

An Anterior Approach to Entire Length of Humerus and to Distal Shaft for Fracture Fixation

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Background: The aim of study was to confirm the clinical effectiveness and results of wide and single anterior approach for fractures occurring along length of humerus.

Methods: A total of 23 patients with humeral fracture were enrolled into our study who were able to participate in at least one year of follow-up. Seven patients had segmental comminuted humeral fractures and 16 patients had distal humeral fractures. We made various tractions of the muscles to expose the proximal and the middle third humerus between the biceps and brachialis and the distal humerus by partial splitting of lateral side of biceps through a single incision. Postoperatively, we measured the Mayo elbow performance index (MEPI).

Results: we achieved bone union in all 23 patients. Solid union of the bone was achieved at an average 13.9 weeks. Postoperatively, two complications were observed screw loosening and nonunion. Revision surgery was performed in both patients. The patient with bone nonunion was treated using bone grafts. No postoperative infections or peripheral neuropathies were observed. At the final follow-up (average 20 months), we found that the average MEPI functional score of the patients was 91.7 points regardless of the fracture site.

Conclusions: Our whole humerus with a single incision was effective for the treatment of segmental comminuted and distal fractures. we believe it is a useful alternative to preexisting methods of fracture fixation.

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Key Words: Humerus; Humeral shaft fractures

Introduction

Conservative treatment of humeral fractures is associated with risks of complications such as shoulder stiffness and malunion, resulting from long-term cast immobilization.^{1,2)} So physicians tend to recommend surgical treatment for humeral fractures to not only avoid these risks but also achieve earlier joint exercises and accelerated return to daily activities. Factors to consider for the treatment for humeral fractures include the type of fracture, patient's age, and the presence of co-morbidities, such as osteoporosis. Various methods of surgical treatment exist to repair fractures with techniques such as plating, minimally invasive plating, intramedullary nailing, and external fixation, yet the gold

standard for treatment remains controversial.³⁾ Of the current surgical treatments, the most standard method for the accurate reduction of humeral fractures is the internal fixation with plating. However, the extensive approach of this method has been shown to be associated with complications such as injury to the soft tissue and to the periosteum around the fracture site; bleeding; non-unions; injury to the radial nerve and the musculocutaneous nerve; and deep infection. In addition, the morphological characteristics of the humerus necessitate contouring of the plate through bending and rotation, and this manipulation is dependent on individual fracture sites. And during internal fixation with plating the position of the plate and the type of approach to the humerus are determined by inherent anatomical

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features of the humerus. For instance, the anterolateral approach is used for fractures of the proximal to the middle third humerus, whereas the lateral approach and the posterior approach are used for fractures approaching the distal end of the humerus. Especially, the open single approach for comminuted and segmental fractures along the entire length of the humerus and the minimally invasive method for distal humeral shaft fractures both are dependent on anterior approach for good clinical outcomes.

From September 2008, we performed a wide anterior surgical approach for humeral fractures without exposing any neurovasculature and without causing much soft tissue injury. We believe that this approach will be particularly effective for comminuted humeral fractures and for segmental ones because the wide anterior approach allows in a single incision to access the entire length of the humerus. Unlike the standard procedure that generally requires the use of multiple approaches (a combination of the proximal anterolateral, the lateral middle third, and the distal posterior approaches), the wide anterior approach can be used alone for fractures scattered across the whole humerus. With our wide anterior approach, the treatment of comminuted and segmental fractures encompassing the entire length of the humerus and of distal fractures that would otherwise be difficult has become feasible. In this study, we investigated the clinical outcomes of this approach for humeral fractures.

