracture

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ABSTRACT

Objective: The aim of this study was to compare clinical and radiological outcomes of elder and younger patients with comminuted proximal humerus fracture treated with osteosynthesis with locking plate.
Methods: A total of 70 patients (30 males and 40 females; mean age 65.4 years) operated on for Neer 3- or 4-part proximal humeral fractures between 2010 and 2016 and followed for at least one-year were included in the study. The reduction was achieved through intraosseous window to minimize soft tissue stripping in all patients and structural allograft at metaphyseal diaphyseal junction was used aggressively to resist varus force. Group 1 consisted of 32 patients aged 70 or older (14 males and 18 females; mean age: 77.8 ± 5.1), while Group 2 consisted of 38 patients younger than 70 (16 males and 22 females; mean age: 58.2 ± 9.3). The groups were compared for their clinical and radiological outcomes.
Results: There was no significant difference in clinical outcomes by Oxford score (54.8 ± 2.7 vs 56.6 ± 3.4, $p = 0.13$) and ASES score (89.7 ± 5.7 vs 90.8 ± 8.2, $p = 0.68$). Two groups had similar radiological outcomes regarding neck shaft angle, greater tip height and offset. However, group 2 had better final shoulder forward elevation (162.6 ± 8.7 vs 135.4 ± 14.7ß, $p < 0.05$) and shorter duration to achieve maximal range of motion (4.37 ± 2.37 vs 8.14 ± 3.25 months, $p < 0.05$) than group 1. Two groups had similar complication rates (9.4% vs 7.9%). All the complications were related to greater tuberosity including mal-reduction and avulsion.
Conclusion: With the prerequisite of good alignment with robust medial cortical support and untouched soft tissue over medial metaphysis area via intra-osseous reduction, comminution of proximal humeral fracture can achieve satisfactory result and low complication rate by osteosynthesis with locking plate system, regardless of age. In addition, we suggested to use structural bone graft for comminuted medial cortex fracture with multiple fragments or bony defect more than 2 cm.
Level of evidence: Level III Therapeutic study.

Introduction

Along with increase of incidence and aging of the affected population, proximal humerus fractures have been gaining more attention and debates regarding the optimal treatment in the past decade.[1] Surgical results of various methods of osteosynthesis for Neer 3- or 4-part fractures, especially in elders, has been associated with high complications and poor function results. Suboptimal reduction, loss of fixation and avascular necrosis are the commoners.[2,3] Hemi-shoulder arthroplasty had been considered a preferred surgery than osteosynthesis for 3- or 4- parts fractures in elders for its predictable pain relief. However, due to commonly lacking of rotator cuff integrity, most patients were left with modest function and poor strength.[4] This preference was reversed since the introduction of locking plating systems. With current locking technology, the functional outcomes have been improved.[5–7] However, a notable number of complications are still reported, especially in elderly.[8–10] Avascular necrosis, varus malunion or cut-out of sharp screw tips with subsequent joint destruction had been reported as the leading causes of readmission and secondary operation.[9] Therefore, there were concerns exist

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regarding complications and functional results and we would like to identified the benefit of osteosynthesis with locking plate system for elder patients.

Nonetheless, most of the reported complications with locking plate system were related to surgical technique and inadequate bony support, which could be prevented or enhanced. The authors hypothesized that with prerequisite of nearly anatomical reduction, structure allograft for medial support restoration, rotator cuff integrity, and supervised early rehabilitation, elder patient can achieve good outcomes with current locking plating system. Furthermore, by adhering to reduction technique through intraosseous window, less soft tissue stripping could decrease the incidence of avascular necrosis. The purposes of this study are to compare clinical and radiologic results after osteosynthesis with anatomic locking plate system for comminuted proximal humerus fracture between young and elder patients, and report complications.

Materials and methods

This is a retrospective cohort study had been conducted through a consistent surgical technique and rehabilitation protocols from January 2010 to January 2016, to collect all adult patients with Neer 3- or 4-part proximal humerus fractures under a single surgeon. They were all treated, regardless of age, with open reduction and fixation with locking plate system (PHILOS Synthes). Patients refrained from early and coherent rehabilitation exercise due to multiple fractures, polytrauma, neuromuscular disorder or other conditions were excluded. The study protocols were approved by the local ethics committee.

