Plating of humeral shaft fractures: Comparison of standard conventional plating versus minimally invasive plating


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Summary

Purpose: This study compared clinical outcomes and complications in patients with humeral shaft fractures treated using two methods of fixation by plating.

Methods: Minimally invasive plate osteosynthesis (MIPO, n = 29) was prospectively performed from around the middle of the study period, while open reduction and plate osteosynthesis (ORPO, n = 30) had been the original standard method. Locking compression plate was used in these two groups. Major characteristics of the two groups were similar in terms of fracture type, fracture location, age, associated injuries and numbers of open fractures.

Results: Primary union was achieved in 28 of 29 in the MIPO and in 27 of 30 in the ORPO. Mean time to union was similar in the two groups. Mean operation time in the MIPO (110 min) was shorter than in the ORPO (169 min) (P < 0.05). Bone grafting was performed in five patients of the ORPO, but in no patient in the MIPO (P < 0.001). There was one case of deep infection in the ORPO. Functional outcome was satisfactory in both groups.

Conclusions: Minimally invasive plate osteosynthesis may achieve comparable results with the open plate osteosynthesis method in simple as well as complex fractures of humeral shaft. Although MIPO potentially has the radiation hazard, it may reduce the perioperative complications with a shortened operation time.

Level of evidence: Level III. Case-control study.

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The study was conducted at Kyungpook National University Hospital, Daegu, Republic of Korea.

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Introduction

When operative treatment is required, plate osteosynthesis with open reduction (ORPO) has offered a successful result [1–3], with the advantages of anatomical fracture reduction. However, this technique involves extensive soft tissue stripping and disruption of the periosteal blood supply, which increase the risks of nonunion and deep infection [4,5]. Intramedullary nailing is a good option and provides excellent bone healing, because of its biomechanical advantages and the closed nature of the insertion technique [6,7]. Nevertheless, shoulder and elbow function may be disrupted depending on the nail entry site [8,9]. Recently, it was reported that comminuted humeral fractures can be successfully treated by minimally invasive plate osteosynthesis (MIPO) [10,11]. And, this technique offers the advantages of less soft tissue dissection and blood loss. However, there is only one report about the comparison of these two methods with dynamic compression plate (DCPs) [12]. Also, it did not include the results according to the fracture classification. In this cross-sectional study of comparing MIPO and ORPO, we assessed the radiological result including union rate and time and functional result. Additionally, the demographics of each procedure and complications were investigated.

Patients and methods

After receiving institutional review board approval, 51 patients with an unstable humeral shaft fracture were collected, who were treated with MIPO or ORPO from January 2003 to April 2009. The criteria used for selection were:

1) a fracture located at least 5 cm distal to the surgical neck and 5 cm proximal to the olecranon fossa;
2) a grades I or II open fracture;
3) a fracture with polytrauma and;
4) early conservative treatment failure.

Pathologic fractures, refractures and severe open fractures (Gustilo-Anderson [13] grade III) were excluded.  

From March 2006 to April 2009, MIPO was consecutively performed in humeral shaft fractures of above criteria. Among 34 patients with MIPO, 29 were followed regularly for more than a year (average, 18 months; the MIPO group). Before the start of MIPO for humeral shaft fractures, the standard operation was ORPO and IM nailing was not performed in our institute. To enable comparisons, we applied the same amount of study period of MIPO (from January 2003 to February 2006) into ORPO group. Thirty-five patients underwent ORPO in this period and 30 of them were followed up at least a year (average, 22 months; the ORPO group). The locations, patterns of the fractures and open fractures are listed in Table 1. AO/OTA classification was used, which is arranged in order of increasing severity according to the complexities of the fracture (type A-simple, type B-wedge, type C-commminated). The two operating surgeons involved were experienced at both procedures. A locking compression plate (narrow LCP-57 cases, metaphyseal LCP-2 cases [MIPO group], Synthes®, Oberdorf, Switzerland) was used in all 59 patients.

