

Complications and Outcomes of Minimally Invasive Percutaneous Plating for Proximal Humeral Fractures

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Background: The minimally invasive plate osteosynthesis (MIPO) technique using periarticular locking plates may be a good option for the repair of displaced proximal humeral fractures. However, axillary nerve complications related to this technique may be underestimated. The purpose of this study is to evaluate the outcomes of the minimally invasive plating, focusing on the complications.

Methods: The records of 21 consecutive patients treated for proximal humerus fractures using the MIPO technique with locking plates were retrospectively reviewed. These patients were treated between March 2009 and March 2011 with a minimum one-year follow-up. The clinical function, complications, and radiological bony union were evaluated.

Results: All of the patients, with one exception, showed at least 90 degrees of flexion and abduction at the shoulder joint six months postoperatively. The average Constant scores at three months, six months, and one year follow-ups were 74.0 (range, 62 to 90), 79.4 (range, 64 to 91), and 82.7 (range, 66 to 92), respectively. All of the patients achieved bony union within the average of 3.2 months (range, 2 to 6 months). There was one case of delayed union, one case of intra-articular screw penetration, and one case of axillary nerve paresis (incomplete injury), which did not completely recover during the one year of follow-up.

Conclusions: The MIPO technique using periarticular locking plates is a useful option for the treatment of selected cases of displaced proximal humeral fractures. However, nerve complications such as axillary nerve paresis should be considered along with implant-related complications when choosing patients for minimally invasive plating.

Keywords: *Humerus, Fracture, Minimally invasive, Locking plate, Axillary nerve*

Although fractures of the proximal humerus are common, most are treated with the conservative management,¹⁻³ including hanging casts or U-slaps. The surgical treatment is required for severely displaced fractures and for the cases with factors that can lead to failure in conservative treatment.⁴

Antegrade humeral nailing and open plating through a deltopectoral approach are well known tech-

niques for operative fixation of proximal humeral fractures. However, the increasing popularity of biologic fixation and advances in the design of locking plate systems have affected the surgical approaches for fracture management.⁵ The submuscular plating technique is a minimally invasive plate osteosynthesis (MIPO) technique^{6,7} with locking plates as the good option, for selected cases of displaced proximal humerus fracture, in terms of the blood supply and stability.^{5,8,9}

Several studies have reported the complications related to minimally invasive plating, such as avascular necrosis (AVN) of the humeral head, intra-articular screw penetration, and screw loosening.¹⁰⁻¹³ However, the incidence of axillary nerve paresis (incomplete injury), which is one of the most likely complications, have rarely been

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reported.^{14,15)} This study evaluated the outcomes of proximal humeral fractures treated with the MIPO technique with locking plates, focusing on the complications related to the MIPO technique.

METHODS

We retrospectively reviewed the medical records of 21 consecutive patients with displaced proximal humeral fractures. The study was approved by the Institutional Review Board. These patients were treated from March 2009 to March 2011 using the MIPO technique with periarticular proximal humeral locking plates (Zimmer, Warsaw, IN, USA). A minimum of one-year of follow-up data were evaluated for each patient. There were 1 male and 20 female patients with an average age of 61 years (range, 16 to 82 years).

The Neer and Orthopedic Trauma Association (OTA) classifications were used to characterize the fracture patterns (Table 1). Regardless of varus-valgus fracture type, only 2-part surgical neck fractures and 3-part fractures with displacement¹⁰⁾ (> 1 cm or $> 45^\circ$) were included in this study, because we believe that such fractures are amenable to reduction by minimally invasive percutaneous techniques. The fractures including lesser tuberosity fragments were excluded, because indirect reduction and internal fixation of such fragments are difficult using a direct lateral approach without damaging the anterior humeral circumflex artery.^{5,9)} However, the reduction and internal fixation of the greater tuberosity fragments may be facilitated through proximal incisions of the direct lateral approach.⁵⁾ Four-part fractures and articular surface fractures, such as head-splitting or impression fractures, were excluded. The patients with neurological symptoms in the injured upper extremity were also excluded to avoid selection bias. In short, our inclusion criteria were by fracture types, which only included the displaced 2-part surgical neck fractures and 3-part fractures, without the lesser tuberosity fracture and the neurological symptoms.