Methods

Subjects of Study

We enrolled a total of 23 patients on whom we carried out internal fixation using anterior plating for either segmental or distal humeral fractures between September 2008 and December 2014. The average postoperative follow-up period was 20 months (range, 12–45 months). Our patients consisted of 19 men and 4 women and had an average age of 45.6 years (range, 17–84 years). The indications for surgery were patients with unstable humeral fractures for which reduction was unfeasible using preexisting methods. Using the AO/OTA classification, we classified the fractures into three subgroups: 12 patients had type A fractures; 7 patients had type B fractures; and 4 patients had type C fractures. We also classified the patients with respect to fracture site: 16 patients had distal humeral fractures and 7 patients had segmental fractures that were found along the entire length of the humerus. We excluded patients with pathological fractures, refractures, or type III or above open fractures from recruitment (Table 1).

Surgical Approach

The operation was performed with the patient under general anesthesia and in supine position and the affected arm in abduction. Tourniquets were not used throughout the surgery. To reach the proximal humerus, we made a skin incision using the

Table 1. Cases Analysis of Anterior Plating of Whole Humerus Fractures (Total 23 Cases)

| Variable | Value |
|--|---|
| Period (year. month.) | 2008. 9.–2014. 12. |
| Sex (male:female) | 19:4 |
| Average age (yr) | 45.6 (17–84) |
| Fracture type by AO/OTA by fracture site | A: 12, B: 7, C: 4 Distal: 16, segmental: 7 |
| Average bony union rime (wk) | 13.9 (9–28) |
| Complications | Nonunion: 1, screw loosening: 1 Initial radial palsy: 2* |
| Bleeding (ml) | 170.8 (15–300) |
| Operation time (min) | 112.3 (60–215) |
| Average follow-up duration (mo) | 20 (12–45) |

Values are presented as range only, number only, or median (range).

*Number/total number=4/23, 17.4%.

delto-pectoral anterior approach. The incision was made from the coracoid process following the anterolateral biceps brachii whilst preserving the cephalic vein. We then folded the biceps brachii medially and confirmed the brachialis at the proximal attachment site of the deltoid. Next, using the boundary between the biceps muscle and the humeral muscle to gauge the position of the proximal humerus, we pushed apart the humeral muscles longitudinally to expose the underlying proximal humerus. To reach the middle third humerus, we used the same method as that used to make an incision to reach the proximal humerus but exposed the middle third humerus by pushing apart longitudinally the corresponding section of the brachialis muscle. We were able to make the incision for the middle third humerus without difficulty because the incision site was independent of potentially problematic nerves such as the radial nerve, which does not run within the intramuscular regions of the humerus, and the musculo-cutaneous nerve, which situates in the posterior biceps tendon. To reach the distal humerus, we exposed the middle third humerus through longitudinal bisecting the brachialis and safely accessed the anterior humerus (Fig. 1, 2).

Flexing the elbow by 90° relaxes the humeral muscles and makes the anterior approach much easier, so we flexed the patient's arms in this way during the operation. We limited the periosteal dissection to the region of damaged periosteum by the fracture and to the anterior periosteum where anterior plating will be carried out. We did not make additional dissections of the soft tissue or of the periosteum for the reduction of the posterior fractures unless we thought that stability of the reduction would otherwise be compromised. We were able to position the plate anteriorly even for proximal humeral fractures by reaching the muscles of the middle third humerus between the deltoid and the biceps muscles. Because of the biceps tendon

