Midterm Results of Minimally Invasive Plating Osteosynthesis Versus Open Reduction and Internal Fixation for the Treatment of Mid-distal Humeral Shaft Fractures: A Case-match Controlled Comparison Study

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Research article

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Abstract

Background: Surgical treatment of humeral mid-distal shaft fractures is controversial. The purpose of this case-match controlled comparison study was to determine the safety and effectiveness of applying the MIPO technique compared with conventional ORIF for treating humeral mid-distal shaft fractures.

Methods: This study was conducted from January 2012 to December 2016, and patients of mid-distal humeral shaft fractures were eligible for this study. The patients were followed up for a minimum period of 1 year. The clinical and radiographic outcomes were evaluated. The inclusion criteria were age between 18 to 60 years and acute displaced mid-distal humeral shaft fracture. The exclusion criteria were intra-articular fractures of the elbow, vascular insufficiency of the upper limb, pathological fracture and multiple or open fractures. The medical records and radiographs of all eligible patients during hospitalization and follow-up after discharge were reviewed. We use a 1:2 (MIPO/ORIF) case-match based on gender and age. All patients had at least 3 years of postoperative follow-up.

Results: In total, 216 patients with mid-distal humeral shaft fracture underwent surgery at the departments of orthopedics of the Seventh Medical Center of PLA General Hospital and Beijing Chaoyang Hospital. Of them, 28 underwent MIPO and 56 case-matched controls underwent ORIF; all of them had complete 3-year follow-up data. No significant differences were observed in baseline characteristics between both groups. UCLA scores and MEPS were significantly higher in the MIPO group than in the ORIF group. Furthermore, UCLA score and MEPS grades in the MIPO group were significantly superior to those in the ORIF group. There was no statistically significant difference in major complication rates between both groups; however, the total major complication rate was significantly different between both groups.

Conclusion: This study demonstrates that MIPO has a statistically significant clinical benefit over ORIF, including better shoulder and elbow joint function, with few overall major complications after at least 3 years of postoperative follow-up. MIPO is a safe and effective method for treating mid-distal humeral shaft fractures when surgery is indicated.

Introduction

MIPO is currently applied to treat long bone fractures of limbs.¹ The operation has the advantages of small incision, less soft tissue dissection, preservation of hematoma around the fracture and little influence on blood supply of fracture block at the fracture end. Therefore, the fracture healing rate is high, the risk of infection is reduced, and bone grafting is basically unnecessary.

The surgical treatment of mid-distal humeral shaft fracture is controversial. Diverse opinions exist in the literature between the values of open reduction and internal fixation (ORIF) with plate² and MIPO for treating mid-distal humeral shaft fracture. ORIF has been regarded as the gold standard in the treatment of humeral shaft fractures. The advantages of ORIF are anatomical reduction, strong fixation, and little impact on elbow and shoulder joint function.³ Nevertheless the disadvantages of this technique are also

obvious, including large incision, more soft tissue dissection, serious blood supply damage to the fracture end, resulting in fracture healing difficulty, prone to bone nonunion, and high risk of iatrogenic radial nerve injury.⁴ MIPO for the treatment of mid-distal humeral shaft fracture has the advantages of small soft tissue dissection, avoidance of exposing radial nerve, and low risk of iatrogenic radial nerve palsy.^{5, 6}

This case-match controlled comparison study aimed to discover the safety and effectiveness of MIPO compared with conventional ORIF for the treatment of mid-distal humeral shaft fractures.

Patients And Methods

Study subjects and criteria

This retrospective case-controlled study was implemented at the Seventh Medical Center of PLA General Hospital and Beijing Chaoyang Hospital. All cases with mid-distal humeral shaft fracture between January 2012 and December 2016 were eligible for this study. The MIPO group comprised patients who underwent closed reduction and MIPO. The ORIF group comprised patients who underwent ORIF with plate and was considered the control group. The inclusion criteria were patients aged between 18 and 60 years and those with acute displaced mid-distal humeral shaft fracture. The exclusion criteria were cases involving intra-articular fractures of the elbow, vascular insufficiency, pathological fracture, and multiple or open fractures. The medical records and radiographs of all eligible patients during hospitalization and follow-up after discharge were reviewed.

We used a 1:2 (MIPO/ORIF) case-match based on sex and age (± 3 years). All patients had at least 3 years of postoperative follow-up. The research was approved by the research ethics committees of the two hospitals.

MIPO

To perform MIPO, patients were placed in the supine position under brachial plexus or general anesthesia. The shoulder was abducted to 90° on a radiolucent table to allow fracture reduction and intraoperative radiography. Two mini-incisions were made. One is a proximal incision, located between biceps and deltoid, about 4 cm long, whereas the other was a distal incision approximately 4 cm long along the lateral spine of the humerus in the gap between the triceps and brachioradialis. Through these two incisions, a tunnel was made under the muscle across the fracture fragments and the locking compression plate (LCP) was placed into the incision. After the indirect reduction quality was checked, the proximal side was fixed with three 3.5 mm diameter locking screws and the distal side was fixed with four 2.5 mm diameter locking screws (Fig. 1).

