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Efficacy of Additive Trans-cuff Augmentation Sutures for Proximal Humeral Fractures Stabilized by Locking Plates in Elderly Patients

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Background: The purpose of our study was to evaluate the functional and radiologic outcomes of additive augmentation sutures through rotator cuff for proximal humeral fractures stabilized locking plate in elderly patients.
Methods: We enrolled 74 patients over the age of 60 years who received internal fixation using locking plates for proximal humeral fractures. Of these, 50 patients had additive augmentation sutures through rotator cuff. The mean age at the time of surgery was 72.1 years (range, 60–89 years), and the mean follow-up period was 17.5 months (range, 12–62 months). The humeral neck-shaft angle and humeral head height were used as radiological markers to assess the effect of additive augmentation sutures through rotator cuff. We allocated the patients who received additive augmentation sutures into group A and those who did not into group B.
Results: At the final follow-up, the mean Korean Showlder Society score and Constant scores were 88.96 ± 12.1 and 86.6 ± 11.9, respectively, in group A and 86.21 ± 11.8 and 85.3 ± 11.7, respectively, in group B ($p=0.368$, 0.271). At the final follow-up, the mean loss in humeral neck-shaft angle from the time of immediate postoperative measurement was 1.6° in group A and 4.8° in group B, whereas the mean loss in humeral head height was 0.82 mm in group A and 0.52 mm in group B ($p=0.029$, 0.178).
Conclusions: The surgical outcomes of internal fixation using locking plates for proximal humeral fractures were clinically and radiologically good in elderly patients over the age of 60 years without any observable complications. Further, the loss of humeral head shaft angle at the final follow-up from its initial postoperative measurement was significantly smaller in patients who received an additive augmentation suture than in those who did not. Thus, we conclude that augmentation sutures are a beneficial option for elderly patients that clinicians can consider at the time of surgical decision making.
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Key Words: Proximal humeral fracture; Locking plate osteosynthesis; Trans-cuff augmentation sutures; Clinical outcome; Radiologic outcome; Elderly patient

Introduction

The incidence of proximal humeral fractures in the elderly is increasing due to an increase of sports activity and osteoporosis.[1,2] Unstable and displaced proximal humeral fractures are generally accepted indications for operative treatment.[3] Current treatments include osteosynthesis using proximal humeral nails and plates, tension band wiring, percutaneous or minimally invasive techniques such as pinning, intramedullary flexible nails, and screw osteosynthesis, and hemiarthroplasty.[4-7] Surgical treatment requires anatomical reduction and a stable fixation, which proves to be especially difficult in an osteoporotic bone. Unreduced or poorly reduced fractures with varus angulation of the neck-shaft angle can be a cause of avascular necrosis of the humeral head.[8,9]

With the advent of locking plates and screw fixation, a greater number of displaced proximal humeral fractures are being treated with osteosynthesis.[10-14] Locking plates may have a mechanical advantage over standard implants in osteoporotic bones.[13,15] Nevertheless, complication rates after surgical stabilization re-

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main high.[11,16,17] Several studies report complications, of which the two most commonly reported are varus inclination and screw penetration. Gardner et al.[13] reported that a varus collapse is typically caused by rotator-cuff forces, thereby suggesting that reduction maintenance necessitates some medial support. Other than these, loss of fixation is another frequently observed complication and in locking plates this requires removal of the screws to avoid impending joint destruction.[18]

Fixation loss is a problem often met after surgical treatment of displaced unstable proximal humeral fractures in elderly patients with osteoporosis. Despite many approaches and attempts to overcome this problem no definitive consensus operation exists. One reason for the loss of fixation is an insufficient anchorage of screws in the humeral head. Liew et al.[19] also found screw purchase to be significantly greater when screws were placed into the medial subchondral bone and cautioned about relying on fixation in the superior humeral head. When necessary, the fixative construction should be augmented with heavy sutures, which passes adjacent to bony fragments, goes through rotator cuff tissue, and winds back to the fixation implant to provide maximal implant-fragment stability.[20] In other words, the displacing force of the rotator cuff must be reduced through additive fiber cerclages. In patients who received plate fixations without additive fiber-cerclages, subacromial impingement and tuberosity displacement are observed more frequently than in those who received plate fixations with additive fiber-cerclages.[21] However, to date, the effect of additive augmentation sutures in proximal humeral fractures stabilized by locking plates is clinically unclear.

