

An Anterosuperior Deltoid Splitting Approach for Plate Fixation of Proximal Humeral Fractures

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Background: The purpose of this study was to evaluate the usefulness and safety of the anterosuperior deltoid splitting approach for fixation of displaced proximal humeral fractures by analyzing the surgical outcomes.

Methods: Twenty-three patients who could be followed-up for at least 8 months after the treatment of displaced proximal humeral fractures through the anterosuperior deltoid splitting approach were enrolled. We evaluated the reduction of the fractures and surgery-related complications at the last follow-up using X-ray results and clinical outcomes comprising the University of California at Los Angeles (UCLA) scoring system and the Korean Shoulder Society (KSS) score.

Results: At the last follow-up of patients treated using the anterosuperior deltoid splitting approach for internal fixation of proximal humeral fractures, we found 22 cases (95.6%) of bone union, a mean UCLA score of 28.3 (range, 15 to 34) and a mean KSS score of 82.1 (range, 67 to 95). Various surgery-related complications were noted; a case of varus malunion after fracture displacement, a case of nonunion, a case of delayed union, two cases of impingement, and a case of partial axillary nerve injury, which recovered completely through the follow-up.

Conclusions: Plate fixation using the anterosuperior deltoid splitting approach could be another reliable option for treating displaced proximal humeral fractures.

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Key Words: Humerus; Anterosuperior deltoid splitting approach; Minimally invasive plate osteosynthesis

Introduction

Fractures of the proximal humerus, a relatively common type of fracture, compose 5% of all fractures of the bone. Their numbers are increasing with the growing aged population.¹⁾ As stable fractures in most individuals, they are successfully treated in 80% of nonsurgical interventions. However, unstable fractures with severe displacements or comminution require surgical interventions of anatomical reduction and internal fixation that allow shoulder function-restoring joint exercises to be implemented early on.²⁾ Various surgical interventions exist for proximal humeral fractures and the recently developed locking compression plates for fixation are considered as effective tools for osteosynthesis of fractures of the proximal humerus.³⁾

Different approaches for fixation of locking compression plates are used by orthopedic surgeons. For example, the deltopectoral approach commonly disrupts vascular supply to the fracture site and aggravates displacement of fractures. Abundant vascular supply is compromised by the invasive skin incision and unnecessarily large dissection of the soft tissue during the surgical intervention. Knock on effects of a compromised vascular supply are complications such as deep infection, bone nonunion, delayed bone union, and avascular necrosis of the humeral head. Further, fractures are displaced even more by the need to laterally pull the deltoid and internally rotate the shoulders to insert plates. As an alternative to this approach, the authors have employed a minimally invasive plate fixation technique using the anterosuperior deltoid splitting approach. We used this

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approach to treat proximal humeral fractures and evaluated its usefulness and safety by analyzing the surgical outcomes.

Methods

Subjects of Study

From November 2010 to February 2012, we enrolled 23 patients, who were able to participate in a prospective follow-up study of at least 8 months, with displaced fractures of the proximal humerus for an anterosuperior deltoid splitting approach of internal plate fixation. The mean follow-up period was 15.9 months (range, 8 to 23 months). The mean age of the study subjects was 64 years (range, 36 to 83 years), and of these 69.5% (16 patients) were over the age of 60. The study subjects comprised of 8 males and 15 females, and the fractures were on the right shoulder in 11 patients and on the left in 12. The mode

of injury was a fall in 18 cases (78.2%), accidents on either the road or a fall in 4 (17.3%) and 1 (4.3%), respectively. A total of 8 patients (34.7%) had a combined-injury; a fracture in a different region in 6 patients, an injury in the ulnar nerve in 1, and a ligament injury of the knee in 1. A total of 13 patients (56.5%) had an underlying disease; hypertension in 7 patients, diabetes in 5, hypothyroidism in 2, rheumatoid arthritis in 1, asthma in 1, and chronic obstructive pulmonary disease in 1. According to Neer's classification of fractures,⁴⁾ 4 patients had a 2-part fracture (17.3%), which also connected to the neck, 17 patients had a 3-part fracture (73.9%); of which 15 patients had fractures connected to the neck from the greater tuberosity and 2 from the lesser tuberosity, and lastly 2 patients had a 4-part fracture. According to the Müller AO fracture classification, 4 patients had a type A2 fracture, 10 had type B1, 6 had a type B2, 1 had type B3, and 2 had type C2. According to the Lego fracture classifica-

