Minimally invasive plate osteosynthesis (MIPO) in diaphyseal humerus and proximal humerus fractures

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Objective: Our aim was to evaluate the results of minimally invasive plate osteosynthesis (MIPO) using locking plates in diaphyseal humerus and proximal humerus fractures.

Methods: Nine patients who underwent open reduction and MIPO for the treatment of diaphyseal and proximal humerus fractures between June 2006 and October 2009 were included in this study. One S3® and 8 PHILOS® plates were used. Mean age was 75.2 (range: 32 to 86) years and all patients were females. Mean follow-up was 33.9 (range: 14.8 to 54.8) months. According to AO/ASIF classification, four patients had 12C1, two patients 12A1, one patient 12A2, and two patients 11A2 fractures. Axillary and radial nerves were explored and protected in all patients. Patients were evaluated radiographically for union and functionally using the Constant-Murley score.

Results: None of the patients had nonunion, avascular necrosis, axillary or radial nerve paralysis or implant failure. Mean Constant-Murley score was 86.8±2.2 (range: 70 to 100). Mean union time was 3.2 (range: 2.5 to 5) months.

Conclusion: MIPO of humerus diaphysis and proximal fractures allows for preservation of blood supply in fracture fragments, owing to less soft tissue and periosteal injury. When the procedure is performed with the lateral double incision, exposure and preservation of the axillary and radial nerves are necessary. Early return of function in the shoulder and elbow joints and favorable healing time are the major advantages of this method in this rare subset of humerus fractures.

Key words: Fracture; humerus; minimally invasive; MIPO; osteosynthesis; PHILOS®.

Treatments performed to preserve the blood supply of the bone using internal splinting, bridging and new plate designs providing limited contact with the bone are referred to as biological flexible fixation methods. These methods emphasize the importance of soft tissue on fracture healing and do not compromise circulation by using anatomic reduction to achieve a rigid fixation. In the indirect approach, acceptable reduction of the fracture is advised to provide movement of the fractured tips with a relatively stable fixation. Alignment of the fracture by bridging is favored instead of absolute rigid fixation with compression. The use of indirect reduction for alignment of the fractures minimizes soft tissue stripping.[1] In addition, indirect reduction reduces surgical trauma and promotes formation of the callus by "biological flexible fixation". Biological flexible fixation is achieved with minimal bone-implant contact, long-distance bridging and locked internal fixators with fewer screws. Implants prevent micro movements during fixation with plates, which provides absolute sta-

bility. Biological flexible fixation tolerates the micro movements between the fracture fragments, and in fact, requires some motion for union. This micro movement is preserved by using locking screws between the bone and implant.[2] By doing so, the method does not compromise an early and full recovery.[3] Nevertheless, a live bone is required to achieve successful results.[2] In their experimental study on sheep femurs, Baumgaertel et al. investigated the radiological, biomechanical and microangiographic differences between anatomic rigid, fixation and biological (bridging) fixation, and proved that indirect reduction and bridge plating was superior to rigid anatomic fixation employed by direct reduction.[4] Mineralization in fracture callus occurs faster and more effectively in indirect reduction, compared to anatomic reduction.[4] In a study on cadavers, Farouk et al. demonstrated that conventional plating techniques impaired the blood flow to the bone more than the minimally invasive approach that utilized percutaneous plates.[5] Preserved blood flow in biological plating techniques may lead to clinical results, such as delayed unions, recurrence of the fracture, decrease in infection incidences, as well as increase in union rates and decrease in graft utilization.