ORIF

To perform ORIF, the patient was lying on the healthy side with the affected side on the upper side. The shoulder joint was abducted and extended 90°. After a median incision was created, the triceps was split

and the proximal periosteum of the fracture was peeled to avoid the radial nerve. Radial nerve exposure is not necessary. The fracture ends were anatomically reduced and firmly fixed with dynamic compression plate (DCP) under direct vision. The fracture ends of type A were compressed (Fig. 2).

Follow-up and outcomes

All cases were evaluated at 1, 3, 6, and 12 months and 2 and 5 years postoperatively. The primary outcomes compared were shoulder and elbow joint function, including the University of California at Los Angeles (UCLA) scoring system and Mayo Elbow Performance Score (MEPS). Shoulder function was graded excellent (≥ 34 points), good (33–29 points), or poor (< 29 points) based on the UCLA scoring system, whereas elbow function was graded excellent (≥ 90 points), good (75–89 points), fair (60–74 points), or poor (< 60 points) based on MEPS. Secondary outcomes were operation time, intraoperative blood loss, bone union time, and major complications, such as iatrogenic radial nerve palsy, infection, myositis ossificans, and nonunion. Radiographic assessment was assessed by anteroposterior and lateral radiographs of the humerus. Bone union criteria were defined as complete union of at least three of the four cortices in the radiographic assessment, and no clinical symptoms of pain.

Statistics

SPSS version 23.0 (IBM, Armonk, NY, USA) and GraphPad Prism version 8.3.1 (GraphPad Software, USA) were used for statistical analysis. Continuous variable was described as mean $\pm$ standard deviation and compared using the independent samples t-test. Categorical variable was described as rate and compared using the Pearson chi-square test. Additionally, all patients included in the case-match controlled comparison study were considered as a cohort, and survival analysis was performed using the Kaplan–Meier method, in which total major complications and time interval between operation day and complication time were considered as the outcome variable and “time to event,” respectively. The log-rank test was performed to compare survival curves of the two groups, and the Mantel–Haenszel test was used to estimate hazard ratio (HR) of total major complications. $P < 0.05$ was statistically significant, and $P < 0.01$ was highly significant.

Results

Between January 2012 and December 2016, 216 patients with mid-distal humeral shaft fractures underwent surgery at the departments of orthopedics of the Seventh Medical Center of PLA General Hospital and Beijing Chaoyang Hospital. Of these patients, 28 underwent MIPO and 56 case-matched controls underwent ORIF; all of them had complete 3-year follow-up data. Approximately 33.3% of the patients were female, and the mean age of all patients was 31.7 ± 12.5 years. The follow-up duration was 47.1 ± 7.4 (36–65) months (MIPO group, 47.2 ± 2.2 , range 36–60 months; ORIF group, 47.1 ± 7.8 , range 36–65 months).

There were 18 men (64.3%) and 10 women (35.7%) in the MIPO group, with a mean age of 36.0 ± 12.3 (range 18–59). The mechanisms of injury were wrestling in 10 (35.7%) patients, throwing in 9 (32.1%),

fall in 6 (21.4%), and car accidents in 3 (10.7%). The classifications were A1 in 13 (46.4%) patients, B1 in 12 (42.9%), A2 in 1 (3.6%), B3 in 1 (3.6%), and C1 in 1 (3.6%) depending on the Orthopaedic Trauma Association (OTA) classification. In the ORIF group, there were 36 males (67.9%) and 18 females (32.1%), with a mean age of 36.8 ± 12.8 (range 18–58) years. The mechanisms of injury were wrestling in 23 (41.1%) patients, throwing in 17 (30.3%), fall in 9 (16.1%), and car accidents in 7 (12.5%). The OTA classifications were A1 in 29 (51.8%) patients, B1 in 18 (32.1%), A2 in 3 (5.4%), C1 in 3 (5.4%), A3 in 2 (3.6%), and B2 in 1 (1.8%). Moreover, four (14.3%) cases in the MIPO group and 7 (12.5%) in the other group had preoperative radial nerve injury. There was no significant difference in the baseline characteristics (Table 1).

The UCLA scores in the MIPO group were great higher than the ORIF group (34.4 ± 1.7 vs. 31.2 ± 3.9 , $p=0.000$). In the MIPO group, 27 (96.4%) patients showed excellent results and 1 patient (3.6%) had a poor result. In the ORIF group, there were 35 (62.5%) excellent cases, 14 (25%) good cases, and 7 (12.5%) poor cases. The MIPO group was highly significantly superior to the ORIF group in terms of UCLA scores and grades ($p=0.003$). The patient with poor shoulder function in the MIPO group was obese. Due to poor compliance, the shoulder joint did not undergo timely functional exercise, resulting in adhesion around the shoulder joint. In the patients with poor shoulder function in the ORIF group, 3 had nonunion, 2 had myositis ossificans, and 2 had iatrogenic radial nerve injury.