Table 1. Patient Demographics

| Case No. | Age (yr)/sex | Underlying disease | Associated injury | Neer classification | AO classification | Lego classification | Complications | Clinical results | |
|----------|--------------|---------------------|---|---------------------|-------------------|---------------------|-----------------------|------------------|-----|
| | | | | | | | | UCLA | KSS |
| 1 | 71/F | HTN | - | 4 Part | C2 | 12 | - | 30 | 83 |
| 2 | 76/M | - | - | 3 Part | B1 | 7 | Non-union | 15 | 77 |
| 3 | 72/F | - | Femur trochanter fracture | 3 Part | B2 | 7 | - | 30 | 88 |
| 4 | 72/F | - | - | 3 Part | B3 | 7 | - | 31 | 84 |
| 5 | 81/M | - | - | 3 Part | B1 | 7 | Impingement | 24 | 67 |
| 6 | 79/F | HTN | Cubital tunnel syndrome | 3 Part | B1 | 7 | - | 33 | 91 |
| 7 | 40/F | Hypothyroidism | - | 3 Part | B1 | 8 | - | 33 | 86 |
| 8 | 70/F | HTN, hypothyroidism | - | 3 Part | B2 | 7 | - | 32 | 92 |
| 9 | 67/F | DM, RA | Ulnar olecranon fracture | 2 Part | A2 | 1 | - | 29 | 77 |
| 10 | 36/F | - | Distal radius fracture | 3 Part | B1 | 7 | - | 30 | 91 |
| 11 | 69/F | DM | Knee MCL rupture | 4 Part | C2 | 12 | Fixation loss | 26 | 75 |
| 12 | 60/F | - | - | 2 Part | A2 | 1 | - | 30 | 83 |
| 13 | 76/F | DM | - | 3 Part | B1 | 7 | - | 18 | 68 |
| 14 | 63/F | DM, HTN | - | 3 Part | B2 | 7 | - | 18 | 69 |
| 15 | 77/F | Asthma | Distal radius fracture | 3 Part | B1 | 7 | - | 34 | 88 |
| 16 | 55/F | - | - | 3 Part | B2 | 7 | - | 31 | 84 |
| 17 | 74/M | HTN, COPD | - | 3 Part | B2 | 7 | - | 29 | 88 |
| 18 | 83/M | DM | - | 3 Part | B1 | 7 | - | 27 | 75 |
| 19 | 52/M | HTN | Scapular spine fracture Fibular shaft segmental fracture | 2 Part | A2 | 1 | Axillary nerve injury | 34 | 94 |
| 20 | 57/M | HTN | - | 2 Part | A2 | 1 | - | 28 | 75 |
| 21 | 41/M | - | - | 3 Part | B1 | 7 | Impingement | 34 | 95 |
| 22 | 77/F | - | - | 3 Part | B1 | 7 | - | 25 | 76 |
| 23 | 45/M | - | Nasal bone fracture | 3 Part | B2 | 7 | Delayed union | 30 | 83 |

UCLA: University of California at Los Angeles scoring system, KSS: Korean Shoulder Society score, M: male, F: female, HTN: hypertension, DM: diabetes mellitus, RA: rheumatoid arthritis, COPD: chronic obstructive lung disease, MCL: medial collateral ligament.

tion, 4 patients had a type 1 fracture, 16 had type 7, 1 had type 8, and 2 had type 12. Finally, 8 and 15 patients enrolled into our study had a preoperative varus or valgus deformity, respectively (Table 1).

Treatment Methods

Under general anesthesia, the patients were treated in a beach-chair position. An image intensifier was used to assist surgery. First, two incisions were made; a proximal incision and a distal incision. The proximal incision, which axially opens a skin section, 5 cm in length, posterior to the anterolateral acromion, exposes the deltoid. The distal incision axially opens a skin section above the humeral shaft that is sufficiently away from the fracture. When making both incisions, we cared not to injure the axillary nerve and the brachial circumflex artery, and cared to minimize soft tissue dissection so that we could maximally preserve vascular supply to the fracture site. Through these incisions, we used the anterosuperior deltoid splitting approach, the process by which the proximal humerus is exposed, to reduce the fracture. The anterosuperior deltoid splitting approach sepa-

rates the thin lining of fat between the anterior and the middle deltoid region. The axial separation or split exposes the bone, after a tunnel that runs to the proximal humerus is made without injuring the axillary nerve. Then, through the distal incision, the displaced humeral head, displaced greater tuberosity or the lesser tuberosity were reduced.