In plate applications, incisions are made on the distal end of the fracture line. In diaphyseal fractures, the plate is moved above the periosteum and placed percutaneously to bypass the fracture line, and screws are placed through the proximal and distal incisions (bridge-plating). Today, the minimally invasive plate osteosynthesis (MIPO) approach, as defined by Krettek et al. is favored, whereas wide incisions without exposing the fracture line had been earlier preferred in biological fixations.[6-9] In the MIPO method, minimal incisions are performed to place and screw the plate away from the fracture line. After fracture reduction and extremity alignment are confirmed by fluoroscopy, the plate is moved above the periosteum through these incisions. The plate is then screwed through the proximal and distal incisions. It is not essential to shape the plate to exactly fit the contours of the bone in plate fixations. In this method, implants providing minimal surface contact with the bone are preferred.[6-9]

Although conservative treatment returns successful results of 90% in diaphyseal fractures of the humerus, there are absolute and relative surgical treatment indications in cases, such as multiple traumas, open fracture, bilateral fracture, floating elbow, and obesity. Soft tissue interposition and circulatory disorders are more commonly seen in segmental fractures of the humerus when compared to other fractures. The incidence of nonunion increases if these types of fractures are treated conservatively.[10]

In treatment of diaphyseal fractures of the humerus with open reduction internal fixation, a nonunion rate of 5.1% and radial nerve palsy complication rate of 5.8% to 17.6% can be expected.[11-13] Today, MIPO is a popular treatment method in long bone surgeries, returning lower complication rates.[13-16]

In our study, we evaluated the results of open reduction and locked plate fixation using the minimally invasive double incision in diaphyseal fractures of the humerus and proximal diaphyseal fractures.

Patients and methods

Nine patients who underwent MIPO between June 2006 and October 2009 were retrospectively evaluated. The mean age of the patients was 75.2 (range: 32 to 86) years. One patient had a proximal fracture, one had a diaphyseal fracture and the remaining 7 had proximal diaphyseal fractures. According to AO/ASIF classification, 4 patients were classified as Type 12C1 (of which 3 had accompanying fractures of Type 11B3, 11A2 and 11A1), 2 were classified as Type 12A1, another 2 as Type 11A2, and one as Type 12A2.

Patients were seated in the beach chair position at an angle of 60° and the C-arm was placed across the patient. The first incision was performed longitudinally, starting from the anterolateral edge of the acromion to 6-8 cm downwards. The deltoid muscle was freed from the avascular fibrosis raphe between the anterior and medial deltoid head. The axillary nerve was suspended and preserved. Then, the skin and subcutaneous tissue were laid open with a distal lateral incision of 6-8 cm, depending on the level the fracture distally reached. The radial nerve was found between the brachialis and brachioradialis muscles with blunt dissection, suspended and preserved (Fig. 1). To prevent axillary and radial palsy caused by compression and stretching, Parabeuf retractors were used instead of retractors with lever arms, e.g. Hohmann (Fig. 1). Rotational movements were executed with the forearm in supination, elbow in 70° flexion, and shoulder in 60° abduction. Thus, the axis was fixed with traction applied from the elbow as the biceps muscle was aligned perpendicular to the bicondylar axis. The reduction was verified on anteroposterior and lateral fluoroscopic images. A submuscular tunnel, starting over the periosteum toward the distal, was prepared with an elevator applied through the proximal incision. A 4.5 mm locking screw guide applied at the locked plate was used as a handle to distally move the plate from the prox-
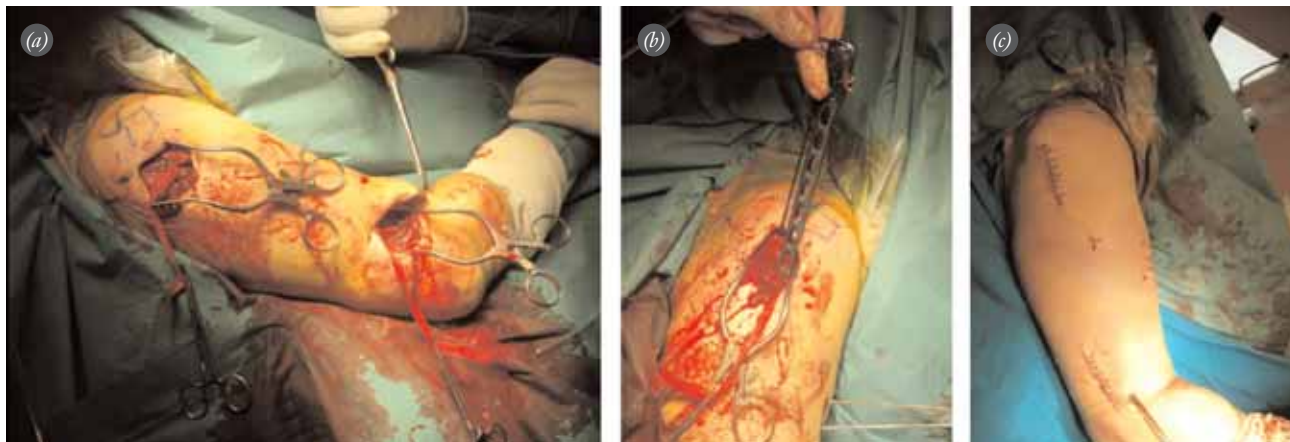
Fig. 1. **(a)** Axillary nerve is preserved in proximal and radial nerve in distal incisions; **(b)** plate application through proximal incision; **(c)** both incisions are closed. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

