TRAUMA SURGERY

Lessons learned from treating patients with unstable multifragmentary fractures of the proximal humerus by minimal invasive plate osteosynthesis

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Abstract

Introduction The authors present clinical and radiographic results of minimal invasive plate osteosynthesis (MIPO) for three- or four-part fractures of the proximal humerus.

Patients and methods Twenty-six patients with three- or four-part proximal humeral fractures treated with the MIPO technique through the deltoid splitting approach were clinically and radiographically evaluated at a minimum of 12 months with an average of 20.1 months. The valgus-impacted type of three-part fracture was excluded to verify the results of the MIPO with unstable multifragmentary fractures of the proximal humerus.

Results Twenty female patients and six male patients were included (mean age 67 years; range 18–90 years). No cases of nonunion were seen. The mean forward flexion, abduction, and external rotation were 145°, 119°, and 48°, respectively. The mean visual analog scale (VAS) for pain was 1.47 points. The mean Disabilities of the Arm, Shoulder, and Hand (DASH) score was 14.5 points, and the mean UCLA score was 29.6 points. The mean neck-shaft angle was 134°. Twenty-three patients had adequate medial support, and three patients did not have adequate medial

support on initial postoperative radiographs. Five shoulders (19 %) developed complicated results. Two cases of proximal malposition of the plate (7.7 %) and two intra-articular screw penetrations (7.7 %) were observed. One case of osteonecrosis of the humeral head was identified at the final follow-up (3.8 %).

Conclusion The MIPO technique provides reliable radiologic and functional outcomes for three- and four-part proximal humeral fractures. Our results might support the use of MIPO for treating unstable multi fragmentary fractures of proximal humerus such as three- or four-part fractures to decrease osteonecrosis of humeral head.

Keywords Humeral fracture · Proximal humeral fracture · Locking plate fixation · Minimal invasive approach · Minimal invasive plate osteosynthesis · MIPO

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Introduction

Fractures of the proximal humerus are a common orthopedic problem. Although surgical options for treating displaced proximal humeral fracture are numerous, including surgical fixation using extra- or intramedullary fixation techniques or humeral head replacement, locking plate fixation for proximal humeral fractures has gained considerable popularity over the past decade [1]. A traditional approach of locking plate fixation in the proximal humeral fracture has been a standard or extended deltopectoral approach, which provides excellent visualization of fracture sites. However, extensive soft tissue stripping is required to apply a plate on the lateral side of proximal humerus. This soft tissue stripping may inhibit fracture healing and increase the risk of osteonecrosis and early collapse caused by injury of the ascending branch of the

anterior circumflex humeral artery. Furthermore, additional soft tissue stripping is required and this complication risk increases in multifragmentary fractures such as three- or four-part fracture classified by the Neer classification of proximal humeral fractures.

Minimally invasive plate osteosynthesis (MIPO) has become increasingly popular for managing metaphyseal comminuted fractures. MIPO minimizes additional trauma to an already injured region and promotes biologic healing of the fracture site. Most surgeons expected the favorable outcomes of MIPO in the proximal humerus fracture and several clinical series on the effectiveness of MIPO for treatment of proximal humeral fractures have been reported [2–8]. However, the study populations in the most clinical studies are mixed with simple fracture type such as two-part or valgus-impacted three-part fractures and multi fragmentary fractures such as three- or four-part fracture. Because the simple fracture types of proximal humerus have favorable outcomes regardless of the surgical approaches or technique, the advantages of a MIPO over the standard technique should be verified only in three- or four-part fracture. To date, there is little published study on the clinical and radiologic outcome of MIPO-treated three- or four-part fractures exclusively [9, 10].

The purpose of this study was to investigate radiologic and clinical outcomes of MIPO for treatment of three- or four-part fractures of proximal humerus classified by the Neer classification of proximal humeral fractures. We also described our surgical technique, and shared our clinical experiences of MIPO for treatment of three- or four-part fractures.