The purpose of our study was to evaluate the functional and radiologic outcomes following a trans-cuff additive augmentation sutures in proximal humeral fractures stabilized by locking plates in elderly patients. In addition, we sought to investigate the clinical benefits of implementing additive augmentation sutures in these patients. We hypothesize that the mechanical support provided by additive augmentation sutures through the rotator cuff is important for establishing a stable construct.

Methods

Patient Selection

Of the 125 patients who underwent surgical treatment for dislocated unstable proximal humeral fractures between May 2007 and June 2013, 74 patients over the age of 60 years who were able to participate in at least a year follow-up study were enrolled into our study. All 74 patients received an internal fixation using locking plates, and in 50 patients we carried out a further additive augmentation suture through the rotator cuff. The mean age of the patients at the time of operation was 72.1 ± 14.8 years (range, 60 to 89 years) and the mean follow-up period was 17.5 months (range, 12 to 62 months). Sixteen patients (21.6%) were males and 58 patients (78.4%) were females. All selected patients were operated on within a week of injury and the mean time interval from injury to operation was 4.5 ± 1.2 days. We divided the patients according to whether they received or did not receive an additive augmentation suture through the rotator cuff; 50 patients who received additive augmentation sutures were allocated to group A and 24 patients who did not were allocated to group B (Table 1).

Preoperative and Postoperative Evaluations

Postoperative clinical evaluations were performed regularly on an outpatient basis (at 2 weeks, 6 weeks, 3 months, 6 months, 9 months, and 12 months postoperatively and at the last follow-up), and the results of the last follow-up were analyzed. Postoperative subjective pain score was measured using the visual analog scale (VAS). For postoperative shoulder range of motion (ROM), forward flexion, external rotation at the side, and internal rotation to the back were assessed. The Korean Shoulder Society score (KSS) and Constant score[22] were used for clinical assessment.

Preoperatively, routine roentgenograms with antero-posterior, lateral, and axillary views were taken followed using computed tomography. All patients were evaluated with plain x-rays on a regular basis postoperatively until bone union was observed. We measured the neck-shaft angle and humeral head height as our radiological parameters and compared these values at the immediate postoperation and at the final follow-up (Fig. 1).

Operative Techniques

All operations were performed by a single surgeon (C.N.S). During surgery, the patient was placed in a beach chair position with the bed inclined at about 30°. The sterilized ipsilateral arm was not fixed and was rested on a removable, height-adjustable tray table. Before draping, the portable C-arm (image intensifier) was optimally positioned to take radiographic images.

To begin with, we made an incision starting just inferior to the

Table 1. Patients Demographics

Variable	Group A (n=50)	Group B (n=24)
Sex (male/female)	13/37	3/21
Age (yr)	73.1 (61–89)	70.2 (60–85)
Follow-up (mo)	16.2 (12–60)	19.7 (12–62)
Neer classification		
Two part	17 (34)	9 (37.5)
Three part	28 (56)	13 (54.2)
Four part	5 (10)	2 (8.3)
Bone graft	21 (42)	0 (0)

Values are presented as number only, median (range), or number (%).
Group A: patients who received additive augmentation sutures, Group B: patients who did not receive additive augmentation sutures.