imal incision and place it in the tunnel opened over the periosteum. In 2 patients S3® (DePuy, Kirkel-Limbach, Germany) plates (Fig. 2) and in 7 patients PHILOS® (Proximal Humerus Internal Locked System; Synthes-Stratec Medical, Oberdorf, Switzerland) plates were used for fixation. First the proximal, then the distal fragments were fixed to the plate using 4.5 mm locking screws. A minimum of 3 to 4 screws were used for each fracture fragment fixation. Mitek anchor sutures (DePuy, Johnson and Johnson, Boston, MA, USA) were additionally used in 2 patients for rotator cuff repair (Fig. 2). A drain was placed through the distal incision in all patients and removed one day after surgery. The average drainage was 60 (range: 40 to 120) cc. All patients wore a shoulder sling for 3 weeks. Wrist, active and passive elbow movements and shoulder pendulum exercises

were begun the first week as a part of standard fracture rehabilitation course. Radiological and functional evaluations of the patients took place on the postoperative 3rd and 6th weeks and 3rd and 6th months. Anteroposterior and lateral follow-up radiographs were taken. When a callus was observed in three of four (medial and lateral, anterior and posterior) cortexes, it was considered as a union. The mean follow-up time was 33.9 (range: 14.8 to 54.8) months. The 3rd, 6th and 12th month Constant scores were statistically evaluated according to Dunn's (multiple comparison) test.

