



## Dual plate for comminuted proximal humerus fractures

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The purpose of this study is to evaluate radiological, clinical results and complication rates of dual plate fixation for severe metaphyseal comminuted fracture of proximal humerus. 21 patients who have proximal humerus fractures with impaired posteromedial buttress were enrolled. Fractures were treated with dual plate technique using Proximal Humeral Locking plate and Variable Angle Plate. Radiographic results were analyzed based on duration of union. For evaluation of the degree of anatomical reduction, neck shaft angle on the anteroposterior view was measured by simple plain radiography using the Paavolainen method, while anterior-posterior angulation was measured on the axial view. Degree of anatomic reduction was good in 17 patients (80.95%), fair in 3 patients (14.28%), and poor in 1 patient (4.77%). One case of impingement, and one case of avascular necrosis were noted. The dual plate technique provides stable fixation and satisfactory clinical and radiological results for severely comminuted metaphyseal fracture of the proximal humerus.

**Keywords :** Proximal humerus ; comminuted metaphyseal fracture ; dual plate

### INTRODUCTION

Proximal humerus fractures account for approximately 4-5% of all fractures. Proximal humerus fracture accounts for as high as 45% of all humerus fractures (3,9,11). The recently introduced

locking plate is more widely used clinically due to its small size, low rigidity, high elasticity, and biomechanical properties such as fixed initial angle and rotational stability. However, in severely comminuted fracture over meta-diaphyseal area of the proximal humerus, which loss the function of posterior and medial buttress, the use of a lateral locking plate alone does not provide stable fixation, leading to complications such as varus collapse, anterior-posterior angulation, screw cutout, nonunion, malunion, and hardware failure (12,13,17). Therefore, we have applied the dual plating technique using a locking compression plate (LCP) plate in patients with absent of medial hinge due to severe medial comminuted fracture in order to provide primary stability and buttress the postero-medial hinge. We attempted to use the dual plating technique with a proximal humerus locking plate (PHILOS, Synthes, Switzerland)

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and an additional small plate (Distal radius locking plate-Variable Angle LCP Distal Radius System, Synthes, Switzerland) in 21 patients with severe comminuted meta-diaphyseal proximal humerus fractures. We evaluated the clinical and radiological results and complication rates of the dual plate fixation technique. This study presents prospectively selected patients before fixation of proximal humerus fractures with dual locking compression plate.

### MATERIALS AND METHODS

The inclusion criteria for this study were patients with comminuted meta-diaphyseal proximal humerus fractures, according to the AO Foundation and Orthopaedic Trauma Association (AO-OTA) classification into 11-A3.3 or 11-B2.3. The exclusion criteria for this study were patients with vascular injury, young patients who has physeal injury, and significant dementia or the inability to participate in physical therapy postoperatively.

From Jan. 2008 to Sept. 2013, 89 patients diagnosed with a proximal humerus fracture were selected. Of those 89, 46 patients received surgical treatment. Adult patients who sustained closed, unstable proximal humerus fracture without vascular complication at the time of injury subsequently underwent operative management.

Out of 46 patients, 21 patients with loss of posteromedial buttress due to severe metaphyseal comminuted fracture were categorized into suitable candidates (AO 11-A3.3 or 11-B2.3) for dual plate technique, had received dual plate technique as planned.

The average age of the 21 patients who received surgical treatment was 62.3 years (range, 31-86 years). The average postoperative follow-up duration was 25.1 months (range, 12-38 months). Among them, 6 patients were males and 15 patients were females. According to AO-OTA classification, 8 patients were categorized as 11-A3.3 (38.09%) and, 13 patients were categorized as 11-B2.3 (61.91%). The causes of the initial fracture in the dual technique group were slip down (15 patients, 71.42%), traffic accident (2 patients, 9.54%), and fall down (4 patients, 19.04%) (Table 1). We

Table 1. — Dual plate fixation group demographic characteristics

Sex(M:F)	6 : 15
Follow up periods(months)	24~31(27.4)
AO-OTA classification	
11-A3.3	8 (38.09%)
11-B2.3	13 (61.91%)
Mechanism of injury	
Slip down	15 (71.42%)
Fall down	4 (19.04%)
Traffic accident	2 (9.54%)

followed up at postoperative 3 weeks, 6 weeks, 12 weeks, 6 months, 12 months and 24 months. We educated the patients according to the rehabilitation programs until postoperative 12 weeks. Then, clinical and radiological outcomes were evaluated with regular x-ray check-ups every year.