K-wires were used for temporary fixation of the reduced fractures. Then, an image intensifier was used as a quick method to confirm the reduction. The proximal incision was used to approach distally and insert the Philos plating system (Synthes, Oberdorf, Switzerland), and during this, traction to the deltoid and axillary nerves was minimized by maneuvering the shoulder with slight abduction to prevent injury to the axillary nerve. The axillary nerve was covered up manually using the surgeon's fingers, and the plate was inserted in between the nerve and the outer surface of the proximal humerus.

The proximal end of the plate was positioned posterior to and level to the peak of the greater tuberosity. K-wires were used for temporary fixation of the plate while keeping in mind to prevent plate-induced acromial impingement. Through the

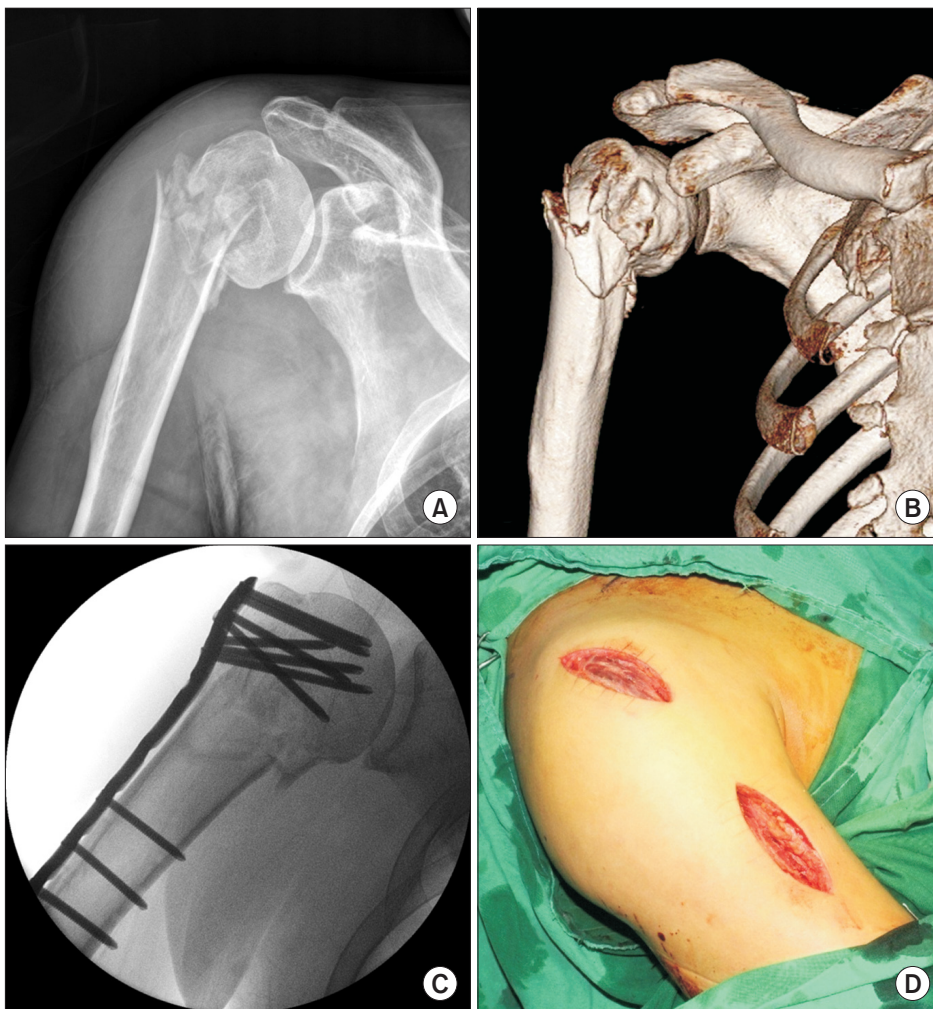


Fig. 1. A 52-year-old male sustained a proximal humeral fracture by a fall to the ground. (A) A radiograph shows a 2-part displaced fracture of the proximal humerus. (B) Reconstructed three-dimensional computed tomography scan show a marked displacement of a fracture fragment with varus angulation of the neck-shaft angle. (C) A radiograph taken during the operation shows the changing of the neck-shaft angle from a varus to a valgus angulation by valgus forcing of the distal humeral fragment. (D) An intraoperative photo shows the anterosuperior deltoid splitting approach.

distal incision, we gradually moved the plate against the wall of the humeral shaft using cortical screws. In case of varus angulated humeral heads in certain patients, the plate was nevertheless placed as adjacent to the humeral shaft as we could so that the proximal end of the plate could provide the support for the displaced humeral head. In case of varus deformity, the proximal fragment was forced laterally to the distal fragment to make a valgus angulation, and cortical screws were used to fix the plate to the shaft. If the proximal and distal medial cortical bones touched and varus deformity impended, locking screws were used for additional fixation to prevent varus deformity (Fig. 1). The locking screws were fixed through the proximal incision. This anterosuperior deltoid splitting approach typically does not allow internal support screws plate for fixation to be used due to high risk of axillary nerve injury. Thus, permanent fixation of the plate was achieved through the rotator cuffs using non-absorbable sutures to reduce a displaced fracture of the greater tuberosity. Even where a greater tuberosity fracture was not found, non-absorbable sutures were used for additional fixation.