Results

Nonunion, avascular necrosis, axillary or radial nerve palsy was not observed in any patient. Average surgery time was noted as 72.6 (range: 66 to 150) minutes. The
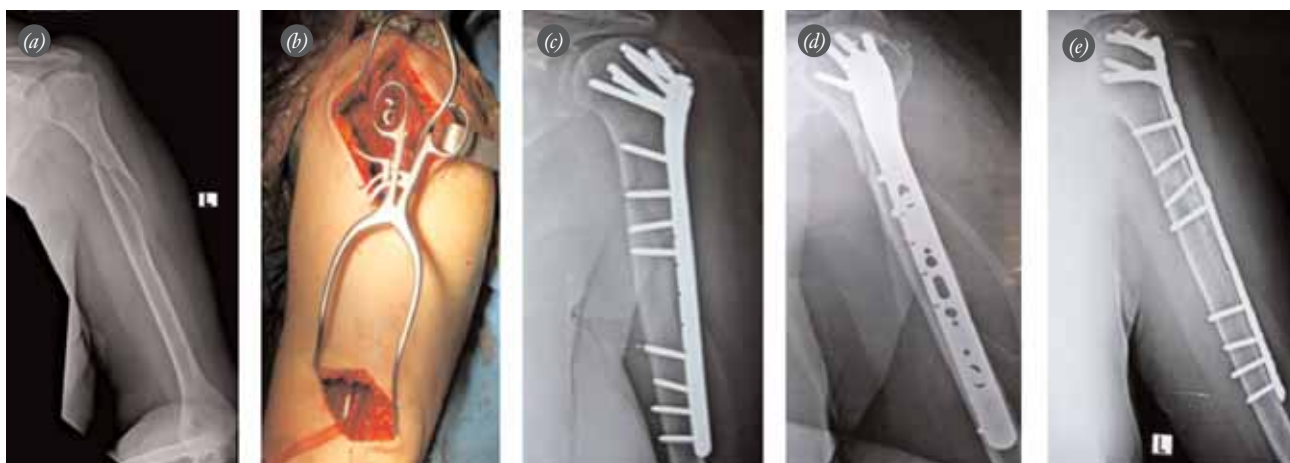
Fig. 2. Views of 82-year-old female patient. **(a)** Type 11A1 and 12C12 fractures are seen. **(b)** Surgical intervention. **(c, d)** Early postoperative radiographs showing fixation with S3® humerus plate and rotate cuff repair with anchor suture. **(e)** Union is seen on the 3rd month radiograph. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]
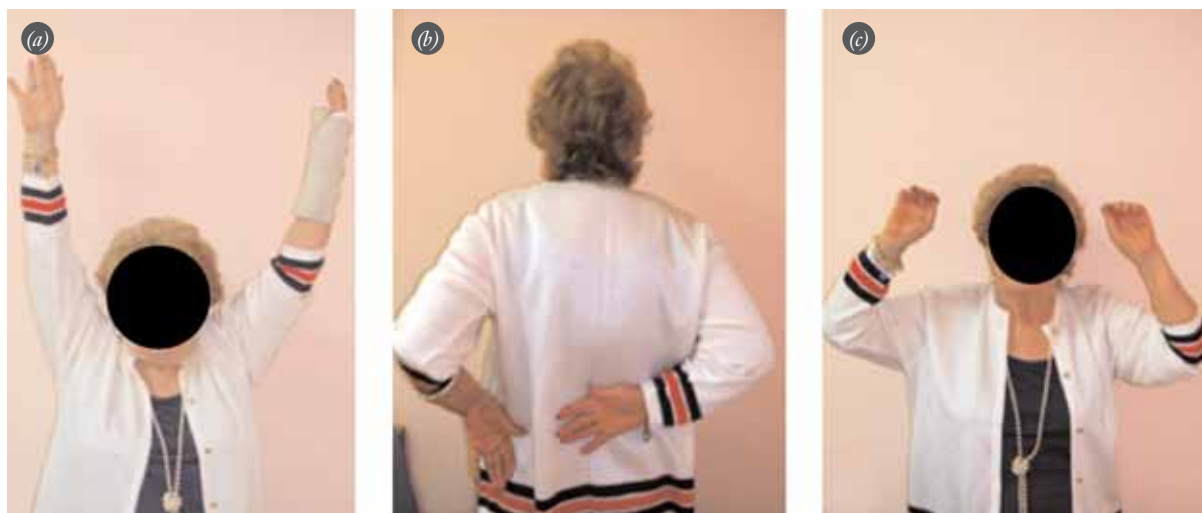
Fig. 3. **(a-c)** Range of movement at the 3rd postoperative month. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

mean Constant-Murley score was 86.8±2.2 (range: 70 to 100). The average time to union was 3.2 (range: 2.5 to 5) months (Figs. 3 and 4). All patients had an abduction above 90° at the end of the 3rd and above 150° at the 6th month (Fig. 3). The mean Constant-Murley score was 64.8±1.7 at the 3rd, 73.5±1.3 at the 6th and 86.8±2.2 at the end of the 12th month. According to Dunn's test, there was a significant difference between the Constant scores taken at the above intervals (p=0.0001). The Constant score at the end of first year was statistically higher than those measured at the 3rd and 6th months (p=0.007), and the Constant score at the 6th month was higher than the score the 3rd month (p=0.007). Mayo

wrist (performance) score was excellent in all patients at the end of the 3rd month (mean: 92.5).