The same surgeon (JP) performed all of the interventions using the MIPO technique and the periarticular anatomical locking plates. The postoperative follow-ups were conducted monthly for the first three months, and the radiographs were taken at each follow-up clinic visit. After the initial three months of follow-up, all patients were followed every three months. If there was no evidence of progression to union by the third month, the patients returned at one-month intervals for the radiographic confirmation of union. The mean follow-up duration was 20.8 months (range, 12 to 24 months). The radiographic

union and the active range of motion were assessed at each follow-up, and the Constant scores were measured at 3, 6, and 12 months postoperatively. The radiographic union was defined by bridging callus formation in at least three cortices on the radiographs made in two orthogonal projections.¹⁶⁻¹⁸⁾ We defined the clinical union as an absence of tenderness or pain on the fracture site at rest.

Surgical Technique

All surgical procedures were performed within one week of the injury. Prophylactic antibiotic (cefotiam 2.0 g daily) was usually given intravenously for three days in all the patients. Each patient was positioned either in the supine position or the beach chair position on a radiolucent table, with an image intensifier placed at the head of the operating table. A direct lateral longitudinal incision was made beginning at the anterolateral tip of the acromion and extending approximately 5 cm distally. A deep dissection was performed through the avascular anterior raphe at the junction of the anterior and middle heads of the deltoid in line with the fibers of the deltoid.⁵⁾

The axillary nerve was not fully explored unless there were difficulties in the indirect fracture reduction. If larger incisions were needed for the fracture reduction, the cord-like axillary nerve was manually palpated under the deltoid by the surgeon. Once the axillary nerve was felt, the raphe incision was carefully extended distally by the sharp dissection.

A submuscular tunnel for percutaneous plate insertion was developed with the blunt elevator or the plate itself using the locking screw sleeve as the handle. A periarticular proximal humeral locking plate (Zimmer) was slid proximal to distal under the axillary nerve without plate precontouring, because the plate is anatomical. The plate was inserted distal to the rotator cuff insertion, in order to prevent the impingement syndrome between the acromion and the plate tip. The plate remained posterior to the bicipital groove and was placed laterally.

Rather than using the distal multiple stab wounds to secure the plate to the humeral shaft, we used a separate distal skin incision^{7,11)} in most cases, while avoiding exposure of the fracture site. The multiple stab wounds were used only for the cases that were easily reduced. The lower skin incision was made distal to the axillary nerve from the lateral side of the humeral midshaft. The distal end of this incision was limited to keep 8-cm above the lateral epicondyle of the distal humerus in order to prevent radial nerve injury. This separate distal skin incision was used for both the indirect fracture reduction and the plate fixation to the humeral shaft.