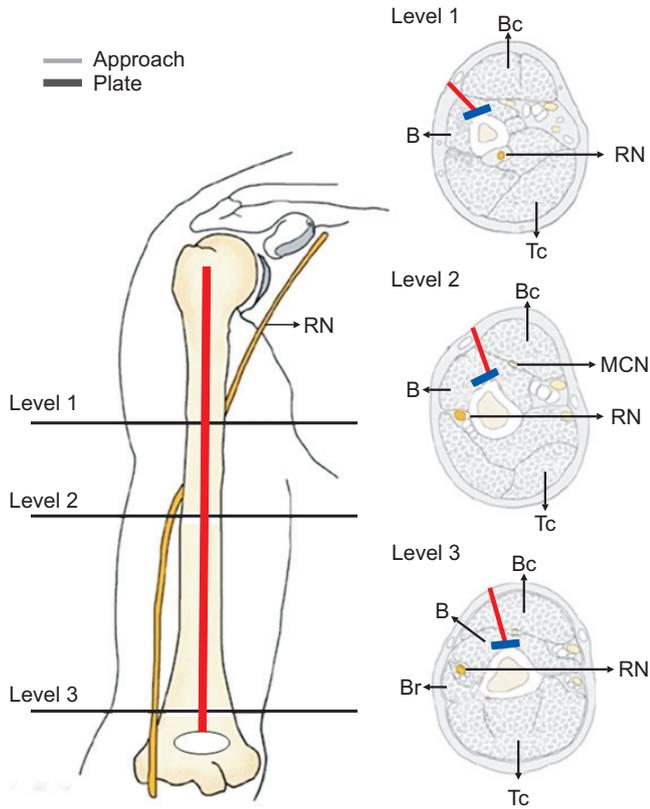


Fig. 1. Schematic illustration of anterior whole humerus approaches. B: brachialis, Bc: biceps brachii, RN: radial nerve, Tc: triceps brachii, MCN: musculocutaneous nerve, Br: brachioradialis.

long head, anterior plating as performed more laterally the nearer it was positioned proximally.

We used a 4.5 mm narrow-locking compression plate (Synthes, Oberdorf, Switzerland) for all patients. Generally, plate fixations require contouring of the plate, which involves prebending the plate or positioning it at an angle over the fracture site in a way that the plate fits around the bone contour. Unlike standard procedures, our anterior approach does not require modifying the plate; rather, we positioned the plate in its flat form at the anterior corner, which is where the anterolateral cortical bone and the anteromedial cortical bone meet (Fig. 3, 4). Inherent features of the locking plates mean that when the plate forms a cortical contact with the fracture site, there forms a small space between it and the reduced humerus. If needed, we carried out additional screw fixation or cerclage wire fixation to stabilize this area.

Assessment

We assessed the intraoperative and the postoperative parameters of surgery. Intraoperatively, we assessed the feasibility and ease of making an anterior approach to the fractures of the humerus. Postoperatively, we assessed the shoulder and elbow range of motion periodically in relation to the anterior position

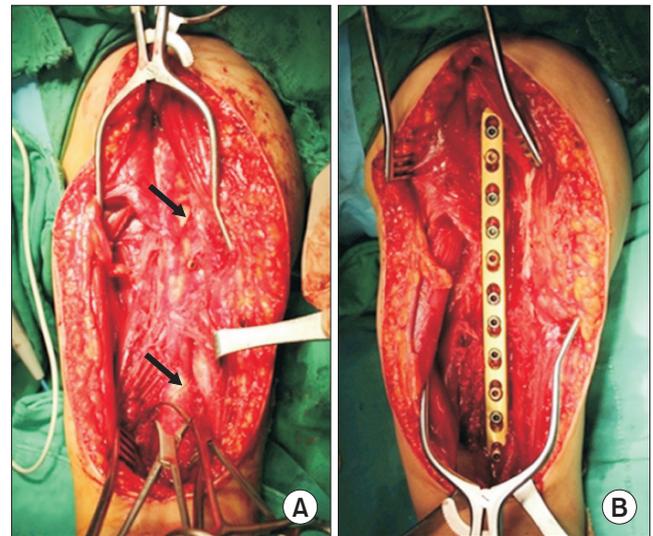


Fig. 2. (A) Anterior approaches for whole humerus without further dissection of posterior periosteum on whole humerus, soft tissue and radial nerve (arrows; fracture site). (B) No prebending or twisting of 4.5 mm locking plate on anterior cortex of whole humerus.

of the plate and, radiologically, callus formation and bone union. At the final follow-up, which was on average 20 months postoperatively (range, 12–45 months), we evaluated parameters such as shoulder pain, radiological features, range of motion, bony deformities of the elbow, complications such as radial nerve palsy, and the Mayo elbow performance index (MEPI) for shoulder function.