All surgeries were done through anterolateral incision which starts from the mid-point between coracoid process and anterior corner of acromion and is carried 8–10 cm distally and laterally toward the insertion of deltoid. The raphe between anterior and middle third of deltoid is split in line with muscle fiber. The fatty streak embedding the terminal branch of axillary nerve can usually be identified at around 6 cm distal to acromion. Greater tuberosity is firstly found and tagged with sutures. Through the window between two tuberosity and shaft fragment, humeral head is pushed inner and upper-ward with a finger or blunt end of an elevator while the greater tuberosity is brought anteriorly and inferiorly with the sutures (Fig. 1). Valgus neck shaft angle could usually be achieved with this manner. In anatomy, greater tuberosity should be around 0.5 cm lower to the highest level of humeral head. Relationship between greater tuberosity and head fragment cortices apposition over the endosteal side of head and shaft fragment can be fine tuned through the intraosseous window and even under vision.

There were two indications for structural allograft. First, medial cortex fracture was comminuted and failed self-support after reduction. Second, a metaphyseal-diaphyseal defect was larger than 2 cm. A 4–6 cm of structure allograft from proximal radius, distal ulnar or fibular can be used to support reduction. The plate is positioned lateral to biceps and 0.5–1 cm distal to the upper edge of greater tuberosity. Calcar screws are emphasized to support medial metaphysis and resist varus load. Lesser tuberosity can be reduced and secured either by sutures or a free screw. Nearly all the soft tissue stripping are limited to the bare area lateral to the bicep tendon sheath. Soft tissue envelope over medial metaphysis is left untouched. Rotator cuff, especially supraspinatus, are repaired or prophylactic attached to the side holes of plate with non-absorbable heavy sutures.

Passive forward elevation starts from the next day after surgery followed by active assisted motion one month later. Fully active motion is only allowed from third month. Early active forward elevation is prohibited to prevent upward migration of greater tuberosity. Monthly follow-up is arranged for first three months and then every 3 months in the first year. Regular yearly follow-up is encouraged for all the patients.

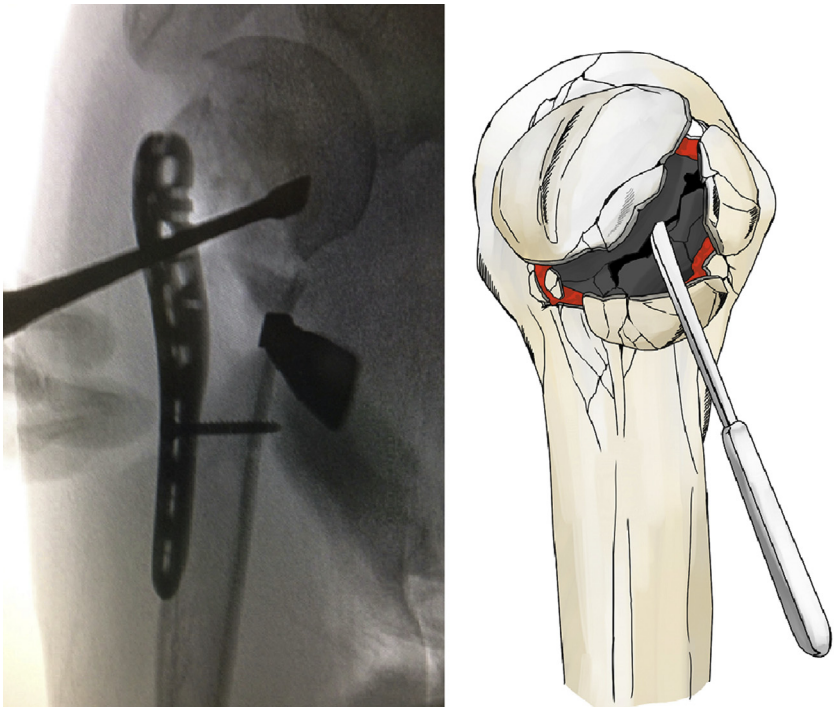

Fig. 1. Through the window between two tuberosity and shaft fragment, humeral head is pushed inner and upper-ward with a finger or blunt end of an elevator while the greater tuberosity is brought anteriorly and inferiorly with the sutures.