Patients and methods

A retrospective study of a case series was conducted to evaluate the radiographic and clinical outcomes of the operative treatment for three- or four-part proximal humeral fractures with the MIPO technique using the deltoid splitting approach between April 2010 and April 2012. This study was approved by our institutional review board. The inclusion criteria for the study were: (1) three-part proximal humeral fractures with a surgical neck displacement ≥1 cm and/or 45° of angulation and greater tuberosity displacement ≥0.5 cm, and (2) four-part fracture with anatomical neck, greater tuberosity, and lesser tuberosity displacement ≥0.5 cm and/or 45° of angulation. We excluded patients with a valgus-impacted type of three-part proximal humeral fracture, because this type of fracture is similar to the two-part fracture in terms of clinical outcomes, difficulty of surgical technique, and the incidence of complications. We also excluded patients with associated neurovascular injuries, pre-existing arthritis and prior

traumatic injury. Of 65 consecutive patients with displaced proximal humeral fracture treated by the MIPO technique, 32 were two-part or valgus-impacted type of three-part fractures, 1 was patient with associated neurovascular injuries, 1 was pre-existing post-traumatic arthritis, and 5 were lost to follow-up. Finally, 26 patients with three-part or four-part proximal humeral fractures were enrolled in this study.

Surgical technique

All patients were treated with the MIPO technique using a deltoid splitting approach and locking plate fixation with the PHILOS proximal humeral plate (DepuySynthes, Paoli, PA, USA). All surgeries were performed under general anesthesia and fluoroscopic assistance. The patients were positioned supine on a radiolucent table. A small folded sheet was placed under the affected shoulder to produce semi-lateral position. A longitudinal skin incision was created slightly distal to the anterolateral edge of the acromion and extended digitally 5 cm. After deltoid splitting and removal of subacromial bursa, the tuberosity and humeral head were exposed (Fig. 1). The greater tuberosity fragment was reduced to the humeral head using the traction suture in the rotator cuff tendon. The greater tuberosity fragment was reduced and fixed using the provisional 1.6 mm K-wire (Fig. 2). Alignment between humeral head and shaft was reduced by traction and the joystick technique. The submuscular tunnel for plate placement was made with a Cobb's elevator, and the plate was inserted through the tunnel while taking care to keep the plate directly along the bone to prevent trapping the axillary nerve. The axillary nerve can be easily palpated under the deltoid muscle with the index finger. A second 3 cm incision with minimal soft tissue dissection was performed under fluoroscopic guidance to locate the center distal holes. The two locking sleeves were, respectively, anchored into the proximal and distal locking holes. These locking sleeves were used as a handle to aid with proper plate placement for preventing proximal malposition of plate. The provisional 1.6 mm K-wires or drill bit were fixed to the humeral head and shaft through the proximal and distal locking sleeves after confirmation of proper plate position and reduction. One 3.5 mm bicotrical screw was used to attach the plate to the humeral shaft and reduce the humeral shaft to contour with the anatomical contoured plate (Fig. 3). Additional 3.5 mm locking screws were fixed into the distal hole to add stability. All available 3.5 mm locking screws were fixed to the subchondral bone of the humeral head through the proximal locking holes. The proximal locking screw should be as long as possible to prevent varus collapse. The proximal locking screw reached the subchondral bone of the humeral head being careful not to penetrate the

