上腕骨近位端骨折の手術成績：順行性髄内釘とロッキングプレートの比較

Surgical outcomes of displaced proximal humeral fractures: antegrade intramedullary nail versus locking plate

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Running title

Antegrade intramedullary nail versus locking plate for displaced proximal humeral fractures

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INTRODUCTION

Proximal humeral fractures comprise the second most common type of fracture of the upper extremities in the elderly and account for 5% of all fractures in adults[1,2]. Particularly, adults aged ≥60 years are vulnerable to complex three- and four-part humeral fractures[3]. In 2005, approximately 12.8 million Japanese individuals suffered from osteoporosis and this number is gradually increasing[4]. Most patients with non-displaced or minimally displaced fractures are conservatively treated. However, displaced proximal humeral fractures often require surgical treatment, for which several surgical instruments have been developed.

Antegrade intramedullary nails or locking plates are the most commonly used surgical instruments for treating such fractures. However, achieving stable fixation is often difficult due to the comminuted medial fragment and osteoporosis background, particularly in the elderly. Several previous studies have assessed the use of antegrade intramedullary nails and locking plates for treating proximal humeral fractures[5-11]. However, there is no clear consensus regarding the optimal management of proximal humeral fractures.

The present study aimed to compare the postoperative shoulder range of motion (ROM) and complication rate in patients with proximal humeral fractures that were treated using antegrade intramedullary nails and locking plates at the Ryukyus University Hospital and affiliated hospitals. Fourteen experienced orthopedic surgeons were involved in this study, and the patients in this study are most likely to represent patients with proximal humeral fractures who underwent surgical treatment in Okinawa.

PATIENTS AND METHODS

Patient selection

Between 2008 and 2016, 108 proximal humeral fractures in 108 patients were treated with internal fixation using antegrade intramedullary nails or locking plates. The exclusion criteria included patients with open fractures, neurological injury-related fractures, and pathological fractures. All patients agreed to participate were included in the study, postoperative follow-up period were at least 12 months. The research protocol was approved by the Institutional Review Board of our institute (No. 388), and all patients provided written informed consent prior to initiating the study.

All procedures were conducted at the Ryukyus University Hospital and affiliated hospitals by one of 14 experienced orthopedic surgeons. The use of antegrade intramedullary nails or locking plates was dependent on the surgeon's preference. The 108 shoulders were categorized into two groups based on the method of internal fixation: N (antegrade intramedullary nails) and P (locking plates) groups (54 patients per group). Anteroposterior radiographs were used to assess the fracture type using the Neer classification. Accordingly, 42, 48, and 18 shoulders were found to have two-, three-, and four-part fractures, respectively. Cases were grouped as two-part fractures or three- and four-part fractures.

N group

Antegrade intramedullary nail fixation was performed using the New Straight Nail System® (Teijin Nakashima Medical, Okayama, Japan). The N group comprised 11 men and 43 women. Two-part fractures were found in 23 shoulders (5 men and 18 women) and three- or four-part fractures in 31 shoulders (6 men and 25 women). The mean patient age at operation was 67 (range, 35–91) years for two-part fractures and 70 (range, 46–85) years for three- or four-part fractures. The mean follow-up periods were 18 (range, 12–78) and 24 (range, 12–64) months for two-part and three- or four-part fractures, respectively (Table 1).

P group

The locking plate fixation was performed using the PHILOS® System (DePuy-Synthes, Solothurn, Switzerland). The P group comprised 15 men and 39 women. Two-part fractures were found in 19 shoulders (3 men and 16 women) and three- or four-part fractures in 35 shoulders (12 men and 23

women). The mean patient age at operation was 66 (range, 21–87) years for two-part fractures and 61 (range, 20–83) years for three- or four-part fractures. The mean follow-up periods were 19 (range, 12–48) and 23 (range, 12–114) months for two-part fractures and three- or four-part fractures, respectively (Table 1).

Surgical technique

In both groups, surgery was performed under general anesthesia with an interscalene nerve block with the patient placed in the beach-chair position. After reduction, antegrade intramedullary nail or locking plate was fixed. For patients with large bone defects, the iliac bone or alpha-tricalcium phosphate paste (artificial bone) with local cancellous bone chips was grafted.

N group

A longitudinal incision was made using the through anterolateral transdeltoid approach in the supraspinatus muscle by splitting the anterior and middle thirds of the deltoid muscle. Comminuted fractures were reduced using the deltopectoral approach. The nail was inserted near the top of the humeral head, which inevitably damages the cartilage of the humeral head. After nail insertion, a proximal interlocking screw was inserted from the lateral aspect of the humeral head. Subsequently, two or three distal interlocking screws were inserted at the deltoid insertion to avoid radial nerve injuries. Another proximal interlocking screw (from the anterior to posterior direction) and an end cap were also placed. Finally, the incised rotator cuff was closed using non-absorbable sutures (Figure 1).

