Minimally invasive plate osteosynthesis for proximal humeral fractures: clinical and radiologic outcomes according to fracture type

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Background: This study evaluated the clinical and radiologic outcomes, according to fracture type, of proximal humeral fractures treated by the minimally invasive plate osteosynthesis (MIPO) technique.

Materials and methods: Of 85 patients with proximal humeral fractures who were treated by the MIPO technique, 62 were evaluated: 27 with 2-part fractures, 24 with 3-part fractures, and 11 with 4-part fractures. An additional inferomedial screw or fibular allograft was used when severe medial cortical comminution was found in the proximal humerus. Clinical and radiographic outcomes were evaluated during the follow-up of 37 months.

Results: There was a significant difference in the Constant scores of patients with 4-part fractures compared with those with 3-part fractures (\(P = .039\)). The neck-shaft angle in 4-part fractures (121\(^\circ\) \pm 3\(^\circ\)) at final follow-up was significantly lower compared with other fracture types (2-part: 129\(^\circ\) \pm 9\(^\circ\), \(P = .036\); 3-part: 129\(^\circ\) \pm 2\(^\circ\), \(P = .031\)). Complication rates (72.7\%) of 4-part fractures were significantly higher than with other fracture types (2-part, 7.4\%; 3-part, 20.8\%; \(P = .001\)). Sixteen fractures were fixed with an additional inferomedial screw, and 3 patients had insertion of a fibular allograft.

Conclusion: Satisfactory clinical and radiologic outcomes were obtained by the MIPO technique in proximal humeral fractures. In addition, medial cortical support can be performed with an inferomedial screw or fibular allograft in the MIPO technique. However, the MIPO technique for 4-part fractures showed relatively inferior outcomes compared with 2- and 3-part fractures. Conversion to open plating is also considered if adequate reduction, that is, a neck-shaft angle >120\(^\circ\), is not able to be obtained in the MIPO technique for 4-part fractures of the proximal humerus.

Level of evidence: Level IV, Case Series, Treatment Study.

Keywords: MIPO; proximal humeral fractures; fracture type; outcomes

Various methods of surgical treatment for displaced proximal humeral fractures have been introduced, including external fixation, percutaneous K-wire fixation, open plating, and intramedullary nailing. Among them, open plate fixation of proximal humeral fractures has shown rapid improvement in clinical outcomes with the

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development of the angular stable plate. However, open reduction and plating through the traditional deltopectoral approach may lead to several concerns, including nonunion from extensive soft tissue stripping, deltoid muscle injury, and devastating infection.

The minimally invasive plate osteosynthesis (MIPO) technique was developed to achieve biologic fixation and to minimize complications of open reduction. The incision of MIPO is made at a sufficiently remote area away from the fracture site to preserve the periosteum around the fracture area for indirect bone healing, thereby obtaining higher rates of union, a lower infection risk, and a decreased need for bone graft. Although MIPO has been applied for the purpose of fixation of lower extremity fractures, the application of the MIPO technique has recently been extended to proximal humeral fractures as an alternative to open reduction and internal fixation. Furthermore, the MIPO technique has also improved with the development of the angular stable plate.

Overall functional outcomes after open locking plate fixation are dependent on the type of proximal humeral fracture. Whereas satisfactory outcomes can be achieved in displaced 2- or 3-part fractures, outcomes are less satisfactory in 4-part fractures on the basis of the Neer classification. Although several studies have reported excellent clinical results after the MIPO technique in the treatment of proximal humeral fractures, few studies have analyzed the clinical and radiologic outcomes according to the fracture pattern in patients with proximal humeral fractures treated with the MIPO technique.

The purpose of this study was to evaluate functional results and to analyze the clinical and radiologic outcomes according to the type of fracture in patients with proximal humeral fractures treated with the MIPO technique.

Materials and methods

This is a retrospective case series of patients with proximal humeral fractures treated with the MIPO technique from March 2009 to July 2011. Of 85 consecutive patients with displaced proximal humeral fractures, 23 were lost to follow-up within 2 years after operation because of relocation, death, severe medical conditions, or refusal to be included in the study. Finally, 62 patients were evaluated (follow-up rate of 73%). The mean follow-up period was 37 months (range, 24-53 months).