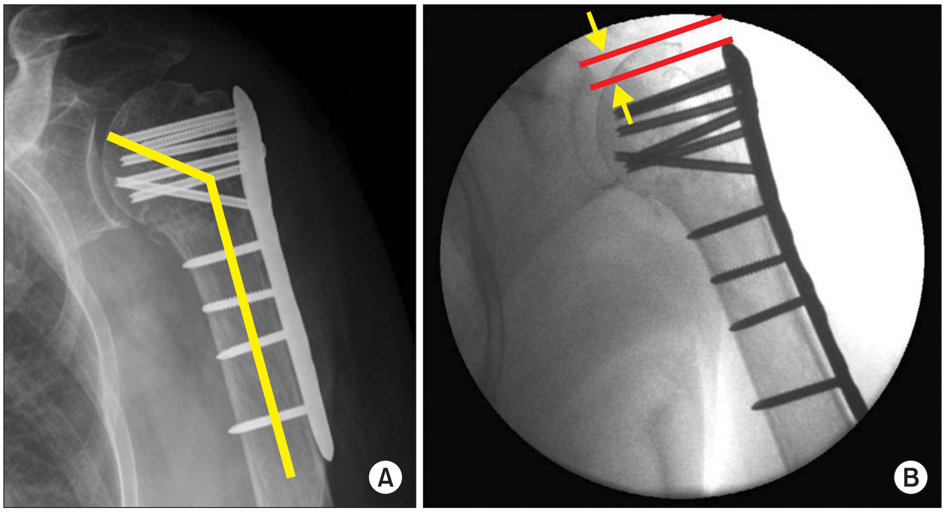

Fig. 1. Radiological assessments. (A) Neck shaft angle. (B) Humeral head height.

coracoid process and extending towards the proximal area of the insertion of the deltoid using the deltopectoral approach. During the procedure, we gained sufficient exposure through a partial release of the anterior deltoid insertion and the abduction of the arm. First, the head of the humerus was reconstructed using a few sutures or cerclage wires or both if required as described by Hertel,[23] which in their words is akin to reconstructing a broken eggshell. We held the larger fragments like tuberosities into their anatomical positions using pointed reduction clamps and fixed them using Kirschner wires (K-wires). If the medial calcar was fractured, we made sure that they were held reduced as much as possible as this could cause postoperative varus displacement during healing.

Next, the fracture was reduced by ligamentotaxis, which is the manipulation of the upper arm and the buttressing effect of the plate (Periarticular Proximal Humeral Locking Plate; Zimmer Inc., Warsaw, IN, USA). Taking into consideration of the extent of the fracture, the desired length of the plate was chosen; usually plate length that can accommodate approximately 3 to 4 holes distal to the fracture is sufficient. We created space for the plate close to the bone via blunt insertion of the plate along the distal fragment of the fracture and along the humeral shaft. The proximal humerus was usually already exposed and the fracture clearly visualized from this approach. Through traction and manipulation, we restored length of the plate and aligned it to its desired position, the ideal position being the upper tip of the plate around 5 mm inferior to the greater tuberosity. In case of a residual valgus deformity of the humeral head, the plate was placed slightly higher than the tip of the greater tuberosity.

To fix the correctly positioned locking plates with screws, we temporarily stabilized the plate by holding it down with a thumb on the proximal fragment and drilled a non-locking hole just distal to the fracture and perpendicular to the bone fragment. As the screw is tightened, the reduction of the valgus deformity gradually occurs as the shaft that is usually displaced medially also lateralizes to a reduced state. Thus, this was done carefully and the alignment was constantly checked with a C-arm. Once the screw is tightened, the angulation is usually reduced to an acceptable position. If required, a few K-wires were temporally inserted into the proximal part of the plate to maintain a hold on the proximal humerus. These loosely inserted wires help maintain plate position to the head while allowing correction.

After the first screw is screwed in, the plate should already buttress the bone with its anatomically contoured curves, and the fracture is reduced. We then carefully placed the calcar screw at the surgical neck to catch the medial calcar of the fracture that helps resist postoperative varus angulation. Once this was done, the rest of the screws were inserted while checking with C-arm imaging. Care was taken to ensure none of the screws were in the joint, which was thoroughly checked with the C-arm in fluoroscopic mode. Lastly, in selected patients we made additive augmentation sutures through the rotator cuff by anchoring the cuffs to holes on the plate using sutures (Fig. 2), which is anticipated to maximize function of the shoulder after healing.