Proximal humerus was exposed by delto-pectoral approach. Minimally dissected, further though posterior aspect of greater tuberosity with careful consideration not to injure the axillary nerve and posterior circumflex humeral artery, which are identified upon additional exposure. The pectoralis does not typically need to be released. The long head of the biceps brachii can be a source of pain, which often tenodesed at the time of plate fixation in older patients or those with grossly poor tendon quality (18). Allogeneous cancellous bone chip graft (TranZgraft, Tissue bank international, CA, USA) was performed over severely comminuted fracture site in order to fill up the bony defect. Cancellous bone graft was performed in 11 cases (52%), usually in old age patients with severe osteoporosis. The allogeneous chip bones were used as it is (approx. 3mm x 8mm). if the size exceed, minor trimming with sharp rongeur was required. Chip bones were usually filled in meta-diaphysis junction area, according to the hollowness of humeral head and neck area. To minimize cancellous defect, mild impacting, with use of mallet and impactor, was followed.

The proximal humerus locking compression plate (PHILOS, Synthes, Switzerland) was positioned lateral to the bicipital groove and an additional



**Figure 1.** — Dual plate technique with locking compression plate, applied over the proximal humerus lateral side and an additional distal radius locking plate on the posterior aspect of humerus.

locking compression plate (Variable Angle Locking Compression Plate (VA-LCP) Distal Radius System, Synthes, Switzerland) was applied anterior or posterior aspect of greater tuberosity, according to the features of fracture and AP angulation of humeral head, with extreme caution not to interfere the course of circumflex humeral artery and axillary nerve (Figure 1). In order to expose the posterior aspect of proximal humerus, proximal humerus LCP must be fixated at lateral aspect of the proximal humerus to maintain the general alignment and reduction. Then upper arm was internally rotated with approximately 90 degrees abduction to minimize the tension of deltoid, which makes traction easier and allows maximum exposure of posterior aspect of humerus. Dissected supraspinatus & subscapularis tendons were tied on plates by modified Mason-Allen suture with adequate tension.

More detailed description of the operative technique can be found in the report by Choi et al (6).

Abduction brace was applied for 2 months. Passive ranges of motion (ROM) exercises were initiated at seven days postoperatively, using a

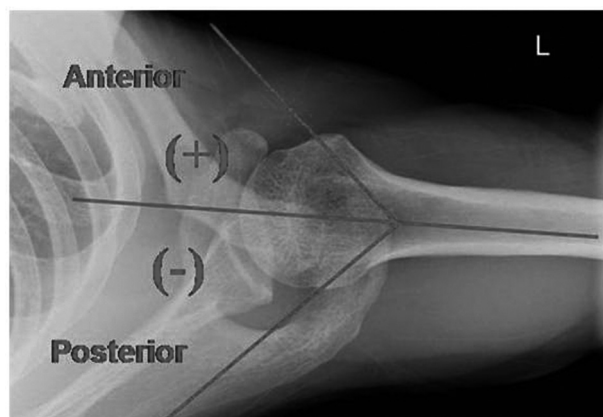
continuous passive movement machine (ORMED GmbH, Freiburg, Germany); patients also performed pendulum exercise. Gradually, active secondary movements using the normal contralateral extremity were started. Passive forward elevation and external rotation are begun at 3 weeks, and resistive strengthening exercises were subsequently added after 6 weeks.

Through ipsilateral shoulder trauma series and, 3-dimensional computed tomography (3D-CT, SIEMENS, SOMATOM-Sensation, Munich, Germany), fractures were classified according to the AO-OTA classification systems (19) Medical records and radiologic examination results, as well as age group, cause of trauma, associated injuries and complications were evaluated.

Clinical results in terms of the University of California Los Angeles (UCLA) shoulder rating scale and Constant scores were compared. The UCLA score evaluated the pain, functional range of motion and strength on a 10-point scale, and the patient satisfaction score was assessed on a 5-point scale, thereby obtaining a total possible score of 35 points. Overall, score of more than 30 points was considered as excellent, a score of more than 23 points was considered as good, a score of 17 points or more was considered as average, and a score of less than 16 points was considered as poor (1). To evaluate the Constant score, the pain score was assessed on a 15-point scale, activity on a 20-point scale, active range of motion on a 30-point scale, and strength on a 35-point scale, thereby obtaining a total possible score of 100 points (8).