The inclusion criteria of this study were 2-part surgical neck fractures with more than 1 cm of displacement or more than 45° of angulation and displaced 3- and 4-part proximal humeral fractures. Minimally displaced fractures of the proximal humerus, combined peripheral nerve injury, pathologic fractures, and open fractures were excluded from this study. There were 23 men and 39 women with an average age of 57 years (range, 29-85 years). The dominant shoulder was involved in 25 patients. All patients underwent surgery within 2 weeks of injury, with a mean time from injury to operation of 2 days (range, 1-8 days). Five patients had associated injuries: 1 with an olecranon fracture, 1 with a femoral shaft fracture, and 3 with multiple rib fractures. All the fractures were classified according to the Neer classification: 27 patients had 2-part fractures (44%), 24 had 3-part fractures (39%), and 11 had 4-part fractures (17%). In all patients, the 3.5-mm proximal humerus anatomic locking plate (PHILOS; Synthes, Paoli, PA, USA) was used.

Clinical outcomes were assessed at the final follow-up visit by the active range of motion of the shoulder joint and the Constant score. Shoulder stiffness was considered as limitation of both active and passive motions in at least 2 directions (forward flexion <120° or 50% restriction of contralateral external rotation and internal rotation). Patient satisfaction of the operation was evaluated by a visual analog scale.

Radiographic evaluations were performed routinely at 2 weeks, 1 month, and 2 months postoperatively and every 2 months thereafter until union was obtained. Nonunion was defined as no progression of radiographic healing during the 3-month period. The neck-shaft angle was measured on an anteroposterior radiograph with 20° of external rotation immediately after operation and at final follow-up to obtain the exact value. Varus collapse, defined as the neck-shaft angle measured on the postoperative radiograph, was decreased to <120° on follow-up radiographs. Malreduction was defined as the neck-shaft angle <120° measured on immediate postoperative radiographs. Operating time was defined as the time from the skin incision to closure.

The outcomes of this study were recorded and evaluated with the statistical software SPSS version 17.0 (SPSS Inc, Chicago, IL, USA). Descriptive evaluation was performed on the basis of the mean and standard error as well as percentage. Age, interval to operation, operation time, and Constant scores were reported as median and range because numbers were shown on a rank sum scale. The Kruskal-Wallis test was used to compare non-normally distributed data among the 3 groups. The Mann-Whitney U test for parametric data and Fisher exact test for nonparametric pair comparisons were used to identify significant differences. P values of <.05 were considered significant.

Surgical techniques

The supine position was preferred with the injured extremity draped free, as posterior angulation or sagging could occur without support underneath the injured arm during the surgery in the beach chair position. Under an image intensifier, closed reduction was attempted with a longitudinal and a varus or valgus (varus force was necessary in most cases) force to the humeral shaft. The proximal skin incision started from the anterolateral corner of the acromion and extended approximately 4 cm distally. After the skin incision, the fiber of the deltoid muscle was split along the anterior raphe. The subdeltoid bursa was also dissected and used to create a protection sleeve for the axillary nerve. In the case of a fragmentation of the greater tuberosity, a nonabsorbable suture was sutured on the bone and rotator cuff tendon junction for mobilization and reduction. A 2.4-mm Kirschner wire was inserted into the humeral head to manipulate the proximal part of the humerus for anatomic reduction. After reduction of the greater tuberosity fragment, two or three 1.6-mm Kirschner wires were inserted for temporary fixation. Kirschner wires were placed so as not to disturb the plate position. The axillary nerve, which traverses in the posterior to anterior direction under the deltoid muscle, could be palpated blindly by the index finger approximately 2 to 3 cm below the inferior
margin of the proximal window. While an index finger palpated and protected the axillary nerve, a subdeltoid extraperiosteal tunnel was made with blunt dissection by a periosteal elevator. After preparation of the submuscular tunnel, the plate was inserted from the proximal window distally while the axillary nerve was protected. The location of the distal incision, which usually started from the oblong Combi-hole for the positional cortical screw and extended to the last hole of the plate, was determined with an image intensifier. The distal portion of the plate was easily found when the interval between the deltoid and biceps muscles was developed. When the distal portion of the plate was placed in the middle of the humeral shaft, the position of the proximal plate was checked (approximately 5 mm below the top of the greater tuberosity). After positioning, a 1.6-mm Kirschner wire was inserted through one of the small holes in the proximal part of the plate for temporary fixation. A cortical screw was inserted in the oblong Combi-hole as a positional screw to reduce the displaced neck-shaft angle indirectly along with the shape of the plate. In the case of a valgus-displaced proximal humeral fracture, the height of the plate to the top of the greater tuberosity was placed in a lower position than expected. Conversely, in a varus-displaced fracture, it could be placed in a higher position while a positional screw was inserted into the bone. Therefore, it is important to check the height of the plate as a high-positioned plate may lead to impingement under the subacromial space. Two 3.5-mm locking screws were inserted in the most proximal holes of the first row. An axillary view was then checked with gentle positioning with 90° of abduction and external rotation of the shoulder joint to confirm anteroposterior angulation and alignment between the plate and proximal humeral shaft. Two additional locking screws were placed through the second proximal holes.