P group

A longitudinal incision was made using the deltopectoral approach. Locking plates were placed in a lateral position to the bicipital groove and 1 cm inferior to the upper humeral greater tuberosity, laterally and posteriorly. Guidewires were inserted through the proximal holes of the plate, followed by distal fixation using cortical or locking screws. At least five locking screws were inserted into the humeral head; moreover, two locking screws were inserted to the humerus diaphysis (Figure 2).

Rehabilitation protocol

The postoperative rehabilitation protocol was similar for both N and P groups. Postoperatively, patient arms were immobilized using a sling and/or abduction pillow for 4–6 weeks. Postoperative passive ROM exercises were initiated 1–3 weeks postoperatively, and active ROM exercises were initiated 4–6 weeks postoperatively. For patients with three- or four-part fractures, longer durations of immobilization and slower ROM exercises were adopted.

Radiographic assessment

Shoulders were radiographically evaluated in the following three views: anteroposterior view in the scapular plane, lateral view of the scapula, and supine axillary view. Radiographs were obtained immediately after operation and at follow-up.

Radiographs were evaluated for bone union and complications. Any complications observed during the entire follow-up period were recorded, including fracture nonunion, avascular necrosis, varus deformity, and screw back-out. Union was defined as visible continuity of the cortical bone that could be assessed using at least two radiographic views. Postoperative avascular necrosis was classified using the Cruess classification[12]. Varus deformity was considered in cases with >20° deformity.

Clinical assessment

Active ROM was evaluated using forward flexion and external rotation, operation time, and blood loss in the N and P groups and then compared between subgroups classified by the type of fracture (two-part versus three- or four-part fractures). Patients were also classified into three age groups (<65, 65–74, or ≥75 years).

Statistical analysis

Descriptive statistics of the clinical data were determined. The Kruskal–Wallis test and Mann–Whitney test were used to determine statistical significance for quantitative variables, whereas the

Fisher exact test was used for qualitative variables. A P-value of <0.05 was considered to be statistically significant.

RESULTS

For patients with three- or four-part fractures, the mean age in the P group was significantly less compared with that in the N group ($P < 0.01$). Gender and mean postoperative follow-up period did not significantly differ between the two groups (Table 1). Furthermore, operation time, blood loss, and mean postoperative follow-up period were not significantly different between the groups. The external rotation of two-part fractures in the N group was significantly better than that of those in the P group ($P < 0.02$) (Table 2). Moreover, for patients aged 65–74 years, the external rotation of three- or four-part fractures in the N group was significantly better than that of those in the P group ($P < 0.001$). Forward flexion was not significantly different between the N and P groups (Table 3).

Among patients with two-part fractures in the N group, forward flexion was better in those aged <65 years than in those aged ≥65 years (Figure 3A). Among patients with three- or four-part fractures in the N group, forward flexion was better in patients aged 65–74 years than in patients aged ≥75 years. Among patients with three- or four-part fractures in the P group, forward flexion was better in patients aged <65 years than in patients aged ≥75 years (Figure 3B). External rotation among patients with two-part fractures was comparable in both groups (Figure 4A). Among patients with three- or four-part fractures in the N group, external rotation was better in patients aged 65–74 years than in patients aged ≥75 years. Among patients with three- or four-part fractures in the P group, external rotation was better in patients aged <65 years than in patients aged ≥65 years (Figure 4B).

Only one patient with a three-part fracture in the P group exhibited nonunion. Avascular necrosis occurred more frequently in patients with three- or four-part fractures (13 patients, 20%) than in those with two-part fractures (1 patient, 2%; $P < 0.02$). Avascular necrosis occurred in six (60%) and four

(50%) patients with four-part fractures in both the N and P groups, respectively. Varus deformity frequently occurred in patients with two-part fractures in the P group (four patients, 21%). Screw back-out was observed in one patient in the N group with a two- and three-part fracture each and in one patient in the P group with a four-part fracture. Re-displacement of the reduced humeral head was performed in one patient with a four-part fracture in the N and P group each; both patients experienced severe pain due to avascular necrosis (Table 4).

DISCUSSION

Stable fixation of displaced proximal humeral fractures in the elderly is often difficult owing to the presence of osteoporosis. Severe comminution and weak bone, which inhibit rigid fixation, are common manifestations of osteoporotic proximal humeral fractures. Recently, several instruments have been developed for ensuring rigid fixation of proximal humeral fractures. Among these, antegrade intramedullary nails and locking plates are considered as the primary instruments[9,10,13-18]. Studies from Western countries have demonstrated comparable clinical outcomes with the use of antegrade intramedullary nails and locking plates[10,13-18]. However, no studies have compared the outcomes using the aforementioned instruments in elderly Japanese individuals with proximal humeral fractures. Thus, the present study investigated surgically treated proximal humeral fractures in elderly patients at the Ryukyus University Hospital and affiliated hospitals and compared the clinical outcomes associated with the use of antegrade intramedullary nails and locking plates.