The radiographic results were analyzed by two orthopedic surgeons based on the duration of union. For evaluation of the degree of anatomical reduction, neck shaft angle (NSA) in the anteroposterior (AP) view was measured by using the Paavolainen method (20). Restoration of the humeral shaft angle of  $130 \pm 10$  degree was considered as good, of 100-120 degree as average, and of 100 degree or less as poor.

To measure the anteroposterior (AP) angle of the humeral head, the angle between the long axis of the humerus and the humeral head on the preoperative 3D-CT or axial view of plain radiography was calculated. The postoperative axial view by plain



**Figure 2.** — Radiological evaluation of anteroposterior angulation using the axial view plain radiograph.

radiography was used to assess the increase in AP angulation (Figure 2).

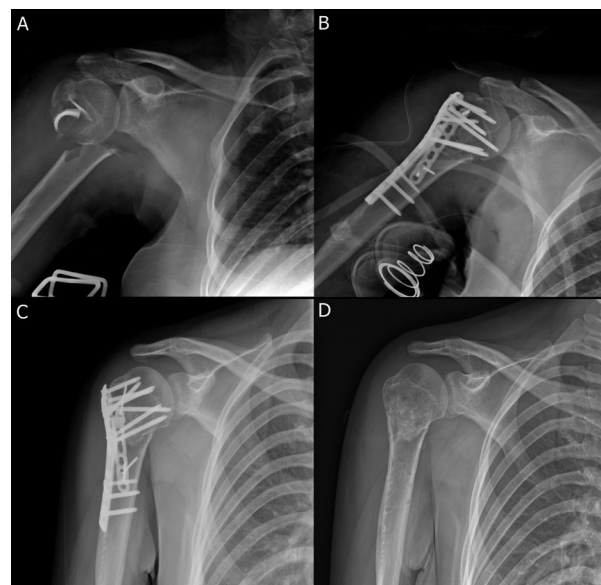
Radiographic union was defined as bony bridging on both views and confirmed with clinical examination. We determined bony union of the fracture by bridging of three of the four cortices on shoulder AP, axillary views.

We independently reviewed the injury radiographs of these patients on two separate occasions, and patients were followed up at intervals of 1 month to 3 months after the diagnosis of the fracture.

All of study procedures followed was in accordance with the ethical standards of the responsible committee on institutional review board.

## RESULTS

All of the patients were evaluated by clinical and radiologic follow-up, by status of fracture union, Constant score, UCLA shoulder rating scale, and any complications occurred at the last follow-up. The mean follow-up period was 27.4 months. (range, 24-31 months) The mean Constant score at the final follow-up was 90.4 points (range, 72-96 points) with full recovery of the shoulder range of motion in all the patients. The UCLA shoulder rating scale at the final follow-up was 23 points (range, 21-35 points). 20 patients returned to normal daily activities at an average 3.7 months postoperatively (range, 3-5 months), and were

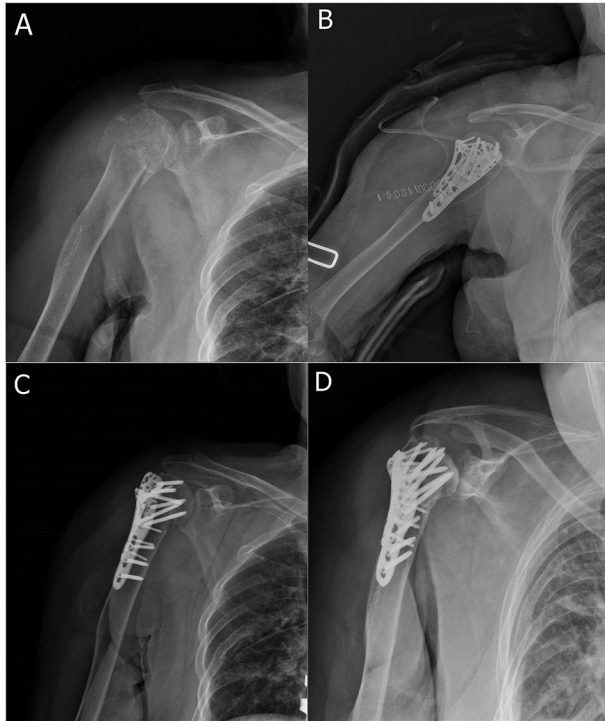


**Figure 3.** — (A) 31 year-old female sustained proximal humerus fracture after traffic accident. (B) Following patient was treated with dual plate technique. (C) Postoperative AP radiographs at 6 months revealed well maintained alignment without angulations. (D) Implant removal was done at postoperative 1 year. Successful bone union was noted.