Patients with age 70 years or elder were designated to group I, and those under 70 years old were designated to group II. The Oxford shoulder scores and American Shoulder and Elbow Surgeons score (ASES) were evaluated for functional outcomes by a nurse specialist during each follow-up. Telephone interview were applied instead after one year when patients could not attend in person. Radiologic outcomes were evaluated regarding the initial reduction quality and interval change afterward. Parameters included neck shaft angle, humeral head height and offset of greater tuberosity.[11] Metaphyseal head extension was as measured according to prior definition.[12] Complications such as loss of reduction, hardware failure, nonunion or avascular necrosis were monitored and recorded.

The images were blindly reviewed by a senior resident surgeon. The charts were reviewed by another resident surgeon.

For all the patients, Paired Student's *t*-test in two-tailed way and the Chi-square test were used to compare the differences of clinical outcomes between two groups. The value of $P < 0.05$ indicates significant difference.

Results

From 2010 to 2016, a total of 81 patients with Neer 3- or 4-part fracture undergoing ORIF with the locking plate by the senior surgeon with identical protocol were included in this study. Eleven patients were excluded because of pathological fractures in three and multiple trauma in three and loss of follow-up in five. Among the 70 patients enrolled, 42 cases were Neer 3-part and 28 were 4-part fracture. Thirty-two patients who were 70 years or elder were designated to group I. The group I contained 19 patients with Neer 3-part and 13 patients with 4-part. The other 38 patients who were younger than 70 years old were in group II. The group II contained 23 patients with Neer 3-part and 15 patients with Neer 4-part fractures (Table 1).

From demographic data, there are no statistic differences regarding gender, fracture pattern distribution and length of follow-up between groups. There were neither significant differences in final clinical scores nor significant interval change of radiological parameters between 2 groups. The only two clinical factors which had significant difference between two groups were post-operative shoulder maximal range of motion and the timing achieving maximal range of motion ($P < 0.05$) (Table 1).

Structure allograft augmentation was applied on 15 patients by using femoral head in 10, proximal radius in 2 and fibula shaft allograft in 3. Eleven grafts were applied in the group I (Fig. 2). The average length of follow-up is 28.3 months (a minimum of 12 months). Fifteen cases with structure allograft all achieved satisfactory clinical outcome by Oxford score (average 55 ± 2.6) without major complications such as infection, loss of reduction, implant failure or avascular necrosis.

There were totally six complications in our serials including 4 situations related to greater tuberosity, one related to hardware penetration and one malunion (Table 2). The 3 complications from group I occurred at 6–12 months after surgery. They all chose living with complications. The patient with one screw penetration from anterior lower quadrant of humeral head actually presented with 140 degree of forward elevation and high functional scores without obvious pain. The other 3 complications in group II occurred at 3–6 months after surgery. The only one case treated with reoperation came from group II due to secondary upper migration of greater tuberosity. The one from group II was treated with revision fixation with one cannulated screw and heavy suture. Intra-operation findings reviewed there was only one locking screw purchase at the greater tuberosity fragment. The patient regained active forward elevation up to 160°.

Table 1
Patients characteristics.

	Group I (n = 32)	Group II (n = 38)	P value
Age (year)	77.8 ± 5.1	58.2 ± 9.3	<0.05
Gender			0.541
Male	14	16	
Female	18	22	
Neer classification			0.56
3-part	19	23	
4-part	13	15	
Follow up time (month)	28.2 ± 17.8	28.5 ± 16.1	0.68
Structural allograft	11	4	<0.05
Femoral head	8	2	
Proximal radius	1	1	
Fibular shaft	2	1	
Clinical outcome			
Oxford score (0–60)	54.8 ± 2.7	56.6 ± 3.4	0.13
ASES score (0–100)	89.7 ± 5.7	90.8 ± 8.2	0.68
Post-operative maximal ROM(°)	135.4 ± 14.7	162.6 ± 8.7	<0.05
Time to maximal ROM(month)	8.14 ± 3.25	4.37 ± 2.37	<0.05
Radiology			
Metaphyseal head extension (mm)	8.4 ± 2.7	8.9 ± 3.0	0.65
Initial neck shaft angle (°)	134.6 ± 7.3	135.7 ± 9.7	0.73
Last neck shaft angle (°)	133.8 ± 6.4	135.2 ± 11	0.66
Initial greater tip height (cm)	0.68 ± 0.35	0.49 ± 0.36	0.13
Last greater tip height (cm)	0.52 ± 0.36	0.41 ± 0.39	0.76
Initial offset (cm)	2.42 ± 0.47	2.47 ± 0.36	0.37
Last offset (cm)	2.49 ± 0.42	2.49 ± 0.34	0.96
Complications	9.4% (3/32)	7.9% (3/38)	0.76
Screw penetration	1	0	
Greater tuberosity partial avulsion	0	2	
Greater tuberosity second migration	1	1	
Varus malunion	1	0	

Footnotes: The American Shoulder and Elbow Surgeons Shoulder *Score (ASES score)*, Range of motion (ROM).