Comminuted fractures were held reduced with the help of bone clamps, K-wires, and sutures. All cases were checked post-reduction with the C-arm before closure to confirm a successful reduction, correct plate placement, and no protruding screws in the joint. In cases of poor bone quality, we performed a fixation using allografting during the insertion of screws.

Postoperative Rehabilitation

All patients were provided with a shoulder sling from the operation room. Passive motion was started from postoperative day 1 with pendulum exercises and then assisted-arm flexion by the aid of the contralateral hand. Active motion was begun after 6 weeks postoperation.

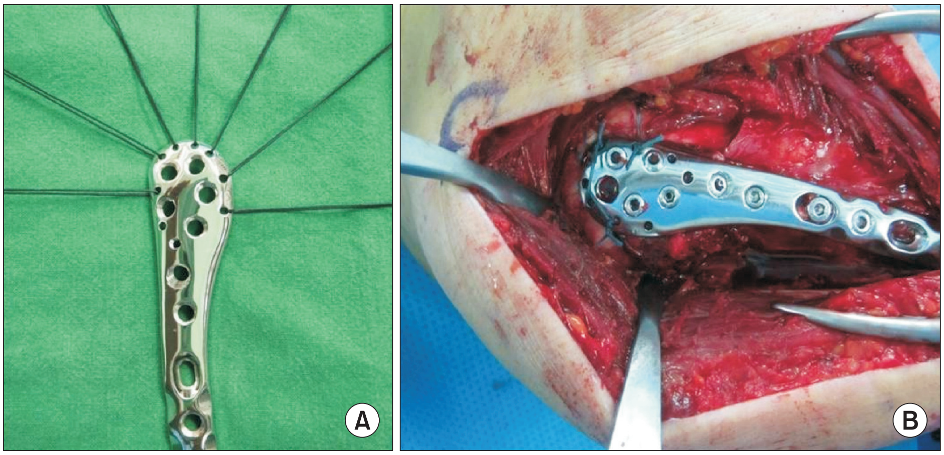

Fig. 2. (A) Additive augmentation sutures through holes on the locking plate. (B) Additive augmentation sutures through the rotator cuff are done by anchoring the cuffs to holes on the plate with the help of sutures.

Table 2. Comparison of Postoperative Clinical Outcomes between Group A and Group B

Variable	Group A (n=50)	Group B (n=24)	*p*-value
Pain (VAS)	1.65 (0–3)	1.74 (0–3)	0.397
ROM (°)			
FF	157.2 (125–170)	154.4 (135–170)	0.194
ERs	52.5 (30–75)	49.6 (20–75)	0.256
KSS	88.96 (67–96)	86.21 (51–92)	0.368
Constant score	86.6 (59–95)	85.3 (47–95)	0.271

Values are presented as median (range).
Group A: patients who received additive augmentation sutures, Group B: patients who did not receive additive augmentation sutures, VAS: visual analogue scale, ROM: range of motion, FF: forward flexion, ERs: external rotation at the side, KSS: Korean Shoulder Society score.

Statistical Analysis

An independent t-test was used to compare the VAS score, ROM, KSS, Constant score, and the radiological results between the two groups. Statistical significance was set to an α-level of 0.05 with 95% confidence intervals. For all statistical analyses, the Statistical Package for the Social Sciences (SPSS) software package ver. 17.0 (SPSS Inc., Chicago, IL, USA) was used.

Results

Pain

We found that the mean subjective pain score, VAS, improved from 4.01 ± 2.6 at 2 weeks postoperation to 1.65 ± 1.7 at the last follow-up in group A (p=0.037) and from 3.96 ± 2.81 to 1.74 ± 1.9 in group B (p=0.042) (Table 2).