Discussion

Fixations that allow for identifiable movements of fracture fragments under functional loading are considered to be relatively flexible fixations.[17] Short plates are exposed to long bending forces; however, the bending stress disperses in long plates, making the fixation flexible.[18] In the minimally invasive intervention performed with lateral double incision, full reduction and compression of the fractured fragments is not accomplished. Thus, this fixation is relatively flexible. In
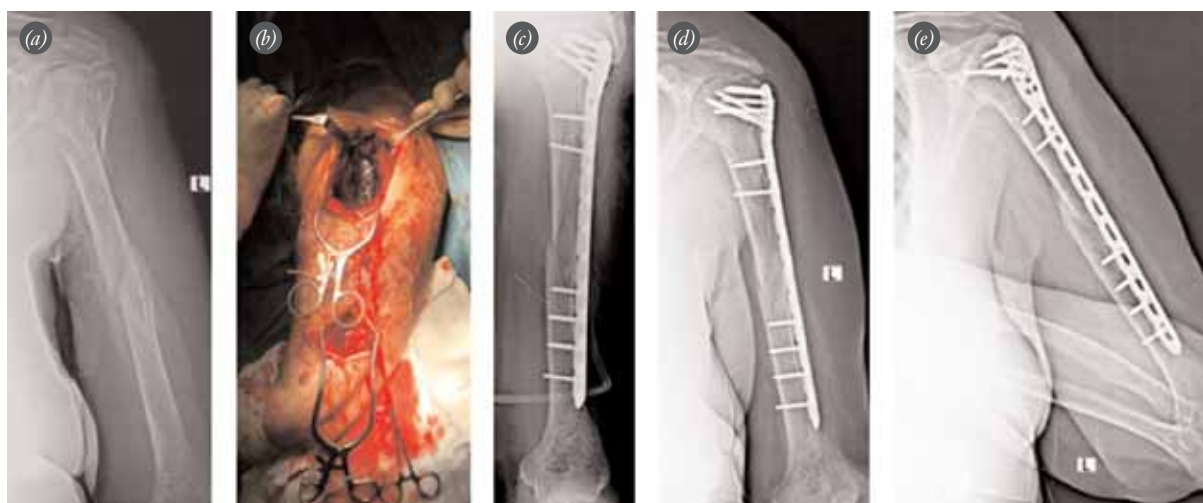
Fig. 4. Views of 70-year-old female patient. **(a)** AO Type 11B2 and 12C22 fractures. **(b)** Surgical intervention. **(c)** Early postoperative radiograph showing fixation with PHILOS® plate. Union is seen on the 3rd month on **(d)** anteroposterior and **(e)** lateral radiographs. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

these types of fixations, the fracture line heals with the formation of a callus that fast bridges the fractured tips. Healing by means of callus is faster and more effective than direct healings in absolute hard fixations with no callus. The soft tissue and periosteum damage is limited as the fracture site is not opened, and this expedites union by preventing the impairment of blood flow at the fracture ends.[17] In contrast to those advantages, nonunion, malalignment, problems with implants, and skin issues regarding these methods have also been reported in the literature.[19-23]

Interposition of the soft tissue between fractured pieces and circulatory disorder among the segmental pieces are more commonly noticed in segmental humerus fractures than other fractures. Open surgical treatment of the segmental fractures may result in nonunion as the already impaired circulation of the segmented piece can worsen due to soft tissue stripping.[10] In MIPO, soft tissues interposed between the segmental fractured pieces can be removed with an elevator to achieve reduction. However, it is important to not strip the soft tissue off the fractured fragments.

As there is no need to lay out the radial nerve in MIPO applications, the plates for humerus diaphyseal fractures have been applied on the anterior face of the humerus in both cadaveric and clinical studies in the literature.[13,16,18,24,25] In diaphyseal fractures extending toward the proximal end, it would be more appropriate to place the plate laterally in MIPO. This enables the reduction of the proximal piece abducted by the deltoid muscle.[14,15]

The axillary and radial nerve can be injured during the surgical fixation of the humeral fracture. Recognizing the layout of these nerves is the key to avoiding complication. The axillary nerve runs around the neck of the humerus from posterior to anterior, at 6.1±0.7 (range: 4.5 to 6.9) cm distal of the upper tip of the humeral head.[26] In our study, the proximal intervention was performed in the form of incision from the anterolateral edge of the acromion to 6-8 cm toward the distal and the axillary nerve was suspended and preserved.