Fig. 1 Plain radiographs of three-part proximal humeral fracture (**a**). The fragments of greater tuberosity and humeral head were exposed through the deltoid splitting approach. Surgeon can manipulate the displaced greater tuberosity under direct vision (**b**). *Asterisk* indicates the displaced greater tuberosity fragment
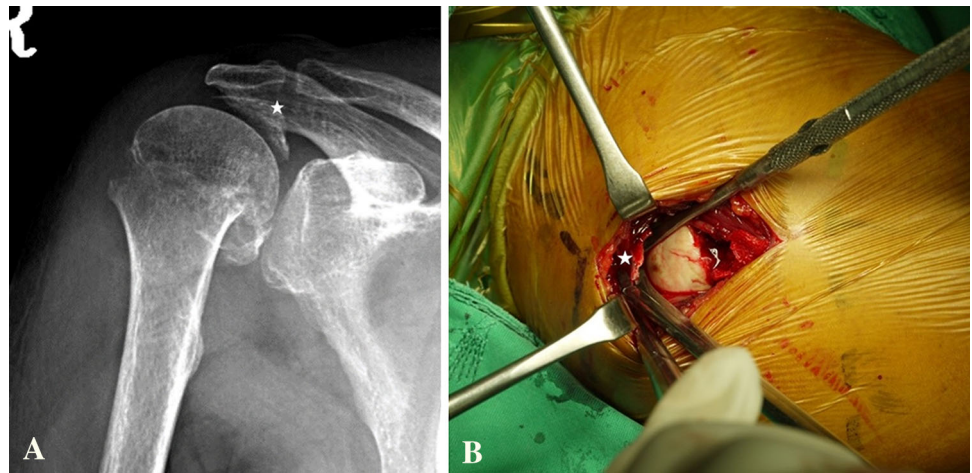

Fig. 2 The greater tuberosity fragment was reduced using the pre-sutured traction suture (No. 2 Ethibond) (**a**). After reduction with traction suture method, the provisional Kirschner wires were fixed between the greater tuberosity and humeral head after acceptable reduction under fluoroscopic guidance (**b**)
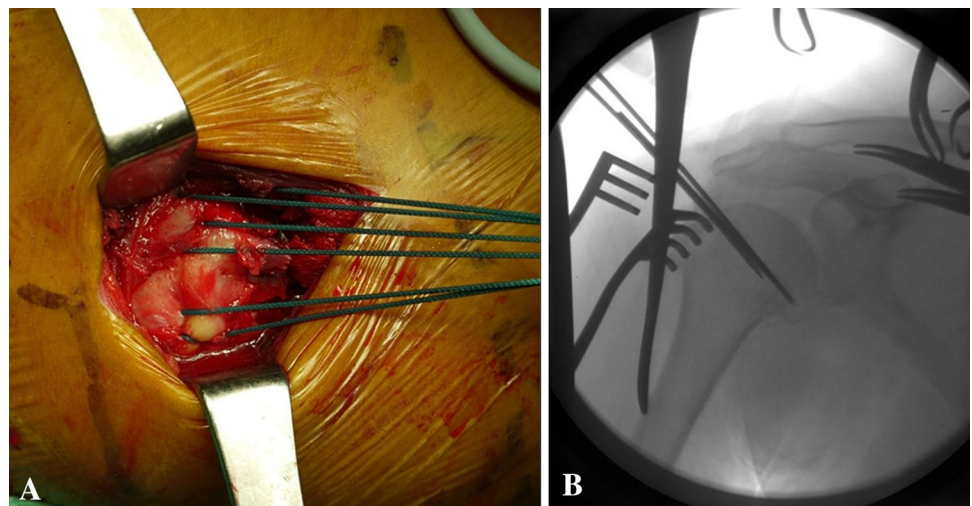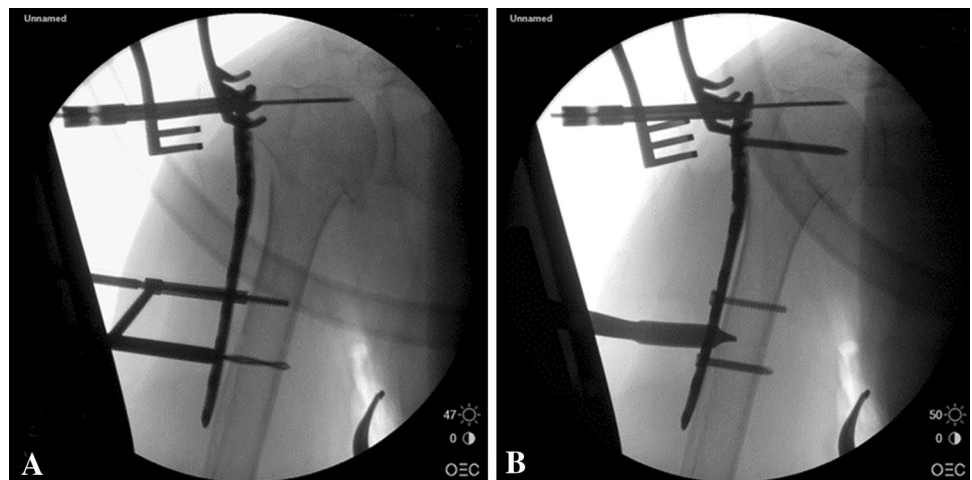