If a patient had medial metaphysis comminution combined with poor bone quality in the proximal humerus, additional procedures with either long inferomedial screw insertion in the third or fourth row of the plate or fibular strut bone allograft were performed to maintain proper reduction. The inferomedial screw, which headed to the inferomedial quadrant of the humeral head, was used to support the medial metaphysis and to prevent varus collapse of the head when anatomic reduction of the medial cortex was not possible. When additional inferomedial screw insertion was needed, abduction of the shoulder of about 90° provided enough space for the locking screws to be inserted in the third or fourth hole of the plate, thereby avoiding the risk of axillary nerve injury (Fig. 1). A fibular strut bone allograft was also considered for insertion through the lateral fracture window to support the head and neck when additional augmentation of the reduction was needed (Fig. 2). In the distal window, additional locking screws were inserted in the distal holes. Range of motion exercise of the shoulder joint was encouraged as soon as the patients were able to tolerate postoperative pain, usually 3 days after the operation.

Results

Patient demographics showed no statistical differences among the 3 fracture types (Table I). No patients were converted to open reduction during the MIPO procedure in this study. The clinical outcomes, such as time to union and satisfaction for the operation, showed no statistical difference between the 3 groups (Table II). However, statistically significant differences were found in the Constant score for 4-part fractures compared with 3-part fractures (P = .041). The neck-shaft angle immediately after the operation averaged 130° ± 1° (range, 124°-135°) in 2-part fractures, 131° ± 2° (range, 115°-144°) in 3-part fractures, and 125° ± 3° (range, 111°-140°) in 4-part fractures. At final follow-up, the neck-shaft angle was measured at 129° ± 9° (range, 122°-133°), 129° ± 2° (range, 110°-147°), and 121° ± 3° (range, 110°-135°) in 2-, 3-, and 4-part fractures, respectively (Fig. 3). The neck-shaft angle in 4-part fractures at final follow-up was significantly lower compared with other fracture types (P = .036 with 2-part fractures and P = .031 with 3-part fractures). Sixteen fractures with severe medial cortex comminution (6 in 2-part, 8 in 3-part, and 2 in 4-part fractures) were fixed with an additional inferomedial screw, which was placed in the inferomedial quadrant of the proximal humerus. Three patients with poor bone quality underwent fibular strut bone allograft insertion to augment medial support of the proximal part of the humerus.

Clinical malfunctions, such as stiff shoulder and radiologic abnormalities including plate impingement, screw penetration, varus collapse, and malreduction, are regarded as complications related to the MIPO technique for the treatment of proximal humeral fractures. Complications occurred in 15 of the 62 patients (24.1%) (Table III). The
number of complications in 4-part fractures after the operation was significantly higher than that in 2-part and 3-part fractures ($P = .001$). One intra-articular screw perforation and 3 impingements to the undersurface of the acromion due to a higher position of the plate were found. A significant varus collapse combined with screw penetration occurred in one patient. A 72-year-old female patient with a 4-part fracture was found to have varus collapse of the humeral head at 2 weeks postoperatively. The patient also showed screw penetration into the glenohumeral joint at 4 months after the operation with progression of varus collapse and underwent surgery to remove the intra-articular penetrating screws. The other patient with a 2-part fracture, a 70-year-old woman, also showed varus collapse at 7 days after surgery. However, we observed bone union without any additional treatment, and no further varus collapse of the humeral head occurred. Five patients were found to have varus malreductions, which were reduced to $<120^\circ$ of neck-shaft angle on immediate postoperative radiographs. Migration of the greater tuberosity was found in a 76-year-old woman with a 4-part fracture on plain radiography at the 1-month follow-up visit. There were no other serious complications, such as infection, avascular necrosis, or axillary nerve palsy.

### Discussion

In this study, treatment of proximal humeral fractures with the MIPO technique provided satisfactory clinical and radiologic outcomes. However, it was technically difficult to reduce and to maintain the proximal humerus fracture indirectly and to restore the function of the shoulder joint in 4-part fractures compared with 2- and 3-part fractures.