Range of Motion

In group A, we found that the mean active ROM for forward flexion changed from 76.3° (range, 50°–110°) at 2 weeks postoperation to 157.2° (range, 125°–170°) at the last follow-up; external rotation at the side, from 31.7° (range, 15°–45°) to 52.5° (range, 30°–75°); and internal rotation to the back, from L3 (range, L1–L5) to T11 (range, T8–L3) (p=0.021, 0.015, 0.027). At the same time-points, in group B, the mean ROM for forward flexion changed from 77.4° (range, 50°–120°) to 154.4° (range, 135°–170°), external rotation at the side, from 30.9° (range, 10°–50°) to 49.6° (range, 20°–75°), and internal rotation to the back, from L2 (range, L1–S1) to T11 (range, T9–L3) (p=0.014, 0.007, 0.036). In terms of the ROM at the last follow-up, we found no statistically significant differences between the 2 groups (p=0.194, 0.256, 0.672, respectively) (Table 2).

Clinical Assessments

At the last follow-up, we found that the mean KSS and Constant scores were 88.96 ± 12.1 and 86.6 ± 11.9, respectively, in group A and 86.21 ± 11.8 and 85.3 ± 11.7, respectively, in group B. There were no statistically significant differences between the 2 groups (p=0.368, 0.271) (Table 2).

Radiologic Results

We found that the mean immediate postoperative humeral neck-shaft angle was 132.9° ± 12.2° for group A and 133.7° ± 13.9° for group B. The respective values at the final follow-up were 131.3° ± 13.9° and 129.9° ± 12.5°, respectively (p=0.352, 0.134). The mean loss of humeral neck-shaft angle at the final follow-up compared to the immediate postoperative fixation was 1.6° ± 0.7° in group A and 4.8° ± 1.2° in group B (p=0.029) (Table 3).

We found that the mean immediate postoperative height of the humeral head was 9.04 ± 3.2 mm in group A and 10.16 ± 2.8 mm in group B, and later, the respective values for the mean final follow-up was 8.22 ± 3.2 mm and 9.64 ± 4.2 mm, respectively (p=0.271, 0.263). Across these two time-points, the mean loss of humeral head height was 0.82 ± 0.5 mm for group A and 0.52 ± 1.1 mm for group B (p=0.178) (Table 3).

Table 3. Comparison of Radiologic Outcomes according to Subgroups

Variable	Group A (n=50)	Group B (n=24)	*p*-value
NSA (°)			
Immediate postoperative	132.9	133.7	0.352
At the last follow-up	131.3	129.9	0.134
Angle loss	1.6	4.8	0.029
HH height (mm)			
Immediate postoperative	9.04	10.16	0.271
At the last follow-up	8.22	9.64	0.263
Height loss	0.82	0.52	0.178

Group A: patients who received additive augmentation sutures, Group B: patients who did not receive additive augmentation sutures, NSA: neck-shaft angle, HH: humeral head.

Complications

In our series, we did not observe any complications such as varus failure, screw penetration, delayed union, nonunion, infection, avascular necrosis, and implant failure in neither group at the last follow-up.

Discussion

Proximal humeral fractures are closely associated with osteoporosis and commonly occur in over elderly patients over the age of 60 years. Stabilizing and promoting fracture healing of displaced unstable fractures in an osteoporotic bone requires optimal treatment, which there is no consensus of as of yet. Various techniques have been used to stabilize fractures of the proximal part of the humerus, including intramedullary nails, plate-and-screw osteosynthesis, tension band wiring, percutaneous pin fixation, and hemiarthroplasty.[6,11,15,17,18] Of these, the locking proximal humerus plate, or osteosynthesis, was designed to maintain a stable fracture reduction even in an osteoporotic bone. Advantages of the locking proximal humerus plate include gentle fracture reduction using indirect maneuvers, a high resistance to avulsion even in patients with poor bone stock because of the combination of fixed-angle screw-plate locking and three-dimensional placement of screws in the humeral head, possibility of early exercise, and a short period of immobilization because of the high initial stability achieved.[24] The advent of locking plates has helped enhance the healing rate of many fractures that come combined with osteoporosis.