Fig. 3 Anatomical contoured plate can be used as a reduction tool. The reduction status of proximal humerus was unsatisfied before fixation of the cortical screw (**a**). One 3.5 mm bicotrical screw was used to attach the plate to the humeral shaft and reduce the humeral shaft to contour with the anatomical contoured plate (**b**)

glenohumeral joint under fluoroscopic guidance. The traction suture of the greater tuberosity fragment was tied through the two K-wire holes for additional fragment stability. Finally, screw placements were checked fluoroscopically to avoid intra-articular screw penetration. After surgery, the shoulder was immobilized in an arm sling and

pendulum exercise was started on postoperative day 3. Sutures were removed 2 weeks postoperatively. Active-assisted exercises using the other arm to assist active elevation were started 4–6 weeks postoperatively.

Follow-up and outcome evaluation

All patients were evaluated clinically and radiographically at the final follow-up after surgery. Objective functional outcome was evaluated by active shoulder motion and the UCLA score [11]. The UCLA score was used to assess shoulder pain (range 1–10 points), function (range 1–10 points), active forward flexion (range 0–5 points), strength of forward flexion (range 0–5 points), and patient satisfaction (range 0–5 points). Functional results according to the UCLA score were classified as excellent (≥34 points), good (29–33 points), and poor (≤28 points). One of the authors evaluated active shoulder motion and the UCLA score. Active range of motion of the shoulder was evaluated by recording forward flexion, abduction, and external rotation at 0° abduction with a standard goniometer. The functional subjective outcome was measured with the visual analog scale (VAS) pain score (range 0–10, with 0 as the no pain, 10 as the maximum pain) and the disabilities of the arm, shoulder, and hand (DASH) questionnaire (range 0–100, with 0 as the best result) [12]. The radiographic evaluation consisted of standard anterior posterior, lateral, and axillary views. Two different orthopedic surgeons assessed union, screw loosening, screw penetration into the glenohumeral joint, loss of reduction, neck-shaft angle (NSA) by Paavolainen et al. [13], and the presence of medial support. The fracture was considered to have adequate medial support if: (1) the medial pillar of the proximal humerus was not comminuted and anatomically reduced, and (2) the shaft was medialized and impacted into the head fragment as shown by Gardner et al. [14]. The NSA was measured twice by two different orthopedic surgeons, and the results were averaged to minimize inter-observer and intra-observer differences. All radiologic assessments were performed using the computer-aided measurement software included in the PACS system.