Table 1. Summary of Cases

Case	Sex/age (yr)	Injury	Neer classification	OTA	Complications	Time to union (mo)	Follow-up (mo)	Flexion/abduction/external rotation/internal rotation			Constant score (at 3 mo/6 mo/1 yr)
								At 3 mo	At 6 mo	At 1 yr	
1	F/66	MVA	3-Part (GT+SN)	11-B1	None	3	27	130/110/50/T12	160/110/60/T10	160/130/60/T10	82/88/90
2	F/22	MVA	2-Part (SN)	11-A3	None	4	27	110/70/50/T12	160/150/60/T10	170/150/60/T5	80/89/91
3	F/62	Fall*	3-Part (GT+SN)	11-B2	None	3	26	50/90/15/S1	160/150/50/T10	160/160/50/T10	62/86/86
4	F/72	Fall	3-Part (GT+SN)	11-B2	Intra-articular screw perforation	3	26	70/80/30/S1	80/90/30/S1	80/90/20/S1	66/65/66
5	M/16	MVA	2-Part (SN)	11-A3	None	3	25	120/100/30/T10	130/120/40/T8	130/120/40/T8	84/86/88
6	F/57	MVA	3-Part (GT+SN)	11-C2	None	3	25	80/60/30/L5	90/90/30/L1	100/90/30/T10	65/68/70
7	F/54	Fall	2-Part (SN)	11-A3	None	3	25	90/60/50/L5	120/120/50/L1	140/130/50/T12	71/79/80
8	F/55	MVA	2-Part (SN)	11-A2	None	3	24	80/50/30/S1	120/90/50/L1	130/100/50/L1	70/78/81
9	F/75	Fall	2-Part (SN)	11-A2	None	3	24	90/50/30/S1	100/90/50/L1	140/120/50/L1	75/77/82
10	F/79	Fall	2-Part (SN)	11-A3	None	3	24	120/90/50/L5	120/110/50/T12	140/140/60/T10	81/80/89
11	F/49	MVA	2-Part (SN)	11-A3	Axillary nerve paresis (incomplete injury)	4	23	70/70/20/L1	80/80/30/T12	90/90/40/T10	66/64/68
12	F/23	MVA	2-Part (SN)	11-A2	None	2	23	140/130/50/T12	150/130/60/T5	170/140/60/T4	90/91/92
13	F/50	MVA	3-Part (GT+SN)	11-B2	Delayed union Proximal screw loosening	6	23	90/50/50/L1	120/90/50/T10	140/120/60/T8	80/87/88
14	F/65	MVA	3-Part (GT+SN)	11-B2	None	3	22	60/90/15/S1	130/120/50/T12	150/140/50/T10	65/84/85
15	F/75	Fall	3-Part (GT+SN)	11-B2	None	3	21	80/50/30/S1	100/90/50/L1	130/110/50/T12	75/78/83
16	F/81	Fall	2-Part (SN)	11-A2	None	3	16	80/50/30/S1	100/90/40/L1	120/120/50/L1	71/77/80
17	F/76	Fall	3-Part (GT+SN)	11-B2	None	3	15	100/50/30/S1	110/90/50/L1	130/120/50/L1	75/77/83
18	F/76	Fall	3-Part (GT+SN)	11-B2	None	3	14	110/90/50/L5	110/110/50/T12	130/140/60/T10	81/80/88
19	F/66	Fall	3-Part (GT+SN)	11-B2	None	3	13	90/50/30/S1	100/90/50/L1	140/110/50/T12	75/78/84
20	F/82	Fall	2-Part (SN)	11-A2	None	3	12	80/40/30/S1	100/90/40/L1	130/120/50/L1	71/77/81
21	F/80	Fall	2-Part (SN)	11-A2	None	3	12	80/50/30/S1	110/90/40/L1	120/120/50/L1	70/78/81

*Fall: from a standing height or less.

OTA: Orthopedic Trauma Association classification, MVA: motor vehicle accident, GT: greater tuberosity, SN: surgical neck, T: thoracic, L: lumbar, S: sacral.

Then, the locking plate was fixed to both the distal and proximal fragments, with fracture reduced and maintained in the desired position using either joystick technique or Kirschner wire under the fluoroscopic guidance. Three to four screws engaging six to seven cortices were placed at both the proximal and distal fragments. The number of locking screws was individualized according to the fracture pattern and stability.

If necessary, the greater tuberosity fragment was usually reduced and fixed in the last step, using the screws or sutures passing through the most proximal plate hole. The wound was sutured with or without a drain after the final confirmation of fracture alignment under an image intensifier.

The patients were allowed to perform the immediate passive range of motion exercises as tolerated and then were progressed to active-assisted range of motion exercises. The strengthening exercises were permitted after the clinical and radiological indications of healing.

RESULTS

The average shoulder flexions at 3 month, 6 month, and 1 year follow-ups were 91.4° (range, 50° to 140°), 116.7° (range, 80° to 160°), and 133.3° (range, 80° to 170°), respectively. The average shoulder abductions at 3 month, 6 month, and 1 year follow-ups were 70.5° (range, 40° to 130°), 104.3° (range, 80° to 150°), and 121.9° (range, 90° to 160°), respectively. The mean Constant scores at 3 month, 6 month, and 1 year follow-ups were 74.0 (range, 62 to 90), 79.4 (range, 64 to 91), and 82.7 (range, 66 to 92), respectively (Table 1).