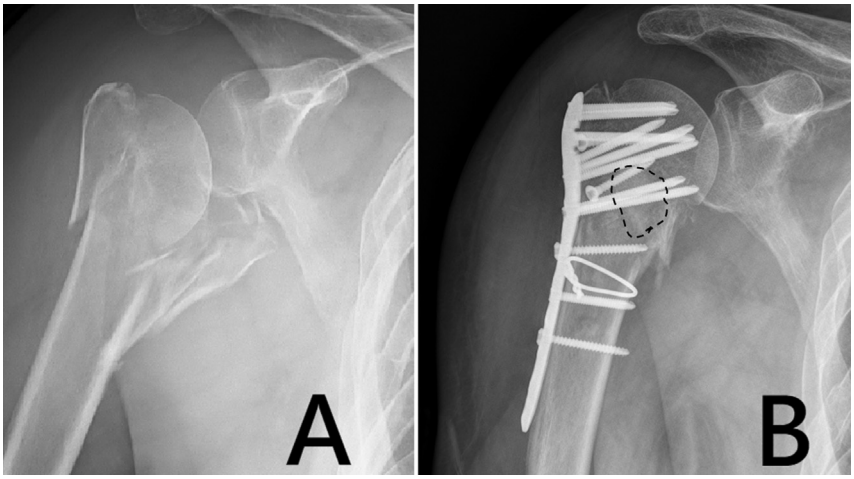

Fig. 2. 71 years old man has right proximal humerus comminuted fracture. (2A) After osteosynthesis with locking plate and augment with structural allograft (femoral head), neck shaft angle and medial support were restored. (2B).

Discussion

Age is usually a concern in treatment planning for patients with proximal humerus fractures because of more osteoporotic bone, less physiological reserve, lower demands and higher medical comorbidity in elders. There are more and more surgeons preferred surgical management for proximal humerus fracture by open reduction and locking plating for patients elder than 65 years old.[1] Concerns and debates still exist regarding complications and functional results especially for 3- and 4-parts fracture. By defining elder group as age 70 years and enrolling Neer 3- and 4-part fractures, our study tested the clinical efficacy of locking plating in even more challenging tasks. All the operations were executed by single surgeon to certify the consistence of surgical requirement. This study aimed to explore, with careful surgical handlings, whether or not surgical complications with locking plating could be diminished for the elder patients with comminuted fracture. By osteosynthesis with locking plate, this study showed that the elder patients are not inferior to the young patients. Although the elder group had less maximal range of motion and slower recovery rate compared to the young group, their final clinical and radiological outcomes are similar between groups. The reasons for less maximal range of motion could be attributed to pre-exist cuff lesion and less muscle strength.

The results from previous studies encouraged the application of osteosynthesis for elders. Jung et al[13] reported loss of reduction rate was 6.7% in his study on risk factor analysis on 252 cases including all age group. The result showed that aging is not an independent factor for loss of reduction via multivariate analysis. A randomize control trial on osteosynthesis with locking plate versus non-operative treatment in elders with 3-part fractures suggested that former could provide good clinical outcome[14] at an expense of 30% (9/30) of re-operation rate. This study, although with mean age 74 years, included patients aged from 56 to 92 years. Only three out of the nine patients who received second operation are older than 70 years. That study did not include elders with 4-parts fracture.

Surgical complications were remained as the main concern for locking plate osteosynthesis in elders. Published studies have reported some implant-related complications associated with locking plate fixation—most commonly, intra-articular screw penetration, postoperative fracture displacement, and avascular necrosis.[15–18] A prospective, multicentre observational trial by Sudkamp et al[3] on elder showed that satisfactory functional outcomes were achieved on the surgical side after 12 months. However, 34% (52/155) patients suffered from complications following the surgery and 40% of these complications were related to inadequate surgical technique. Erasmo et al[2] reported that locking plate osteosynthesis also provided good clinical outcome in severe cases of fracture dislocation. Although the good DASH and Constant–Murley scores were found in this 82 cases study, there were 28% patients had complications and reoperation was required in 12 patients. A meta-analysis of 12 studies with a total of 514 proximal humerus fractures treated with locking plate fixation showed an overall complication rate of 49% and a 13.8% reoperation rate.[9] In our series, with similar good clinical outcome, the complication rate was relative low in both groups (9.4%, 7.9%). The re-operation rate was only 2%. The authors reason that meticulous surgical techniques plays the essential role, which include good alignment with robust medial cortical support and untouched soft tissue over medial metaphysis area via intra-osseous reduction.