Results

Twenty female patients and six male patients (mean age 67 years; range 18–90 years) were included (Table 1). Follow-up was a minimum of 12 months with an average of 20.1 months (range 15–30 months). The right shoulder was injured in 13 patients and the left in 13; 13 of the 26 fractures involved the dominant side. Mechanisms of injury were simple falls (19 patients), motor vehicle collisions (six patients) and fall from height (one patients). Fractures

Table 1 Demographic results

Characteristics	Results
Age (year)[a]	67 (18–90)
Sex[b]	
Male	6 (23%)
Female	20 (77%)
Dominant extremity fractured[b]	13 (50%)
Injury mechanism[b]	
High energy[c]	7 (27%)
Low energy[c]	19 (73%)
OTA classification (11-)[b]	
B	
B1	3 (11.5%)
B2	5 (19%)
B3	3 (11.5%)
C	
C1	4 (15%)
C2	10 (38%)
C3	1 (3.8%)
Neer classification[b]	
Three part	17 (65%)
Four part	9 (35%)

[a] The values are given as the average with the range in parentheses

[b] The values are given as the number of patients with the percentage in parentheses

[c] Low-energy injury: simple fall; High-energy injury: fall from height, motor vehicle accident

were categorized according to the Orthopedic Trauma Association (OTA) classification system and the Neer classification system [15, 16]. There were 11 type B (B1: 3, B2: 5, B3: 3) and 15 type C (C1: 4, C2: 10, C3: 1) fractures by the OTA classification. According to the method described by Neer, 17 patients had three-part fractures and nine patients had four-part fractures.

Mean shoulder motion values were as follows. Forward flexion was 145° (range 80–170°), abduction was 119° (range 80–160°), and external rotation was 48° (range 30–60°). The average VAS for pain was 1.47 points (range 0–5). The mean DASH score was 14.5 points (range 0–59). The overall mean UCLA score was 29.6 points (range 14–35). Final functional outcomes were nine excellent, 11 good, and six poor (Table 2). No incidences of axillary nerve palsy occurred. The average NSA was 134° (range 120–150°). Twenty-three patients had adequate medial support and three patients did not have adequate medial support in initial postoperative radiographs. All fractures united at a mean of 3.8 months (range 3–6).

Five shoulders (19 %) had complicated results. Two cases of proximal malposition of plate (7.7 %, Fig. 4) and two cases of intra-articular screw penetration (7.7 %,

Table 2 Functional results

Evaluation methods	Scores
Visual analog scale for pain	1.47 (0–5)
DASH score	14.5 (0–59)
UCLA score	29.6 (14–35)
Pain	8.4 (4–10)
Function	7.7 (4–10)
Forward flexion	4.2 (1–5)
Strength	4.3 (2–5)
Satisfaction	4.7 (0–5)

The values are given as the average with the range in parentheses

Fig. 5) were observed. One patient of proximal malposition of plate underwent plate removal after bony union, but the other patients did not have implant-related symptoms and did not want to remove the plate and/or screws after bony union. No screw loosening and no loss of reduction or metal failure occurred. One case of osteonecrosis of the humeral head was identified at the follow-up (3.8 %). The fracture pattern of that patient was four-part fracture. The patient was recommended for a prosthetic replacement, but the patient did not undergo replacement arthroplasty (Fig. 6).

Discussion

We showed that the minimally invasive plate osteosynthesis (MIPO) for treating unstable multi fragmentary fractures of proximal humerus provided low risk of osteonecrosis of the humeral head and produced good radiologic and clinical outcomes. Our results might support the use of MIPO for treating unstable multi fragmentary fractures of proximal humerus such as three- or four-part fractures to decrease osteonecrosis of humeral head.