satisfied with the treatment. Based on plain radiographic measurements, 20 patients attained bony union with a range of painless motion, and 1 patient presented avascular necrosis of humeral head. (Figure 4)

The average operation time was 151.2 minutes (range, 236-110 minutes). The average bone union time was 11.8 weeks (95% confidence interval (CI), 10.9 weeks-12.9 weeks). The average preoperative NSA was 89.2 degrees (range, 84.4-107.6 degrees) and the average immediate postoperative NSA was 121.3 degrees (range, 116.2-122.1degrees). The NSA in final follow up was 118.7 degrees (range, 108.7-131.2 degrees).

In our study, the degree of anatomic reduction measured by the Paavolainen method was good in 13 patients (62.0%), fair in 5 patients (23.8%), and poor in 3 patients (14.2%). The average preoperative AP angulation was 12.4 degrees (range, -38.2-55.4degrees), and the average immediate postoperative AP angulation was 3.4 degrees (range, -3.7-4.5 degrees). On the final postoperative follow up X-ray, the average AP angulation was



**Figure 4.** — (A) 86 year-old female with osteoporosis sustained severely comminuted proximal humerus fracture by slip down. (B) Successful anatomical reduction of proximal humerus was achieved. (C) Alignment was well maintained at 4 months postoperatively. (D) 25 months postoperative X-ray revealed loss of sphericity of humeral head due to avascular necrosis.

3.7 degrees, and the AP angulation did not increase with time.

As in complications, 1 case of impingement and 1 case of frozen shoulder, and 1 case of avascular necrosis were noted.

## DISCUSSION

When treating proximal humerus fractures, many factors of fracture type, quality of bone density, age, and the accompanying injury should be considered. Moreover, it is crucial to considerate possibility of contractures due to long-term fixation (16, 23).

Although the optimal surgical treatment for proximal humerus fractures has not yet been determined, many operative techniques have been described, including percutaneous fixation, conventional plate fixation, intramedullary fixation

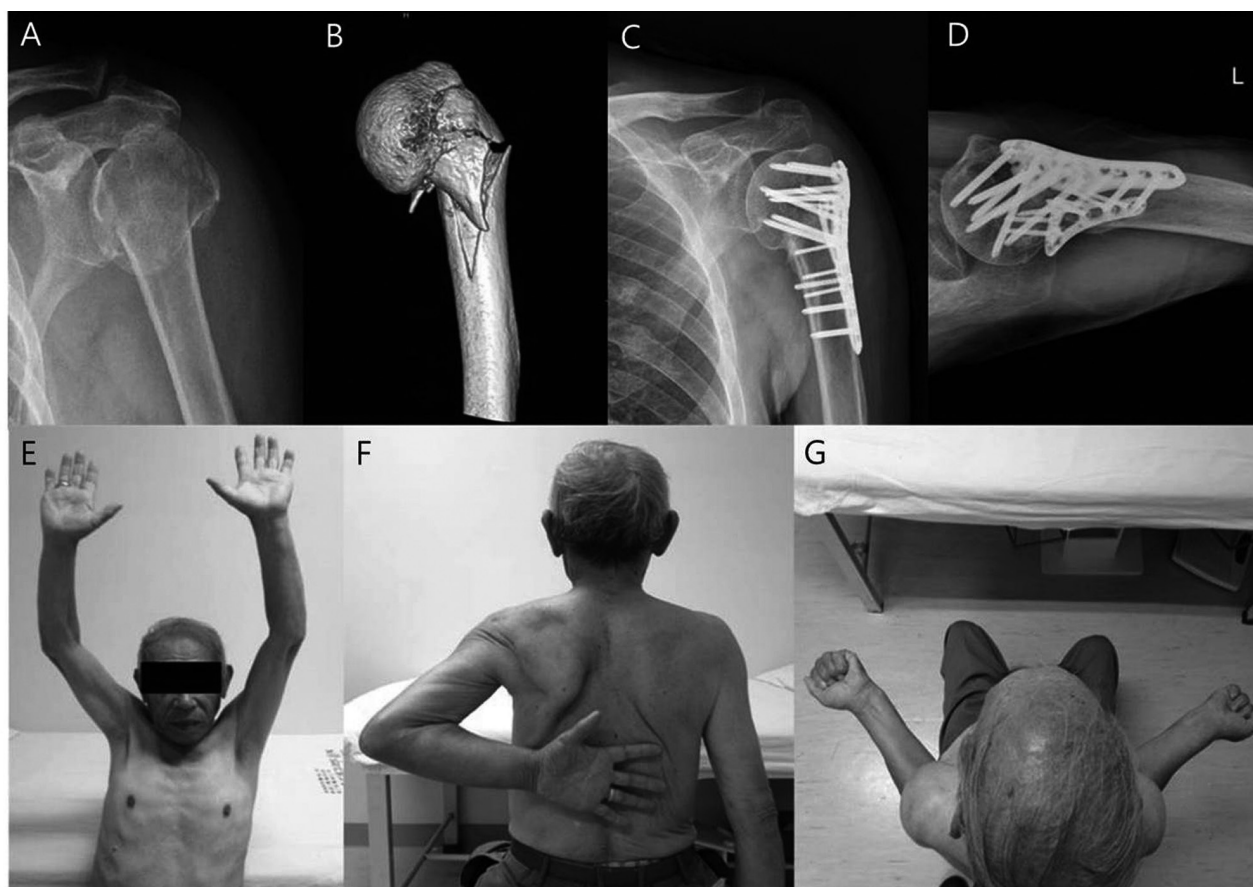
with rods or pins, tension band wiring, and blade plate fixation (2).