Results

We found that the wide anterior approach was useful for the treatment of fractures irrespective of the AO/OTA classification type and of the fracture site. Although two patients presented with radial nerve palsy at the time of injury, we judged by the extent of fracture spicule displacement that the condition would be self-limiting. Thus, we did not expose the radial nerve forcibly during the anterior surgical approach. Indeed, we found that radial nerve palsy in the two patients resolved by the 9th postoperative month. The average time to bone union for the 23 fractures was 13.9 weeks (range, 9–28 weeks). We observed two cases of postoperative complications: bone nonunion and screw laxity. We used a bone allograft for the patient whose fracture did not heal by the 16th postoperative month and substituted a new screw for the patient with a loosened screw. In both instances, we observed successful bone union within 12 weeks of revision surgery (Table 1).

All patients were administered cast immobilization of the long arm for two postoperative weeks, after which the patients were begun on flexion-extension motions of the elbow. By the third postoperative month, all elbows recovered their normal func-

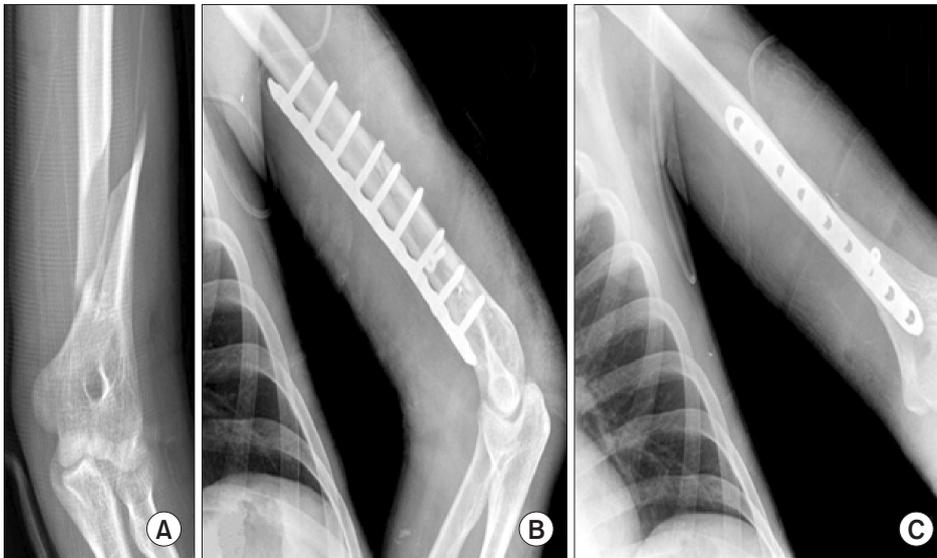


Fig. 3. (A) A 22-year-old female with long spiral distal humeral fracture. (B, C) The anterior plating done with additional screw fixation upto the olecranon fossa.