Treatment of proximal humeral fractures has been revolutionized since the anatomic shaped locking plate was developed for proximal humeral fractures. Numerous investigators reported good clinical outcomes with the use of locking plate fixation with standard deltopectoral approach. However, the overall complication rate remains high. The most common complication is screw joint penetration and osteonecrosis and the rate of revision surgery has been reported to range from 13 to 26.7 % [17]. Posttraumatic osteonecrosis of the humeral head is an important factor related with a painful and functionally poor outcome after treating unstable multi fragmentary fractures of proximal humerus [18]. The risk of developing osteonecrosis is mostly dependent on the fracture configuration and the approach to the fracture. The surgical exposure itself and overzealous dissection during plating increase the risk of osteonecrosis by injury of the ascending branch of the anterior circumflex humeral artery. The reported rate of humeral head osteonecrosis after plate osteosynthesis with extensive soft tissue stripping is up to 34 % [19]. Another published study using the standard deltopectoral approach and reducing soft tissue damage report osteonecrosis in 10–16 % of cases [7, 20, 21]. The MIPO minimizes soft tissue dissection to an already injured region and promotes the biologic healing at the fracture site. The MIPO can minimize compromising the vascularity of the osseous and soft tissue components, which can contribute to prevention
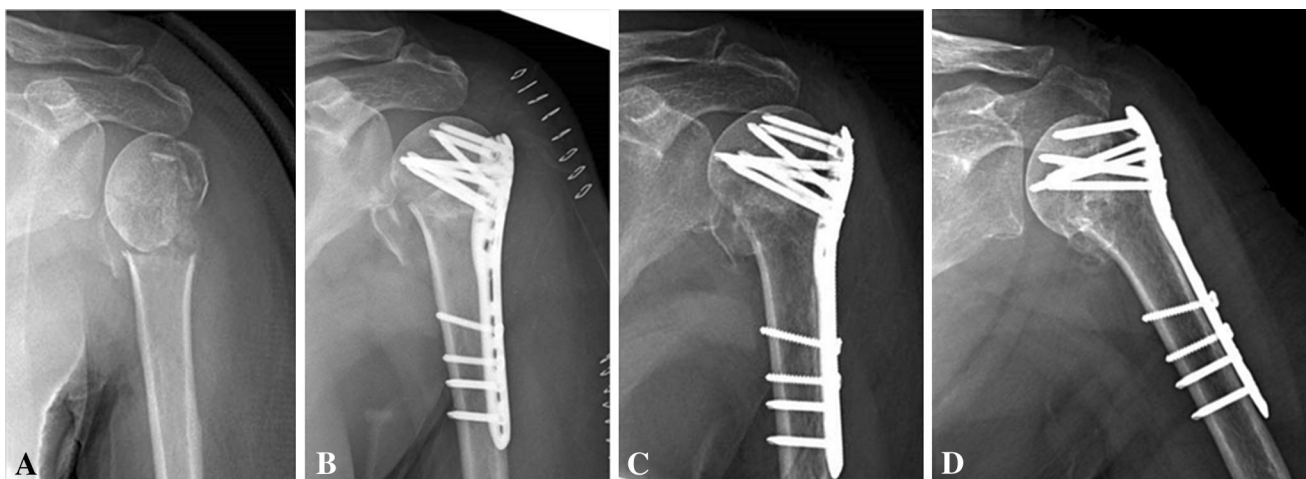