The current trend for treating severe comminuted proximal humerus fractures is to utilize an endosteal implant including fibula shaft allograft, hemiarthroplasty, total shoulder or reverse total shoulder arthroplasty (5,10). However, endosteal implant surgery and shoulder arthroplasty techniques are not widely performed due to the difficult surgical technique, high cost, limited durability and failure of the implant. Though many surgical methods and clinical trials are being conducted to address the disadvantages mentioned above, the optimal treatment of severely comminuted proximal humerus fractures have not yet been established (5, 11).

The effectiveness of osteosynthesis with conventional proximal humerus locking plate was discussed in abundant literatures. In study by Lee et al. (15) 20% of 45 patients had postoperative complications that included loss of fixation, adhesive capsulitis, and deep infection, while Sudkamp et al. (23) reported various complications in 34% of 155 patients including screw penetration, plate impingement, infection, loss of reduction with or without screw perforation, humeral head osteonecrosis, nonunion, screw loosening, plate pullout, and implant breakage. Brunner et al. (4) reported an overall complication rate of 35%. Königshausen et al. (14) reported 12 (23.1%) cases with complications among 73 patients.

Complications can be of two types : 1) technical complications in plate positioning, length of screws or secondary screw cutout which can strongly influence clinical result ; 2) pseudarthrosis or plate fixation failure (7).

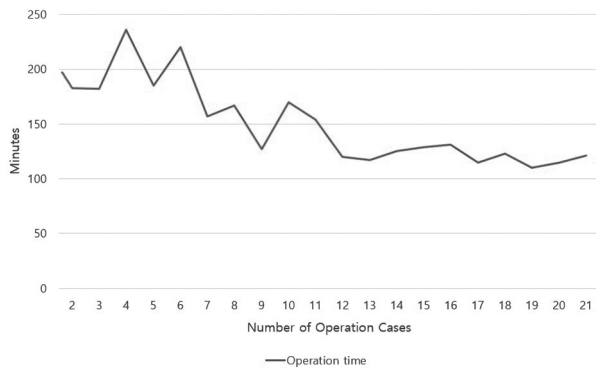
We attempted to prevent these complications by applying additional VA-LCP distal radius plate on the anterior or posterior aspect of the proximal humerus according to the worsened AP angulation of humeral head as dual plate fixation technique (Figure 5). The VA-LCP distal radius plate has dual functions : 1) bridge plate to prevent nonunion and varus collapse of the neck-shaft portion, which are developed by severe comminution, 2) buttress plate to prevent AP angulation of humeral head.



**Figure 5.** — (A,B) Preoperative radiologic images of 74-year-old male indicates severely comminuted fracture of the left proximal humerus due to fall down. (C,D) Fracture site, reduced with small varus angulation, was stabilized by proximal humerus locking plate and the distal radius locking plate, was showed in postoperative radiographs. (E,F,G) Performance status of following patient after 2 years postoperatively. He regained his normal shoulder joint functions. (E) Forward flexion (F) Internal rotation (G) External rotation.