All the patients demonstrated osseous union within

the average of 3.2 months (range, 2 to 6 months). There was one case of a delayed union with a bone defect around the lateral cortex just below the surgical neck with proximal screw loosening. This defect spontaneously filled by six months postoperatively (Fig. 1). The proximal screw loosening (an approximately 5-mm back-out) showed no further problematic movement. There was another case of the screw penetration into the glenohumeral joint that was detected at the first follow-up. However, it was left in place because the patient strongly refused additional surgery. The intra-articular screw perforation remained unchanged on the one-year postoperative radiographs. Any plate failures or inadvertent neurovascular injuries were not observed during the study period. There was one patient presenting with the slight deltoid muscle atrophy, the abductor weakness (grade 3, active movement against gravity) without sensory deficit, and the limited range of motion (11th case in Table 1). The axillary nerve palsy was diagnosed in this patient six months postoperatively, using the electromyography (EMG) and the nerve conduction velocity studies (NCS). The motor NCS showed that the injured axillary nerve had almost half of the normal amplitude compared to the uninjured axillary nerve. EMG and NCS performed at one year postoperatively demonstrated little interval change of axillary nerve palsy (Fig. 2). However, deltoid muscle atrophy disappeared, abductor weakness improved (grade 4, active movement against resistance), and the patient was able to flex and abduct the shoulder to 90° one year postoperatively (Table 1).

No cases of AVN of the humeral head were seen including the last follow-up. There were no cases of rotator cuff tendon injury during the procedures. No cases of impingement syndrome between the plate tip and the ac-

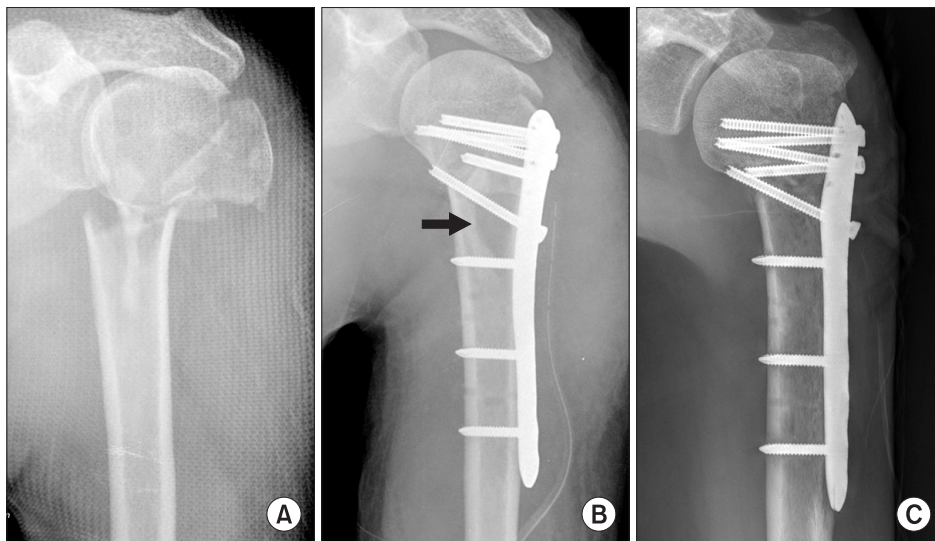


Fig. 1. (A) Proximal humeral fracture. (B) After internal fixation using minimally invasive plate osteosynthesis, a lateral cortical defect (arrow) near the surgical neck was observed on the immediate postoperative radiograph. (C) However, this defect spontaneously disappeared on a radiograph taken six months postoperatively.

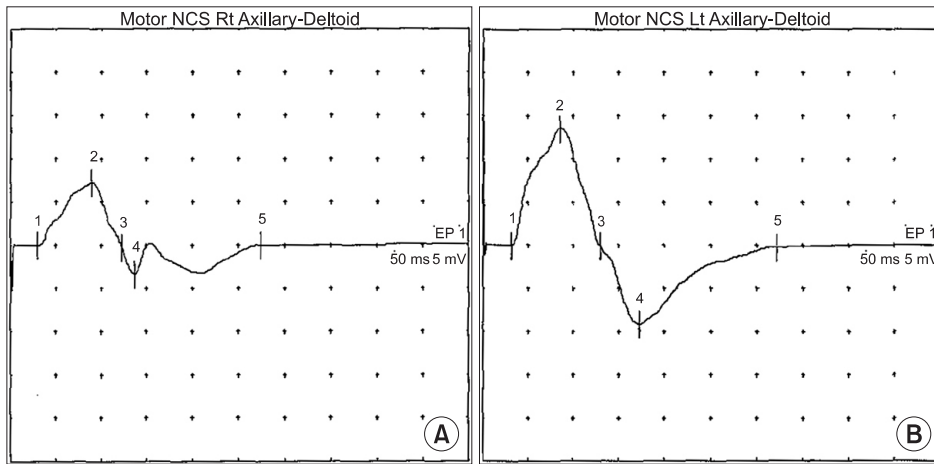


Fig. 2. Electromyography and nerve conduction velocity studies (NCS) performed one year postoperatively showed that the amplitude of the injured right (Rt) axillary nerve (A) was almost half of the normal amplitude of the uninjured left (Lt) axillary nerve (B). EP: evoked potential.

romion, due to deep insertion of the plate, were observed. No hardware removal and no secondary operations were performed during the study period.