Fig. 4 A 54-year-old patient at 18 months follow-up after a left four-part proximal humeral fracture. Preoperative radiographs show a four-part proximal humeral fracture (OTA 11-C2) (**a**). The immediate postoperative radiographs showed that the proximal humeral fracture was treated by minimal invasive plate osteosynthesis (**b**). Fracture union including lesser tuberosity was achieved. However, subacromial impingement was observed at shoulder abduction due to proximal malposition of plate on the final follow-up plain radiograph (**c**, **d**)
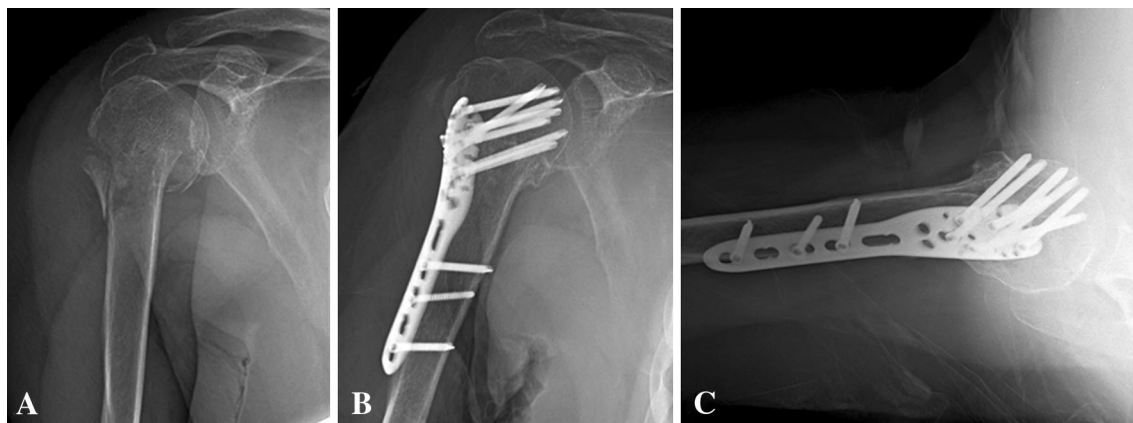
Fig. 5 A 77-year-old patient at the 15-month follow-up after a right three-part proximal humeral fracture. A three-part proximal humeral fracture was observed on preoperative anteroposterior radiograph (OTA 11-C1) (**a**). Fracture union and proximal locking screws penetration into the glenohumeral joint was observed on the final follow-up radiograph (**b**, **c**)
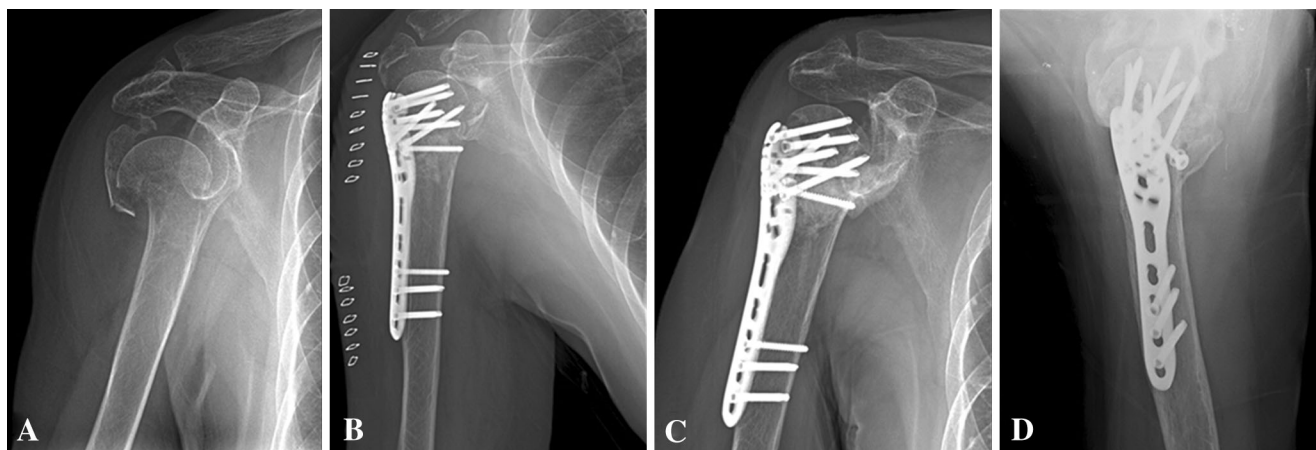

Fig. 6 An 81-year-old patient at the 2-year follow-up after a right four-part proximal humeral fracture. Preoperative radiographs show a four-part proximal humeral fracture (OTA 11-C2) (**a**). The immediate postoperative radiographs showed that the proximal humeral fracture was treated by minimal invasive plate osteosynthesis (**b**). Osteonecrosis of the humeral head was observed on the final follow-up plain radiograph (**c**, **d**)

of the development of osteonecrosis. The cadaveric study showed that minimal invasive approach avoids exposure of the anterior blood supply, preclude deltoid release, and may minimize further devitalization of fracture fragments and the humeral head during fracture reduction and fixation [19]. The rate of humeral head osteonecrosis after MIPO varies between 0 and 8 % [2–10]. Our osteonecrosis rate of 3.8 % (1 of 26 cases) might also support the advantage of MIPPO to treat the multifragmentary fractures of proximal humerus.