Demographics

Mean ages of the MIPO and ORPO groups were 39.6 years (range, 16–83) and 42 years (range, 17–82) respectively. In the MIPO group, there were 16 males and 13 females and in the ORPO group 16 males and 14 females. Most patients sustained injuries in road traffic accidents (19 in the MIPO group and 21 in the ORPO group). The second most common cause of injury was a fall or slip down (10 in the MIPO group and nine in the ORPO group). Type A fracture was most common according to the AO-OTA classification (11 in the MIPO group and 15 in the ORPO group) [14] and the next most common was type B (11 in MIPO and eight in ORPO), which was followed by type C (seven in MIPO and seven in ORPO). Middle one-third fractures were most common (18 in MIPO and 20 in ORPO), followed by proximal fractures (six in MIPO and five in ORPO) and distal one-third fractures (five in MIPO and five in ORPO). According to the Gustilo-Anderson classification, there were three grade I open fractures in the MIPO group and three grade I and two grade II fractures in the ORPO group. Preoperatively, there were three patients with radial nerve palsy in each group. Brachial plexus injury was associated in one patient in the MIPO group and in two patients in the ORPO group and all of them had associated injuries of clavicle or scapular fractures. Fourteen of the 29 MIPO and 16 of the 30 ORPO patients had associated injuries. Demographics and injury characteristics were similar in two groups of treatment (P > 0.05).

Operating technique

Minimally invasive plate osteosynthesis (MIPO)

The operation was carried out in a supine position; with abduction of the injured arm, under image intensifier control. Preserving if possible the cephalic vein, the proximal humeral shaft was exposed through the delto-bicipital interval. A distal incision of 4–5 cm was performed on the anterior side proximal to the elbow crease. The sensory...
branch of the musculocutaneous nerve was usually identified and protected after retracting the biceps muscle. The brachialis muscle was split by blunt dissection. A submuscular tunnel was then developed using the plate and the locking sleeve as a handle. Under image intensifier control, reduction was achieved by manual traction and an additional external fixator was used to maintain the reduction, depending on its difficulty in reduction maneuver. A 9- to 12-hole plate was used for fracture stabilization. The plate was fixed on the anterior surface of the humeral shaft. Generally, three bicortical screws (either locking or cortical screw) were inserted on both sides of the fracture. But, two screws were fixed in two distal shaft fractures. Radial nerve exploration was not undertaken.

Open reduction and plate osteosynthesis (ORPO)
Anterior or anterolateral approach, centered on the fracture site was chosen, with patients in a supine position and the arm on a radiolucent board. Reduction was achieved with opening the fracture site. We tried to gain the absolute stability for type A and B fractures, using compression osteosynthesis or lag screw technique. In type C fracture, indirect reduction was performed while minimizing the soft tissue stripping as much as possible. If necessary, at the discretion of the surgeon, bone grafting was done to treat unsatisfactory defects or gaps after plate fixation. A 7- to 13-hole plate was used for fracture stabilization. A minimum of three screws are advocated for bone fixation on each side of the fracture. Radial nerve exploration was undertaken in cases of initial palsy.

In both methods, the patient’s arm was supported in a neck sling for 3–5 days, postoperatively. Shoulder and elbow ranges of motion (ROM) were initiated as soon as possible. The patients were instructed to move the shoulder and elbow and to use the operated limb to perform daily activities (eating and personal hygiene). Follow-up visits by clinical examination and anteroposterior and lateral radiography were performed at 4–6 weekly until bony union was achieved. Further radiographs were obtained when required and patients returned for 6- and 12-month examinations.

In terms of data collection, operative time was defined as the time from skin incision to closure. In addition, we recorded fracture the union time, perioperative complications, late complications and shoulder and elbow functions. Shoulder scores (UCLA scoring system [15]) and elbow function indices (Mayo elbow performance index [16]) were assessed by a surgeon not associated with the surgical procedure or patient care. Union was defined as the absence of pain and the presence of bridging callus in three of the four cortices on anteroposterior and lateral radiographic views of the humerus. Surgical complications were categorized as wound breakdown, infection, loss of fixation and nerve injury. Nonunion was defined as the absence of fracture union at 6 months postoperatively.