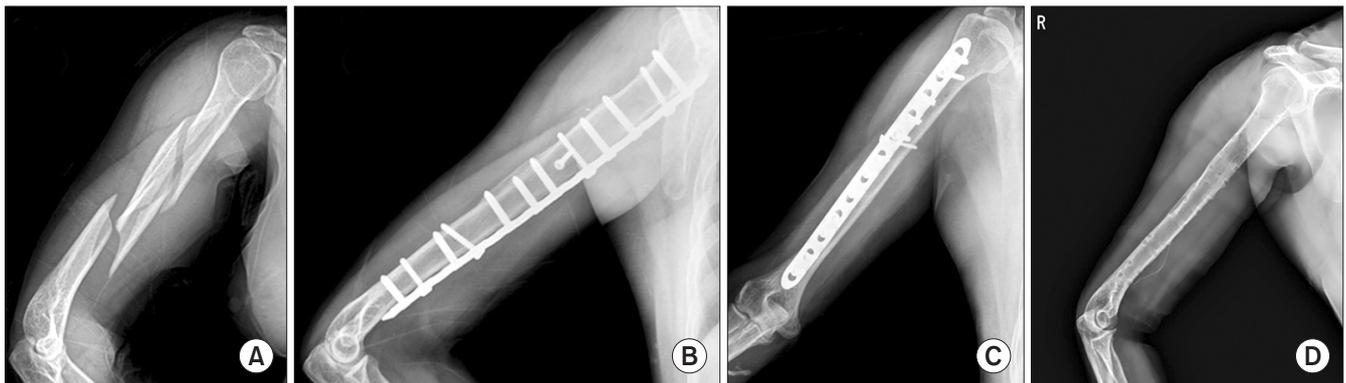


Fig. 4. (A) A case of comminuted spiral segmental humeral fracture of 62-year-old woman. (B, C) Postoperative radiograph on the 10th months shows solid union of fracture, and also full ranges of shoulder and elbow motions with excellent results by Mayo elbow performance index, 93 points. (D) She was full range of motion possible after metal removal operation 18 months later.

tional performance. Thus, our internal plate fixation of the anterior humerus did not debilitate elbow function. We also found that the average MEPI, our indicator of functional performance, was 91.7 points, being fair in all patients but two (2/23, 8.7%). We found that the clinical outcomes of our anterior approach were similar to those of other approaches for various humeral fractures (Fig. 3, 4, Table 2).^{4,17)}

Although our anterior approach was associated with postoperative complications such as non-union and screw laxity, it was not associated with complications like infections and mal-union. We also found that neither the type of AO/OTA classification nor the fracture site influenced the period to bone union.

Discussion

Internal fixation through either plating or nailing after open reduction of humeral fractures has been associated with good

Table 2. End Results after Anterior Plate for Whole Humerus Fractures by MEPI in 23 Cases

| Result | Value |
|-----------------|--------------|
| Mean MEPI | 91.7 |
| Excellent (>90) | 16/23 (69.6) |
| Good (75–89) | 5/23 (21.7) |
| Fair (60–74) | 2/23 (8.7) |
| Poor (<60) | 0 (0) |

Values are presented as mean only or number/total number (%). MEPI: Mayo elbow performance index.

clinical outcomes.^{4,5)} Most humeral fractures occur in the middle third or at the distal border of the humerus, which is where a configuration change occurs from a single circular cross-section to the tip of triangular cross-sections. This has meant that stan-

Standard plate fixation procedures must position the plates over the relatively flat anterolateral face of the humerus, followed by contouring of the plate through bending or rotation so that the plate is shaped along the bone surface. Such anatomical configuration at the site of fixation deterred the use of minimally invasive treatment for distal humeral shaft fractures.

Unlike the lateral approach to the humerus, the anterior approach (Fig. 1, 2) does not require the traction of the musculocutaneous nerve at the proximal humerus or of the radial nerve at the mid- and distal humerus. Because our anterior approach enables fixation of fractures along the entire length of the humerus with a single skin incision, this allows reduction of the fracture site by not only direct observation (meaning that chances of malunions are low) but also without needing to contour the plate. In addition, anterolateral plating generally requires the dissection of a large section of the anterolateral periosteum; whereas, the anterior plating requires only a minimum amount of dissection of the anterior periosteum. The anterolateral plating also requires excessive traction of the lateral muscles during screw insertion. For distal fractures the need to excessively retract the muscles becomes more pronounced (alternatively, a more lengthy incision into the muscles can be made), and a failure to meet the need leads to fixation loss. We used K-wires or reduction forceps to make and temporarily sustain the reduction and fixed the locking plates in neutralization against the relatively flat surface of the anterior humerus. We preserved the posterior fracture provided that it did not interfere with the overall alignment or the stability of the reduction.