Numerous studies have reported diverse functional outcomes of the shoulder joint in patients with proximal humerus fractures treated with the open reduction technique. The MIPO technique can provide clinical outcomes similar to those of the open reduction technique once the surgeon develops appropriate fracture reduction and maintenance skills. However, overall functional outcomes are usually satisfactory in 2- and 3-part fractures but less satisfactory in 4-part fractures after open plating fixation. This study showed similar clinical outcomes after MIPO technique compared with those of open plating related to proximal humeral fracture type. Although a small number of 4-part fractures were included in this study, the functional outcomes in patients with 4-part proximal humeral fractures were significantly worse than the outcomes in those with 2- or 3-part fractures. The number of patients with decreased neck-shaft angle in the 4-part fracture group on final follow-up radiographs was higher than in the other fracture type groups. The 4-part proximal humeral fractures were difficult to reduce anatomically and to maintain properly as well because of comminuted fragments. In this study, however, we could not obtain a proper neck-shaft angle owing to technical difficulties in 3 patients with 4-part fractures and overlooked the decreased neck-shaft angle in 2 patients with 3-part fractures in the operating room. This varus malreduction might have affected the functional and radiologic results. Therefore, when the MIPO technique is
osteoporotic patients and are commonly combined with 4-part fractures. Because 4-part fractures usually occur in the proximal humerus by use of the precontoured plate may be ineffective in this study. However, anatomic reduction of the proximal humerus to the anatomic plate in daily practice was usually performed by pulling the neck-shaft angle was usually performed by pulling the neck-shaft angle in 4-part fractures at final follow-up was significantly lower compared with the other fracture types (P = .036 with 2-part and P = .031 with 3-part fractures).

The neck-shaft angle showed progressive change on final follow-up radiographs. However, insertion of an inferomedial screw through the proximal window in the MIPO technique requires caution because of the risk of axillary nerve injury as the plate hole for the inferomedial screw usually provides limited space owing to the proximity to the axillary nerve. To avoid the risk of axillary nerve injury in the MIPO technique, abduction of the shoulder of about 90° is recommended because this shoulder position provides enough space for the inferomedial screw to be inserted in the plate.

Figure 3  The average neck-shaft angle (NSA) of the patients immediately after the operation and at final follow-up (F/U). *The neck-shaft angle in 4-part fractures at final follow-up was significantly lower compared with the other fracture types (P = .041 with 2-part and P = .721 with 3-part fractures).

Table II  Clinical outcomes of patients after MIPO technique

<table>
<thead>
<tr>
<th>Fracture Type</th>
<th>Constant score</th>
<th>Time to union</th>
<th>Visual analog scale for satisfaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Part fracture</td>
<td>80 (52-90)</td>
<td>5.5 ± 0.7</td>
<td>1.7 ± 0.9</td>
</tr>
<tr>
<td>3-Part fracture</td>
<td>74 (57-96)</td>
<td>5.0 ± 0.2</td>
<td>1.5 ± 0.4</td>
</tr>
<tr>
<td>4-Part fracture</td>
<td>62 (52-90)</td>
<td>5.8 ± 0.7</td>
<td>1.4 ± 0.2</td>
</tr>
</tbody>
</table>

Constant score is presented as mean and range.
* Statistically significant differences were found for 4-part fractures compared with 3-part fractures.

applied to 4-part fractures, surgeons should put in more effort to reduce the comminuted proximal humerus, especially for restoration of the neck-shaft angle. Conversion to open plating is also considered to achieve better reduction when an adequate reduction, such as neck-shaft angle >120°, cannot be obtained through the MIPO technique for 4-part fractures of the proximal humerus.

The neck-shaft angle showed progressive change on final follow-up plain radiographs compared with those immediately after the operation in 4-part fractures. Restoration of the neck-shaft angle was usually performed by pulling the bone to the plate with a 3.5-mm cortical screw that adapted the shape of the proximal humerus to the anatomic plate in this study. However, anatomic reduction of the proximal humerus by use of the precontoured plate may be ineffective in 4-part fractures. Because 4-part fractures usually occur in osteoporotic patients and are commonly combined with proximal part fragmentation and medial metaphyseal comminution, maintenance of the neck-shaft angle could be difficult. Therefore, treatment of fractures in osteoporotic patients or 4-part fractures should include consideration of additional inferomedial screws or fibular strut allografts to maintain medial support of the proximal humerus when anatomic or medial cortical contact is not possible.