DISCUSSION

Even though conservative, nonsurgical treatment is the mainstay for the proximal humeral fracture,¹⁻³ it requires a great deal of the patient compliance. For minority of the patients who require surgical treatment, several options are possible. These options include percutaneous pin fixation, open plating through a deltopectoral approach, antegrade humeral nailing, and humeral head replacement.¹⁹⁻²²

Advances in the locking plate systems and the rise of biological fixation concepts have changed many surgeons' approaches to the fracture treatments. Since plating with the MIPO technique preserves the blood supply, unlike the open plating which requires periosteal stripping, the MIPO technique is gaining its popularity.⁹

The anatomical locking plate systems facilitate plating with the MIPO technique, and they eliminate the need for plate precontouring. Moreover, when the proximal locking screws are cannulated, as in the periarticular proximal humeral locking plates (Zimmer), the screws can be inserted into the metaphyseal region of the proximal humerus along the guide wire without losing a predrilled path.

The advantages of the MIPO technique include the higher union rates, decreased need for bone grafting, lower AVN rates, and fast functional recovery.^{5,10-13} In this study, bony union was achieved in all of the patients, even in those with the osteoporotic fractures. One case of a delayed union (Fig. 1) with a bone defect was eventually filled without the bone grafting at 6 months postoperatively.

The complications associated with the minimally invasive plating for proximal humerus fractures include the intra-articular screw penetration, proximal screw loosening, plate failure, and AVN of the humeral head.¹⁰⁻¹³ Although there have been a few studies^{14,15} reporting axillary nerve palsy due to the MIPO technique for the treatment of proximal humeral fractures, the axillary nerve palsy was only briefly mentioned without any detailed description. We want to report one case of an axillary nerve palsy in more detail. This palsy was confirmed with EMG and NCS at 6 months postoperatively, and was compared to the same test at one year postoperatively. There were little interval changes between the two consecutive EMG and NCSs.

One cadaver study reported that the axillary nerve can be elevated by an average of 13.4 mm from the bone without becoming taut.⁸ However, in the clinical practices, even more elevation, or traction of the soft tissue envelope around the fracture zone, may be necessary during the indirect fracture reduction or the screw insertion near the fracture zone. The axillary nerve palsy in this study might have resulted from the intraoperative traction of the axillary nerve during the insertion of proximal locking screws, because there were no cases of inadvertent nerve injuries during the operations and the patients with neurological symptoms in the injured upper limbs were excluded from this study. Therefore, when assessing the risk-benefit ratio for the minimally invasive percutaneous plating of the proximal humeral fractures, the possibility of traction injury of the axillary nerve should be considered along with the complications mentioned above. The young patients with tight, soft tissue tensions may be more susceptible to such injuries, even though the traction injuries are usually incomplete.

No cases of AVN of the humeral head were seen in

this series, perhaps because of the anterior humeral circumflex artery and its ascending branches being uninjured due to the exclusion of lesser tuberosity fractures.

The main limitation of this study is the small number of patients included in the sample. However, we believe that our report will contribute to the body of literature on the possibility of axillary nerve paresis during the minimally invasive plating for the proximal humeral fractures in the clinical practices. Prospective, large-scaled, controlled trials with EMG and NCS are needed in the future for better objective evaluation of the axillary nerve paresis with the MIPO technique as the treatment for proximal humeral fractures.

In conclusion, the minimally invasive percutaneous plating using the periarticular locking plates is a useful option for the selected patients with displaced proximal humeral fractures. The MIPO technique provides fast union,

good functional recovery, and decreased need for bone grafting. However, when selecting the patients for minimally invasive platings, clinicians must consider not only the implant related complications of screw loosening and intra-articular screw perforation, but also the possibility of axillary nerve paresis.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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