Table 2
Complications.

Group	Complications	Age	Sex	Oxford	ASES	Maximal ROM(°)	Time(m)
I							
Case 1	Screw penetration	80	F	56	91.67	140	6
Case 2	GT secondary migration	77	F	42	81.6	90	12
Case 3	Varus malunion	75	M	54	86.66	130	12
II							
Case 1	GT partial avulsion	44	M	59	93.33	175	3
Case 2	GT partial avulsion	58	F	52	80	165	6
Case 3	GT second migration	56	F	54	93	160	6

Footnotes: Greater tuberosity(GT), male(M), female(F).

Reported negative predictors of loss reduction after plating include osteoporosis, displaced varus fracture, medial comminution fragment, insufficient medial support and inadequacy of reduction.[13] Among them, to restore medial support was the most important factors for maintenance of fracture reduction.[19] Another retrospective study revealed that the absence of comorbidity and the restoration of the medial support were the most reliable predictors of good clinical outcomes.[20] Therefore, calcar screws were routinely placed closed to inferior cortex of humeral head in our practice. Medial support was proven to be an important factor for a good functional outcome in other studies.[13,19] Jung et al reported only 1% patients had loss of reduction with adequate medial support in their serials.[13] In this study, the authors held a low threshold for structural allograft augmentation. The purpose is to resist varus and inferior displacement of humeral head rather than to facilitate bone union in this metaphyseal area. The grafts were shaped so that they could seat well in metaphyseal–diaphyseal junction and push against the lower half of head fragment. More than one third (11/32) of the elder patients received structural allograft. This could contribute to the low rate of loss of reduction in these series.

There was no case of AVN in current study, unlike to previous study.[9] Medial calcar integrity had been proven to be critical for blood supply of the humeral head in a cadaver study, particularly in four-part fractures.[21] In an in vivo study, R. Hertel et al[12] proposed that metaphyseal head extension less than 8 mm was an important risk factor for avascular necrosis of humeral head. In our series, 46% (32/70) of the patients carried this risk factor, however, avascular necrosis developed none of them. The authors attribute this to that the soft tissue over medial aspect was totally left untouched and the whole procedure of reduction was all carried through the intraosseous window between fragments.

Heavy non-absorbable sutures fixation is a common technique to resist deforming forces and stabilized rotator cuff. Multiple studies have reported on suture use with locked plating for proximal humeral fractures.[22–24] and good outcomes were reported. Although a cadaveric study concluded that additive sutures are not required for anatomically reduced fracture,[25] the authors believe that multiple sutures may counteract the deforming forces that act on bony segments and support some power for rotator cuff stability. Based on our observation that secondary avulsion of greater tuberosity could happen on an intact cuff, Protection suture to the plate is advised to carry for all cases, regardless the integrity of the cuff.

The present study has several limitations. First, the number of patients was relatively small and maybe not enough to find difference in some parameters. A larger number of subjects conducted prospectively could add more power on this issue. Second, owing to its retrospective design, selection bias and measurement bias could not be avoided. However, all the patients were treated and followed under a similar protocol by one surgeon. The authors also tried to diminish their influence by blinding the radiology measurement to the patients' data and clinical results.

In conclusion, this study revealed that locking plating could achieve satisfactory results in elders with Neer 3- or 4-part fractures. It is not a panacea for proximal humerus fractures, but many of the complications could be avoid by careful surgical handling. Good alignment with robust medial cortical support, untouched soft tissue over medial metaphysis area via intra-osseous reduction and aggressive structural bone graft are the essential techniques.

Approval giving authority

Institutional Review Board of Taipei Veterans General Hospital.

Conflicts of interest

Tzu-Cheng Yang, Yu-Ping Su and **Ming-Chau Chang** declare that they have no conflict of interest.

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