To prevent postoperative stiffness, pendulum exercise was begun a week after acute pain dissipated, and active assisted exercises were begun after 3 weeks. After bone union was radiologically confirmed, muscle strengthening exercises were implemented.

Clinical Assessment

Postoperative surgical outcomes were assessed by pain, function, range of motion, and muscle strength of the affected arm. Postoperative level of patient satisfaction was assessed using the University of California at Los Angeles (UCLA) scoring system⁵⁾ and the Korean Shoulder Society (KSS) score.⁶⁾ Postoperative and follow-up radiographs were used to confirm reduction of fractures and bone union. Radiographs were used to detect any complications such as infection, shoulder joint stiffness, and loosening of internal fixatives.

Results

Using the anterosuperior deltoid splitting approach for internal fixation of proximal humeral fractures, we achieved 22 out of 23 bone unions (95.6%). For postoperative shoulder range of motion (ROM), we found a mean forward elevation of $133^\circ \pm 9.2^\circ$ (range, 90° to 160°), a mean external rotation of $52^\circ \pm 8.4^\circ$ (range, 30° to 80°), and a mean internal rotation at the 12th thoracic vertebra (range, 6th thoracic vertebra-sacrum). For clinical outcome, we found a mean UCLA score of 28.3 (range, 15 to 34); 3 cases of 'excellent' scores; 12 'good'; and 8 'poor', and finally, we found a mean KSS score of 82.1 (range, 67 to 95). The mean waiting period for treatment was 7.3 days (range, 1 to 46 days), and the mean duration of time the patient was under anesthesia was 144 minutes (range, 85 to 205 minutes). The range

of blood loss during surgery was 30 to 300 ml. The Philos plating system was used without internal support screws in all patients.

In terms of surgery-related complications, we found a total of 6 complications; a case of varus deformity induced by re-displacement of the fracture, a case of nonunion, a case of delayed union, 2 cases of subacromial impingement syndrome, and a case of partial injury of the axillary nerve. In the case of re-displacement of the greater tuberosity fracture, the re-displacement resulted from loosening of the locking screws around 5 weeks after the operation without any obvious external signs. Despite recommendations for revision, the patient refused revision surgery and the bone fused as displaced. For the case of nonunion of the fracture, despite 6 weeks of watchful waiting, pain persisted, the fracture was mildly displaced, and bone union did not form. Thus, the patient was referred to us for a secondary surgery. During the surgery, bone substitutes to fill the severe bone deficits at the medial humeral head were needed. After 4 weeks of surgery, radiological tests showed a successful reduction and a forward elevation of 90° of the arms. After 6 weeks of surgery, even though the patient complained of pain without any particular injury, radiological tests showed a maintained reduction and normal callus formation. After 4 months of surgery, we found that bone absorption began, and at 5 months, we found loosening of the locking screws. Despite this, since callus formation and progressive signs of bone union began to show in parts, we decided to maintain our vigil. However, bone union did not occur even after one year of surgery, so although a bone transplantation was advised, the patient refused to continue with further treatment. In the 2 cases of subacromial impingement syndrome, both patients showed amelioration of symptoms after the locking plates were removed. After 10 days of the plate removing surgery, although an electromyography showed a loss in nerve conduction of the deltoid muscle in one patient, marking an injured axillary nerve, the injury naturally resolved later on.

Discussion

Numerous surgical treatments for displaced proximal humeral fractures exist. Yet, a standardized, systematic approach that can be routinely applied has not been devised. Many studies have used the delto-pectoral approach to make an open reduction and internal plate fixation to treat displaced proximal humeral fractures. However, over-dissection of the soft tissue, unnecessary traction or compression of the deltoid root, avascular necrosis induced by damaged brachial circumflex artery, bone nonunion, bone malunion, and infections are commonly associated complications of this approach.⁶⁻¹³⁾ B athis et al.¹²⁾ have also shown that during open reduction and internal plate fixation of 3-part or 4-part fractures of the proximal humeral head are associated with a 16% prevalence rate of avascular necrosis, whereas during minimally invasive fixation, this association is reduced to

9%. Similarly, Egol et al.¹⁴⁾ showed that, even during open reduction, when dissection of the soft tissue and injury to the vascular tissue is minimized, avascular necrosis occurs less.