Statistical analysis was performed using SAS software, version 6.12 (SAS Institute, Cary, NC). The demographic and fracture characteristics of the two treatment groups were compared using the Khi square test or Fisher’s exact test for nonparametric categorical variables or using the Student’s t test for parametric variables. Operative time and the union time were compared using the Student’s t test and complications using Fisher’s exact test.

### Results
Operative duration for humerus fracture was calculated from skin incision to wound closure (21 from MIPO, 24 from ORPO), excluding some cases unable to calculate from multiple surgeries or combined procedures. Mean operative time

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was 110 min in the MIPO group and 169 min in the ORPO group \( (P < 0.05, \) Wilcoxon’s rank sum test). In the MIPO group, mean intraoperative radiation exposure time for 24 of the 29 patients was 201 s (range 88–415 s). In the ORPO group, fluoroscopy was not used. Autogenous iliac bone grafting was done in five patients in the ORPO group, but in no patient in the MIPO group \( (P < 0.0001, \) Fisher’s exact test). Results of patients are summarized in Table 2.

Radiographics outcomes

Twenty-eight of the 29 (90.5%) MIPO patients and 27 of the 30 (87%) ORPO patients achieved union. Average union times for the MIPO and ORPO groups were 17.3 and 16.7 weeks respectively. Union rates and union times were not significantly different in both methods \( (P > 0.05). \)

All of type A fractures was united in both methods. Among type B fractures, two nonunions occurred in ORPO group, while none occurred in MIPO group \( (\text{Fig. 1}). \) In type C fractures, there were two nonunions (one case by MIPO and ORPO respectively). Nonunion after MIPO was a comminuted fracture of distal shaft, with inappropriate fixation and poor stability. Three nonunions after ORPO were the lack of combined bone grafting. We presume that nonunions after ORPO were caused by inadequate management of small, comminuted fragments \( (\text{Fig. 2}). \)

In all 59 study subjects, fractures healed with less than 10° of angular deformity or with less than 1 cm of shortening. On anteroposterior radiographs, average angular deformities of varus-valgus were 2.2° in the MIPO group (range, 8° of valgus to –1° of varus) and 0.8° in the ORPO group (range, 5° of valgus to –2° of varus). On the lateral radiographs, average angular deformities were 0.6° in the MIPO group (range, neutral to 6° of apex posterior angulation) and 0.5° in the ORPO group (range, neutral to 5° of apex posterior angulation).

Functional outcomes

All patients were able to return to previous employment within 6 months, except for one patient in the MIPO group and three patients in the ORPO group who failed to achieve primary union. Mean UCLA scores were 34.3 and 33.8 in the MIPO and ORPO groups and mean Mayo elbow performance indices were 97.6 and 97, respectively \( (P > 0.05). \)

Complications

One patient in the ORPO group developed an infection, which improved after two debridements and antibiotic treatment. One patient in the MIPO group showed screw loosening while fracture union progressed. This patient was the oldest enrolled in the study and had osteoporosis; re-fixation of screws with cement augmentation led to successful union of this patient. In one patient of each group, iatrogenic radial nerve palsy developed postoperatively. All of nerve injuries had completely recovered at last follow-up, whereas one of brachial plexus palsies showed incomplete recovery.

Discussion

Plate osteosynthesis has been the treatment of choice for humeral shaft fractures when operative treatment is needed \([1,2,17,18]\). However, complications such as healing problems, infections and iatrogenic radial nerve palsy have been reported \([19–21]\). Therefore, plate osteosynthesis of comminuted humeral fracture is a challenging operation, which requires surgical experience and meticulous attention to periosteum, muscles and nerves. Minimally invasive plate osteosynthesis (MIPO) is an emerging procedure for the treatment of humeral shaft fractures \([10,11]\). One of the main advantages of MIPO is that it preserves soft tissue and the periosteal circulation, which promotes fracture healing.
In the MIPO group of this study, most cases achieved primary bony union and it concurs with reports on MIPO [22]. This was also comparable to the result of ORPO group.