Compared with locking plates, antegrade intramedullary nails are supposed to have the advantages of being less invasive and causing less damage to the blood supply of the humeral head[10]. In addition, antegrade intramedullary nails ensure more rigid fixation than locking plates. However, antegrade intramedullary nails have the disadvantages of incising the rotator cuff and damaging the cartilage of

the humeral head when inserting nails[13,14,19]. Reportedly, locking plates have the advantages of greater anatomical reduction and rigid fixation of comminuted fragments. However, their disadvantages include extensive soft tissue dissection, longer operation time, more blood loss, and mechanical impingement with the acromion[20,21] (Table 5).

In the present study, the degree of external rotation that was achieved in the P group was significantly lower than that achieved in the N group for three- or four-part fractures. Locking plates are typically implanted via the deltopectoral approach by incising the anterior surface of the shoulder. The deltopectoral approach is considered to be more invasive than the anterolateral approach for inserting antegrade intramedullary nails. The invasive approach can cause tissue coalescence, resulting in restrained external rotation. During the postoperative period, patients treated using locking plates experienced two- to three-fold greater pain than those treated with antegrade intramedullary nails[18]; this may be due to the more invasive nature of the surgery required for treatment using locking plates.

A meta-analysis by Li et al. demonstrated that operation time and perioperative blood loss associated with the use of antegrade intramedullary nails were less compared with those associated with the use of locking plates for two-, three-, and four-part fractures[22]. In the present study, the operation time and perioperative blood loss did not differ between the N and P groups. This could be because the experienced surgeons in this study preferred using locking plates.

Our results also showed that elderly patients had poorer ROM than younger patients. This is consistent with other reports demonstrating that elderly patients tend to exhibit poorer outcomes due to osteoporosis[10,15,16].

Avascular necrosis and varus deformity are two major complications associated with the surgical treatment of proximal humeral fractures. Avascular necrosis occurs due to humeral head ischemia caused by fractures, leading to screw extrusion at the humeral head. In our study, avascular necrosis occurred in 22.6% and 14.3% of patients with three- and four-part fractures in the N and P groups, respectively; this difference was not statistically significant. Avascular necrosis occurred more

frequently in patients with three- or four-part fractures (13 patients, 20%) than in two-part fractures (one patient, 2%). Boudard et al. reported that avascular necrosis occurred in 26.7% of antegrade intramedullary nails cases and 21.2% of locking plate cases for three- or four-part fractures[17] Hertel et al. reported that the length of the dorsomedial metaphyseal extension, the integrity of the medial hinge, and the type of basic fracture determined using the binary description system are the best predictors of ischemia[23]. In the present study, all 14 patients with avascular necrosis exhibited a high-risk fracture type as defined by Hertel. Specifically, 10 patients showed a medial neck fragment shorter than 8 mm, and 4 patients exhibited disrupted medial hinge. These results suggest that humeral head replacement should be considered in high-risk cases.

Varus deformity in our study occurred most frequently in patients with two-part fractures in the P group. This is consistent with a report by Zhu et al. that demonstrated high rates of varus deformity among patients treated with locking plates for two-part fractures[10]. According to DePalma and Nobuhara, the permissible angle of varus-valgus deformation is up to 20°[24,25] and deformation greater than this angle can cause cuff dysfunction[26]. A biomechanical study revealed that the use of antegrade intramedullary nails entailed greater stiffness for varus, valgus, and torsional loading than locking plates[27]. Gardner et al. reported that placing a superiorly directed oblique locked screw in the inferomedial region of the proximal fragment helped achieve more stable medial column support in the locking plate[28]. However, in our study, the oblique locked screw was inserted in 17 of 19 two-part fractures and did not seem to prevent varus deformities.

Reportedly, complications can be prevented to some extent by improving surgical techniques; for example, varus deformity decreases with the use of additional non-absorbable sutures tagged through the rotator cuff tendons or tuberosity fragments and fixed at the base of the blade, passed through holes in the plate, or fixed using additional screws[29,30]. These complications can also be prevented by maintaining an appropriate external fixation period and adopting a rehabilitation program based on the patient’s age and fracture type[30].

LIMITATIONS

A higher number of cases is required to further evaluate the surgical results of fracture subgroups. Our study design was neither randomized nor prospective. Further, the preferences of the surgeons to use intramedullary nails or locking plates may have affected the results.

CONCLUSIONS

In summary, the surgical treatment of proximal humeral fractures using antegrade intramedullary nails (N group) or locking plates (P group) produced comparable clinical results. Except for external rotation, patients with two-part fractures in the N group showed better outcomes than those in the P group. Elderly patients exhibited especially poor ROM. Avascular necrosis was more likely in patients with three- or four-part fractures.

DISCLAIMER

The authors, their immediate families, and any research foundation to which they are affiliated did not receive any funding or other benefits from any commercial entity related to the subject of this study.