The VA-LCP contoured volar distal radius plate, which can not only easily be anchored with small surgical field exposure, but also enables neurovascular injury free surgery due to its compactness. Moreover, application of dual plate technique was proved to be outstanding in other biomechanical study. Peindl et al. (21) performed a study towards biomechanical stability in proximal tibia fracture using double plate construct, locking plate system, hybrid external fixator, and single lateral periarticular plate. Each fixating methods were tested under sequential conditions of axial, varus rotation, and posterior rotation force. The double plating technique was found to be significantly stiffer for each parameters versus the other three fracture fixation constructs.

The advantages of using a dual plate technique are as followed ; first, the dual plate technique can acquire firmer internal fixation than the single plate technique. Secondly, the surgical technique does not require complicated manipulation compare to other surgical intervention such as fixation of proximal humerus fracture using interamedullary fibular allograft. Lastly, in comparison with other arthroplasties, our method can deduct successful osteosynthesis and adequate bone healing by performing autologous or allogeneous bone graft, instead of metal implants, which has limited durability and require challenging revision arthroplasty in future. Nevertheless, this operation remains technically demanding than conventional single LCP operation, because inexperienced surgeon, extreme



**Figure 6.** — Operation time of each operation cases. The operations time was levelled out and became stable after 12<sup>th</sup> operation.

osteoporosis, and extreme comminution, these are the factors that make this surgery more difficult. As mentioned above, the average operation time was 151.2 minutes (range of 236-110 minutes). The operation time was levelled out and became much more stable after 12<sup>th</sup> operation. It is plausible that requirement to get familiar (Learning curve) with this operation is 12 times. (Figure 6) However, the operation time may vary according to the condition of bone quality and other concomitant injury. We haven't exactly time the operation time of C-arm image intensifier, but we assume the irradiation time weren't be much different than average irradiation time of conventional single LCP operation. Main reduction is retained by proximal humerus LCP, just as single LCP operation. VALCP distal radius plate only functions as buttress, and bridge plate to give additional stability to the construct. Additional operation of C-arm image intensifier is needed to just check the screw length after placing the VALCP distal radius plate.

Prior to surgical intervention, blood supply and bone quality must be assessed. Metaphyseal extension of the humeral head of less than 8 mm, and medial hinge disruption of more than 2 mm can be predictive indicators for vascular injury. Metaphyseal extension of the humeral head, accompanied with medial hinge disruption of more than 2 mm, and an anatomical neck fracture pattern has 97% positive value for future development of AVN (22).

Cortical thickness of humeral diaphysis is very important predictor for bone mineral density which is essential for successful osteosynthesis (22).

Out of 21 patients with severely comminuted proximal meta-diaphyseal humerus fracture with medial hinge disruption, 20 patients acquired improved ROM of shoulder with successful bone union rate of 95.2%. Yet, 86 years old female patient with severe comminution of proximal meta-diaphyseal humerus also had received dual plate technique with adequate reduction. The alignment and reduction state was well maintained at 4 months postoperatively. However, the patient was lost for follow up until 25 months postoperatively. The last followed up X-ray showed avascular necrosis of humeral head. The T-score (BMD) of following patient was revealed to be - 4.5 (Figure 4).

Three types of complications were noted in this study; impingement, frozen shoulder and avascular necrosis. Impingement is a complication that comes from improper technique caused by a lateral plate being positioned too high. Frozen shoulder arises the most often from patients not exercising actively. It is rather from inadequate rehabilitation than improper surgical technique. In old age patient with severely comminuted proximal humerus entailed with osteoporosis, who lacks the potential of osteosynthesis and has possibility of developing avascular necrosis, total or reverse total shoulder arthroplasty should be considered rather than dual plate technique. But In relatively younger patients with comminuted complex proximal humerus fracture, with loss of function of posteromedial buttress, we think that the use of a dual plate could provide stable fixation and prevent with complications of varus collapse, AP angulation, screw cutout, nonunion, malunion, and hardware failure.

Our study has several limitations. First, because our study design did not compare dual plate fixation to other treatment methods currently being used, areas of future research remain. Second, biomechanical study of dual and single plate toward proximal humerus fractures is needed. And lastly, the database of this research in this area is limited to only 21 patients.

## CONCLUSION

Although our study is limited and further research is necessary, the dual plate technique may represent another reliable surgical treatment for severely comminuted proximal humerus fracture in relatively younger patients with preserved rotator cuff.

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