Medial support of the proximal humerus through cortical contact is crucial in maintaining fracture stability and preventing varus displacement.9,13,14,25 Lee and Shin13 reported that the absence of comorbidities and restoration of the medial metaphysis were the most reliable predictors of successful clinical outcome in unstable proximal humeral fractures treated with locking plates. Gardner et al9 demonstrated that superiorly directed oblique locking screws in the inferomedial region of the proximal humerus, called inferomedial screws, may achieve more stable medial column support and allow better maintenance of reduction. In this study, 16 patients who needed additional inferomedial screws showed no varus displacement on the final follow-up radiographs. However, insertion of an inferomedial screw through the proximal window in the MIPO technique requires caution because of the risk of axillary nerve injury as the plate hole for the inferomedial screw usually provides limited space owing to the proximity to the axillary nerve. To avoid the risk of axillary nerve injury in the MIPO technique, abduction of the shoulder of about 90° is recommended because this shoulder position provides enough space for the inferomedial screw to be inserted in the plate.

Fibular strut allograft augmentation in unstable osteoporotic proximal humeral fractures has also been reported with satisfactory clinical outcomes after open plating fixation.3,15 Matassi et al15 demonstrated that either the deltopectoral or deltid-splitting approach is possible for fibular allografts in the augmentation of proximal humeral fracture fixation. Insertion and fixation of the fibular strut bone were not technically difficult in MIPO because MIPO is usually performed through the deltoid-splitting approach. A window for a fibular allograft can be made to be visible directly through the deltid muscle and lateral fracture area of the proximal humerus. Unstable osteoporotic proximal humeral fractures in 3 patients in this study were supported with a fibular strut allograft through the lateral fracture window without further damage to the fracture site. Therefore, fibular strut allograft augmentation can also be used in the MIPO technique as a solution for the worrisome problem of medial cortex comminution in proximal humeral fractures.

Although the MIPO technique with a locking plate for proximal humeral fractures has been found to have satisfactory clinical outcomes, several complications related to implantation, such as intra-articular screw perforation, loosening of the screws, and subacromial impingement, have been recognized.23,24 Studies of the MIPO technique for proximal humeral fractures demonstrated implant-related complications and a loss of reduction of around...
In this study, 1 patient with screw perforation into the glenohumeral joint and 3 patients with subacromial impingement were noted. Proximal humeral fracture with intra-articular screw perforation, which was classified as a 4-part fracture, could not be reduced anatomically with <120° of neck-shaft angle. Secondary loss of reduction is commonly found after fixation with a conventional plate; however, a varus displacement or migration of the greater tuberosity was also observed in locking plate fixation in this study, with a significant varus displacement. The height of the plate to the top of the greater tuberosity may be placed in a lower position than expected in the case of a valgus-displaced proximal humeral fracture or in a higher position in a varus-displaced fracture while a positional screw purchases the bone. Therefore, it is important to confirm the height of the plate because a high-positioned plate may lead to impingement under the subacromial space. In 4-part fractures, the complication rate was reported to be the highest level in both groups of open reduction and the MIPO technique when the fracture type was analyzed as a risk factor.

Although open reduction by the deltopectoral approach is widely used for proximal humerus fracture management, this approach is somewhat difficult because reduction of fracture fragments is usually performed through the anterior window, whereas drilling and plating are applied to the lateral side, which is deeply placed under the deltoid muscle. However, the MIPO technique provides the lateral window through the deltoid-splitting approach, which is a direct and convenient way to reduce fracture fragments, especially posterior fragments, and to handle the plate and screws. Furthermore, the MIPO technique for proximal humerus fractures could preserve the anterior and posterior humeral circumflex arteries, which are important for blood supply to the humeral head. In contrast, longer exposure to radiation during the operation and difficulty in the restoration of the neck-shaft angle or medial comminution are weaknesses in the MIPO technique compared with the open plating technique. However, several additional augmentations, including inferomedial screws and fibular strut allograft, may help maintain anatomic reduction in the MIPO technique for comminuted proximal humeral fractures.

The limitation of this study was the absence of a control group treated with the open plating technique. In addition, the final follow-up period was relatively short to evaluate long-term complications, such as avascular necrosis of the humeral head. A properly powered and conducted randomized trial comparing standard open plate fixation and MIPO for proximal humeral fractures would be of great benefit in determining the value of this technique.

### Conclusions

Satisfactory clinical and radiologic outcomes in terms of bone union and anatomic restoration of the proximal humerus were obtained by the MIPO technique in patients with displaced proximal humeral fractures. In addition, medial cortical support with an inferomedial screw or fibular strut allograft augmentation can be performed in the MIPO technique. However, the MIPO technique for the treatment of 4-part fractures of the proximal humerus resulted in relatively unsatisfactory clinical and radiologic outcomes compared with 2- and 3-part fractures. Conversion to open plating is also considered if adequate reduction, that is, a neck-shaft angle >120°, is not obtained through the MIPO technique for 4-part fractures of the proximal humerus.

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