The lateral approach to the humeral shaft has the advantage of enabling reduction of the fracture with the patient in the supine position, but because the distal deltoid is strongly attached to the region around the incision site a dissection of the attachment is necessary to access the proximal humerus. For fractures occurring below the middle third retraction of the radial nerve is always required. In addition, the lateral approach for internal plate fixation is associated with high risks of radial nerve injury, especially if the radial nerve is found in close proximity to the plate or adhered to the plate (the adhesion may be induced by fibrosis around the fracture site or by compression) or during plate removal. Risk of radial nerve injury resulting from adhesion of the nerve to the plate may increase with revision surgery for complications such as failed plating, refractures, and non-unions. Yildirim et al.⁶⁾ reported that the incidence of radial nerve injury after plate fixation using the lateral approach was 19 out of 72 patients.

The posterior approach to the distal humeral shaft has been preferred for its ease of plate fixation and accessibility to even fractures of the distal elbow.^{7,8)} However, several disadvantages of posterior approach have been reported by Rhee et al.⁹⁾ For instance, the incision of the triceps brachii has been shown to be associated with muscle weakness and with restriction in elbow

movement and the triceps brachii has been shown to directly obstruct the distal viewing window for the radial nerve, which altogether diminishes the accessibility to the lateral intermuscular septum. Another surgical approach for humeral fractures is the minimally invasive plate fixation, which was established to overcome complications associated with preceding methods, such as periosteal circulation defects and deep infection induced by incision and by soft tissue dissection. But the use of minimally invasive plate fixation has been limited because of the high level of radioactive exposure, malunion, and radial nerve injury associated with the procedure.^{6,10)} The anterior plate fixation used in this study does not require excessive traction of the lateral muscles, which meant that we were able to position the plate at the immediate-superior olecranon fossa even when fracture lines were found more distally than expected. Still, if the stability of the reduction was of concern, we inserted additional screws or cerclage wires at the fracture site (Fig. 3).

The properties of locking screws used in locking plates mean that the locking plates do not lend itself to movement of fractures in the superior-inferior configuration, facilitating a robust reduction.¹⁸⁾ As a result, postoperative displacement secondary to a loss in reduction is rare. And because the stability of plating does not depend on how stably the screw-bone contact is made, the locking plate method ensures an effective reduction even for comminuted and complex fractures (as in our study) and for osteoporotic fractures.^{11-13,18)} Therefore, inappropriate bending or rotation of the plates is not required, which often causes a loss in reduction. Rather, because plates can be stably fastened onto the anterior humeral shaft, we can use locking plates alone without bending through just the anterior approach for the internal fixation of fractures of any region of the humerus (distal through to the proximal end) (Fig. 4).

We observed a single case of postoperative complication associated with our wide anterior approach. An elderly female patient with a severe comminuted fracture and combined osteoporosis had presented with a lax screw. We performed a plate substitution to resolve successfully the complication, which comes to show that physicians must choose appropriate plates for patients with severe comminution. Yet the clinical outcomes associated with our wide anterior approach to the entire length of the humerus have been shown to be comparable to those associated with the lateral and the posterior approaches for internal fixation.^{9,14-16)} In sum, we propose that our wide anterior approach is effective for the treatment of comminuted and segmental fractures along the entire length of the humerus, of distal shaft fractures, and of humeral lesions.

Conclusion

In this study, we report the clinical outcomes associated with the wide anterior approach to treat fractures along the entire

length of the humerus—a procedure that we have employed since September 2008. Not only is this approach effective for segmental fractures of the humerus and for distal fractures that are difficult to treat by minimally invasive approaches, but it is also associated with less radial nerve injury and with minimal dissection of soft tissue. Technically, neither plate bending nor rotation is required for this approach, facilitating a relatively easy-to-perform and sturdy internal fixation. Further, we found that the wide anterior approach was not associated with any restrictions in elbow movement at the final follow-up. Thus, we propose that the wide anterior approach is effective for the treatment of fractures and lesions found along anywhere on the length of the humerus.

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