Despite some good clinical results about using the MIPO technique, many surgeons have doubted whether they achieved proper stability using MIPO technique for three- or four-part proximal humeral fractures. Moreover, an inferomedial oblique (calcar-specific) screw cannot be

inserted during MIPO due to the risk of axillary nerve injury [22]. Therefore, another strategy is required for preventing varus collapse in patients with three- or four-part fractures. First, we sutured to the rotator cuff tendon using non-absorbable suture to reduce and fix the greater tuberosity. The greater tuberosity fragment was secured by attaching the non-absorbable suture to the plate through the existing pin holes in the proximal part of the plate. Many authors described this suture-plate tie method during MIPO [4, 6, 10]. Second, we used the multiple and as long as possible screws for the humeral head. The screws should be placed within the subchondral bone of the humeral head, which can be rigidly fixed to the humeral head. Rucholtz et al. [5] also recommend placing the tip of the screw in the humeral head closely ($\sim$5 mm) below the joint line. They

explained that use of a long screw might be the reason why two screw perforations were already seen on postoperative X-rays of the control. In our series, two patients had a screw perforation in the joint. Nevertheless, we consider that the use of long screws is important for preventing varus collapse. Third, if the metaphyseal bone defect is significant, some surgeons use the calcium phosphate cement to fill the metaphyseal defect to prevent collapse [10]. We have no experience with use of the calcium phosphate cement. However, if a significant metaphyseal bone defect is observed, these methods may be helpful.

The risk of axillary nerve injury is an important issue with the MIPO technique for proximal humeral fractures. Although there are reasonable concerns about the risk of axillary nerve injury during the transdeltoid approach and plating, most investigators using the MIPO technique for proximal humeral fractures reported a low incidence of axillary nerve injury [3–6, 10]. Smith et al. [22] reported that the axillary nerve was located 7.2 cm (range 6.2–8.5 cm) below the lateral edge of acromion in a cadaveric study. They insisted that the proximal six holes of the PHILOS plate are a safe zone in which the axillary nerve is not located. We inserted screws only through proximal screw holes in the plate, and did not insert screws through the holes for inferomedial oblique screws. We made a submuscular tunnel to place the plate below the axillary nerve to prevent axillary nerve injury. Cobb's elevator was inserted with its tip contacting the bone when the tunnel was made. The plate was inserted through the tunnel while taking care to keep the plate directly along the bone.

The strength of the present study is focusing only the multifragmentary fractures of the proximal humerus for investigating the outcomes of MIPO technique. Simple fracture type such as two-part or valgus-impacted three-part fracture of proximal humerus have a favorable outcome and low incidence of osteonecrosis regardless of the surgical approaches or technique because of the preservation of the medial capsular blood supply to the humeral head [23]. Therefore, the advantages of a MIPO over the standard technique should be verified only in three- or four-part fracture like this study.

Several limitations of this study should be noted. First, this study was a retrospective case series and we did not compare the outcomes of the standard locking plate fixation with deltopectoral approach. Second, a relatively small number of patients were enrolled and followed. Despite these shortcomings, our results might support the use of MIPO for treating unstable multi fragmentary fractures of proximal humerus such as three- or four-part fractures to decrease osteonecrosis of humeral head. Osteonecrosis rate after MIPO for proximal humeral fractures appear to be lower in this study, but future large prospective comparative studies should verify this issue.

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