The radial nerve lies in the posteromedial of the proximal of the humerus object, in the posterior in the middle of the object and in the lateral in the distal of the object. Anterior intervention to the humerus in many MIPO applications is preferred because it does not need to expose the radial nerve. However, although there is no necessity for a radial nerve exploration, screws can still injure the nerve in the posterior during anterior interventions.[18,23] The radial nerve lies

with the deep brachial artery in the spiral groove in the posterior compartment between the medial and lateral attachment points of the triceps. In plate applications on the anterior of the humerus, the screws applied through the anterior to posterior can injure the radial nerve on the posterior; this region is at the level of the deltoid insertion.[23,27] The radial nerve enters the lateral intermuscular septum (LIS) at 11.8±2.1 (range: 8.1 to 19.0) cm proximal to the lateral epicondyle, going from the posterior compartment to the anterior compartment, and continues obliquely in regard to the humerus. The nerve is merely mobile at this point.[28] The radial nerve is at risk in 2 regions during fracture and fixation. The first is the distal part of the deltoid tuberosity of 6.3±1.7 cm, in the middle part of the posterior body of the humerus. The second region is 10.9±1.5 cm proximal to the lateral epicondyle; the metaphyseal width level on the 1/3 distal lateral humerus side.[27] The radial nerve is in direct contact with the humerus in a small part of the supracondylar ridge. This is the section after the LIS but before the brachioradialis.[29,30] If the radial nerve is not to be exposed, the bottom tip of the plate should not reach the LIS and below it. As the plates reached the LIS and bottom level in all patients in our study, we exposed the radial nerve and preserved it.

The posterior radial collateral artery and lateral antebrachial cutaneous nerve injuries should be watched out for in percutaneous screwing. The posterior antebrachial cutaneous nerve lies with the radial nerve in the spiral groove as the radial nerve penetrates the LIS, enters the anterior compartment at 5 cm proximal of the lateral epicondyle, shows up under the skin, and passes through the anterior of the lateral epicondyle.[31] In our study, no injury was observed in the nerve as none of the plates extended toward the distal.

In order to protect the axillary and radial nerves, Parabeuf retractors were used instead of Hohmann retractors with leverage arms. Traction was not applied to suspended nerves. Attention was paid to avoid drill bit and screw injuries. The size of the plate was chosen to ensure a fixation on the distal fracture segment with 4 locking screws. In segmental diaphyseal fractures with proximal metaphysis, a minimum of 2 and maximum of 4 locking screws were applied on the segmental piece. Percutaneous interfragmentary screws were used in 3 patients with long spiral fractures.

Lau et al.[15] applied the MIPO technique in their series of 17 patients with proximal diaphyseal humerus fracture, using PHILOS® plates in a lateral interven-

tion. The axillary nerve was not exposed in the proximal. To avoid exposing the radial nerve, plate size was chosen to ensure that the plate distal was more than 8 cm above the lateral epicondyle. Yet, neuropraxia was seen in the radial nerve in 3 patients and full recovery was achieved in the 3rd, 6th and 8th month follow-ups. One patient had a delayed union due to implant loosening, 4 cases experienced impingement syndrome due to implementation of the plate at an elevated level and 2 of these patients gained full range of motion following the removal of the plates.[15] In Rancan et al.'s[14] study, MIPO was performed with lateral intervention using PHILOS® plates on 29 metadiaphyseal proximal humerus fractures. The axillary nerve was not exposed proximally but the radial nerve was laid out distally. In the preoperative period follow-ups, one patient had subacromial impingement syndrome and another had to be reoperated using the same technique, due to the disintegration of the distal fracture segment from the plate, following incorrect insertion of the screws and subsequent screw breaking.[14]

Fracture fixation using minimally invasive intervention reduces the soft tissue damage and periosteal stripping, minimizing the damage to the biological environment of the fracture. Due to less soft tissue stripping off the fractured pieces, blood circulation of the fracture fragments is preserved. In conclusion, surgical intervention with lateral minimally invasive double incision is a safe and effective method for fixation of diaphyseal and proximal fractures of the humerus, providing satisfactory healing time and excellent functional results and is an alternative to open surgery.

Conflicts of Interest: No conflicts declared.

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