In order to minimize the associated complications to the delto-pectoral approach, the authors used an alternative antero-superior deltoid splitting approach to treat displaced fractures of the humeral head. The anterosuperior deltoid splitting approach separates the line forming between the anterior and the middle section of the deltoid and minimizes dissection of the soft tissue whilst preserving bone vascularization as much as possible. Further, as only a sufficient amount of internal rotation is required for bone reduction, reduction is likely to be maintained more successfully. This approach has been used previously for plate fixation during reduction of proximal humeral fractures, humeral shaft fractures, and rotator cuff injuries.^{15,16)} Gardner et al.¹³⁾ have also used this approach in 16 patients with fractures of the proximal humerus. However, a disadvantage of this approach is that it is associated with high incidence of axillary nerve injury.¹⁷⁻¹⁹⁾ Axillary nerves are in fact one of the most commonly injured nerves during shoulder-related surgeries.²⁰⁾ Gardner et al.¹³⁾ reported that the axillary nerve is positioned on average 63.3 mm lateral to the acromion and 35.5 mm posterior to the greater tuberosity of the humerus. Thus, due to the close proximity of the proximal humerus and the axillary nerve, the anterosuperior deltoid splitting approach does not allow insertion of internal support screws at the posteromedial sides of the proximal humerus. Since the authors could not insert internal support screws, we aimed to anatomically reduce the posteromedial calcar, which is an important structure that maintains reduced humeral heads, by as much as possible. Nevertheless, other surgeons have shown that if the lateral 5 cm²¹⁻²³⁾ or 4.2 cm²⁴⁾ of the acromion is not disturbed during the deltoid splitting,²¹⁻²³⁾ the axillary nerve will be preserved. However, this also shows that variations exist as to the exact region which the surgeons regard as a 'safe zone'. Thus, on a patient-by-patient basis, surgeons should be aware of the axillary nerve by keeping an eye on it by touch when skin incisions are made.

In our study, we found a case of axillary nerve injury diagnosed using an electromyography after 10 days of surgery. We suspect that the injury was not incurred during surgery, but indirectly from traction to the deltoid muscle. We found that the complication resolved by itself at the outpatient's follow-up, and an electromyography after 2 years showed a healthy axillary nerve.

We used the UCLA scoring system and KSS score as indicators of clinical outcome after surgery. We found poor UCLA scores in 8 patients, but the average age of these patients was 72.7 years, being above that of the total patients. Further, the average ROM of these 8 patients in terms of internal rotation was at the sacrum, which is also below average of the whole study group. The UCLA scoring system comprises of 5 parts; pain,

function, ROM, muscle strength, and patient satisfaction. Each part is scored with marks out of 10, 10, 5, 5, and 5, respectively, giving a total possible mark of 35. Despite scoring highly in the rest of the sections, these 8 patients received an overall poor UCLA score because they had difficulty performing the Brassiere body motion in the ROM section, therefore receiving only 4 out of 10 marks.

Lin et al.²⁵⁾ carried out a plate fixation of displaced proximal humeral fractures in a total of 86 patients. In 43 patients, they carried out a standard delto-pectoral approach and in the other 43 patients, a deltoid-splitting approach. At the 12-month follow-up, they did not find a statistically significant difference in the Constant-Murley score between patients of different treatment groups. However, at the 3- and 6-month follow-up, better clinical outcomes were seen for the deltoid-splitting approach group in terms of pain, satisfaction levels in daily activities, and ROM. Despite disadvantages of the deltoid-splitting approach in that it can potentially damage the axillary nerve, sometimes needs rotational revision, and cannot use internal support screws, it has the advantage that the fracture can be approached with minimal invasion. This means soft-tissue damage-induced complications can be reduced, and excessive traction of the deltoid and internal rotation of the shoulder, which are required for the delto-pectoral approach, can be avoided.

The limitations in our study were that no controls were taken and that the sample size was small. A subsequent study with controls and a larger sample size is needed.

Conclusion

In conclusion, we found that the anterosuperior deltoid splitting approach, a minimally invasive approach for plate fixation of displaced proximal humeral fractures showed satisfactory postoperative clinical and radiological outcomes. By using this approach, we minimized the amount of soft tissue dissection, and by doing so reduced the associated complications that can lead to recurrent displacement of fractures. We believe the anterosuperior deltoid splitting approach is a useful and safe treatment method for displaced fractures of the proximal humerus.

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