MIPO is generally known to achieve better results for comminuted fractures of humeral shaft [11,23], whereas simple fractures are better treated with open, compression plating. In the present study, we evaluated the union rate and time according to the fracture classification, which were satisfactory in both methods. All simple fractures (type A) in MIPO group united (Fig. 3). Accordingly, we assume that MIPO may be a useful method of humerus fractures, regardless of its fracture classification.

Bone graft is not infrequently required to promote fracture healing during the conventional open plating of humeral fractures, such as in comminuted fractures or for treating unwanted gaps after plate fixation [18]. However, autogenous iliac bone grafts (AIBG) may have significant morbidity (up to 44%) of donor site [24]. We also used bone graft to prevent possible delayed union or nonunion in one-sixth of the patients in the ORPO group, which is a higher proportion than that reported previously [17,18]. Consequently, our findings confirm that MIPO prevents the need of bone graft with the high union rate.

Mal-alignment is a common complication of MIPO when applied to long bone fractures. However, in the present study, mal-alignment was not observed in the MIPO group, which concurs with previous report [22,23]. On the other hand, a long time for fluoroscopic control is inevitable for MIPO to have a satisfactory alignment. This may reflect the relatively long radiation exposure time of MIPO group in this study.

The functional outcomes of shoulders and elbows were satisfactory in both study groups, which is consistent with previous reports on plating techniques. Although intramedullary nailing is generally considered a minimally invasive procedure, problems with shoulder or elbow function can occur when nails are inserted in an antegrade or retrograde fashion [1,9]. However, a recent report of MIPO of humeral shaft fractures showed an early recovery of shoulder and elbow joint [25]. Although both methods do not involve fracture site exposure, MIPO may be superior to nailing in terms of reducing functional impairments. However, this topic requires further prospective comparative study.

Surgeons have cautioned regarding the risk of radial nerve injury when either ORPO or MIPO are used for treating humeral shaft fractures. An et al. [12] insisted that MIPO may have lower risk of iatrogenic radial nerve palsy. However, in the present study, we experienced two cases (one case in each group) of iatrogenic radial nerve palsy and we cannot comment on the relative safeties of the two treatment methods. There was only one case of palsy in the early MIPO series from careless retraction to achieve distal exposure. After this case, there has been no occurrence of iatrogenic radial nerve palsy in our institution, as other studies have also reported a low incidence for MIPO [22,23,26]. Therefore, we think that humeral MIPO is a safe method, in terms of radial nerve safety.
The overall incidence of primary radial nerve palsy in the present study is comparable to those reported by previous studies [21,27–29]. Exploration of the radial nerve is commonly performed in these circumstances and nerve transposition may be performed. However, Ekhom et al. [27] insisted that radial nerve palsy does not require exploration during primary surgical intervention, unless a high-energy injury or open fracture is involved. With this in mind, we excluded these injuries from the present study and all patients with radial nerve palsy recovered spontaneously in the MIPO group, without intraoperative radial nerve exploring. However, we still consider the exploration of radial nerve when it is associated with the severe open fracture or distraction injury.

The present study has several limitations. First, patients in the ORPO group were recruited retrospectively. A study on a larger number of patients with a prospective design would help confirm the merits of MIPO for the treatment of humeral fractures. But, we consecutively collected patients of ORPO before the switch to MIPO for humerus fractures, since the nailing of the humerus fracture was never performed in our institute. From this viewpoint, our study may have a certain role. Second, we could not compare the perioperative risks such as infection or bleeding, because only one case of deep infection was encountered in the ORPO group. But, ORPO with longer operative duration in this study may have higher possibility of complications. It is attributable to the procedure of autogenous bone grafting and the larger wound exposure. In this respect, we assume that MIPO may reduce the possibility of perioperative risk.

In summary, minimally invasive plate osteosynthesis can achieve comparable radiological and functional results with the open plate osteosynthesis method in humeral shaft fracture, while reducing the operative time and perioperative complications.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

Acknowledgement

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