However, a retrospective study by Egol et al.[25] on 51 consecutive patients showed that proximal humerus fracture fixation using locking plates was associated with early complication and with their risk factors. In their study, a total of 12 patients (24%) had complications; screws penetration in 8 patients (16%), osteonecrosis in 2 (4%), early fixation failure in 2 (4%), and heterotopic ossification in 1 (2%). Similarly, when Clavert et al.[26] performed locking plate fixation in 73 proximal humeral fractures 8.2% of patients exhibited surgery-related secondary dislocation and 5.5% exhibited nonunion, which led to a significantly poor postoperative Constant score. They concluded that although using locking plates in weak bones enables more fixation security, the increase in complication rate may outweigh the benefits especially patients with severe osteoporosis, comminuted fractures, or with head split, in which case an arthroplasty may be a more appropriate treatment option.

Keeping a locking plate fixed for as long as it is needed for the union of a fracture is not possible in all patients. Secondary displacement or secondary head deformities have been reported in more than 20% of elderly patients.[11,16,17,23] Failure in fixation are induced by rotator-cuff forces.[13] Consequently, it was postulated that fixation constructs should be augmented, for example, with sutures passing adjacent to bony fragments, through rotator cuff tissue, and back to the fixation implant, to provide maximum implant-fragment stability.[20] Additive fiber-cerclages should reduce displacing forces of the rotator cuff and secure tuberosities after their anatomical reduction by acting as a stable circular platform on which head fragments can rest.[27] As such, in a study on the effects of additive fiber cerclages on stable plate fixations, the authors found that subacromial impingement and tuberosity displacement were observed more frequently in individuals without fiber cerclages than in those with.[21] However, even with additive augmentation sutures, we cannot eliminate the displacing forces of the rotator cuff completely. Voigt et al.[28] found no significant difference when additive fiber-cerclages were performed or not performed for a 24 unstable 3-part fracture model with an intact rotator cuff in terms of interfragmentary motion.

Until now, we could not find literature regarding the clinical effects of additive augmentation sutures besides a few biomechanical studies. To the best of our knowledge, our study is the first to test whether an additive augmentation suture through the rotator cuff for proximal humeral fractures stabilized by locking plates has a clinically significant advantage in elderly patients. In this study, we found that proximal humeral fractures in the elderly patients that were internally fixed using locking plates were clinically and radiologically successful according to our chosen parameters. Regardless of whether additive augmentation sutures were made, we observed union in both groups and a satisfactory functional outcome. Further, postoperative ROM of the shoulders was improved almost as well as its contralateral counterpart. There were no signs of postoperative varus failure or screw penetration. However, at the final follow-up, we found that the loss of neck-shaft angle was greater in the group B than in group A. Thus, in case of severe dislocation or comminution of the fracture especially in elderly patients with concomitant osteoporosis, we believe that making additive trans-cuff sutures after internal fixation will provide a sturdier fixation and should be considered as a strong surgical candidate.

Our study has a few limitations. First, being retrospective in nature, our study has limitations related retrospective studies but we tried to minimize these limitations by conducting a retrospective analysis of the prospectively collected patients' data. Second, since the technique was chosen depending on operative findings a presence of selection bias cannot be eliminated. However, the additive augmentation sutures technique, though performed in osteoporotic bones or in more unstable and severely displaced fracture patterns, presented similar clinical results and fracture healing to the suture negative technique. Nevertheless, this confirmed its efficacy for the treatment of osteoporotic complex fractures. In addition, the definition of elderly person was somewhat subjective because the value was an arbitrary cutoff. Finally, the neck-shaft angle and the humeral head height were measured in the antero-posterior view of proximal humerus, the radiologic findings for which may be affected by many factors.

Conclusion

We found good clinical and radiological outcomes without complications after internal fixation using locking plates for the treatment of proximal humeral fractures in elderly patients over the age of 60 years. However, at the final follow-up, we found that in patients who did not received additive augmentation sutures on the rotator cuff a loss in humeral neck-shaft angle of the humeral bone that was greater in those who received additional sutures. Thus, we believe additional strengthening sutures are viable options for elderly patients receiving surgical treatment.

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