Similar results were observed for MEPS. MEPS in the MIPO group was great higher than the ORIF group (97.9 ± 4.2 vs. 86.7 ± 13.6 , $p=0.000$). In the MIPO group, 27 (96.4%) patients showed excellent results and 1 (3.6%) patient had a good result. In the ORIF group, there were 37 (66.1%) excellent cases, 9 (16.1%) good cases, 8 (14.3%) fair cases, and 2 (3.6%) poor cases. The MEPS grades of the MIPO group were statistically superior to those in the ORIF group ($p=0.02$). One patient with myositis ossificans and one patient with intraoperative radial nerve injury had poor elbow function in the ORIF group (Table 2).

The operation time was 144.8 ± 36.1 (90–260) min in the MIPO group and 166.5 ± 54.1 (85–300) min in the ORIF group, with a significant reduction of 21.7 min ($t = -2.14$, $p = 0.036$). Intraoperative blood loss was 112.9 ± 75.3 (30–300) mL in the MIPO group and 229.5 ± 112.7 (100–600) mL in the ORIF group, with a highly significant decrease of 116.6 mL ($t=5.63$, $p=0.000$). The bone union time was 6.2 ± 1.6 (4–9) months in the MIPO group and 6.0 ± 3.3 (3–20) months in the ORIF group, with no statistical difference ($t=0.06$, $p=0.951$).

Iatrogenic nerve injury was not observed in the MIPO group and 4 patients with iatrogenic radial nerve injury (7.1%) were postoperatively identified in the ORIF group with no statistical difference ($\chi^2=2.10$, $p=0.147$). Of the patients with iatrogenic nerve injury, two recovered within 4 weeks postoperatively without intervention and two did not recover 6 months postoperatively; these patients underwent radial nerve exploration, revealing that the radial nerve was cut off in one patient and pressed under the plate in another patient.

No deep infections were observed in the MIPO group, whereas 3 cases (5.6%) in the ORIF group developed deep infection; however, all infections were treated with intravenous antibiotic therapy. No statistical difference was found between the two groups ($\chi^2=1.56$, $p=0.21$).

All cases in the MIPO group met the standard of bone union within 9 months postoperatively. Three patients (5.6%) in the ORIF group had nonunion, and each nonunion was subsequently managed by implant removal and ORIF with bone graft. There was no statistical difference in the incidence of nonunion between the two groups ($\chi^2=1.56$, $p=0.21$).

There were 4 patients (7.1%) with myositis ossificans in the ORIF group; however, this complication was not observed in the MIPO group with no statistical difference between the two groups ($\chi^2=2.10$, $p=0.15$). Only one myositis ossificans needed elbow joint release to improve elbow function.

Internal fixation removal was performed in 20 cases in MIPO group without complication and in 14 cases in ORIF group with 2 complications. One patient had radial nerve injury during the surgery, whereas one patient had refracture after surgery in the ORIF group. No statistical difference was observed between two groups ($\chi^2=3.04$, $p=0.08$) (Table 2).

The overall major complication rates in midterm follow-up were 0 and 16 (0% vs. 28.6%) in the MIPO and ORIF groups, respectively, which significantly differed between the two groups ($\chi^2=9.88$, $p=0.002$). Survival analysis and cumulative complication incidence curves showed that the total major complication rate was highly significantly lower in MIPO group than in ORIF group ($p=0.000$) (Fig. 3). The Mantel–Haenszel test showed that HR (MIPO/ORIF) was 0.20 with 95% CI of 0.07–0.56, indicating that every five patients who underwent MIPO can avoid one major complication compared with those who underwent ORIF.

Discussion

As far as we know, this study was the first to report midterm results of MIPO versus ORIF treating mid-distal humeral shaft fractures. After at least 3 years of postoperative follow-up, shoulder and elbow joint function in MIPO group was statistical superior to that in ORIF group. There was no statistically significant difference in the incidence of each major complication between the two groups; however, the overall major complications rate between the MIPO and ORIF groups had highly significant difference, with HR (MIPO/ORIF) of 0.20. This indicates that every five patients who undergo MIPO can avoid one major complication compared with those who undergo ORIF.

Humeral shaft fracture is a common fracture and can be the result of low- or high-energy trauma, accounting for 3%–5% of all fractures.^{7,8} Although the incidence of humeral shaft fractures is high, the incidence of the mid-distal shaft fractures is low, accounting for about 20% - 30% of all humeral shaft fractures.⁹ Zogbi et al. reported 15 patients with this type of fracture in 6 years¹⁰. In the present study, two hospitals treated 84 patients with MIPO and ORIF in 5 years. Most of the injuries were caused by

wrestling and throwing, and the most common types of fractures were types A1 and B1 of the OTA classification.

The optimal clinical management of a mid-distal humeral shaft fracture is controversial. Intramedullary nailing (IMN) and ORIF of humeral shaft fractures have been reported to obtain similar good clinical results.^{11,12} However, for some distal fractures, it is inappropriate to use an intramedullary implant; there is obliteration of the intramedullary canal proximal to the supracondylar region, and this site can easily be affected by a fracture.¹³ In the present study, all patients were not candidates for treatment with IMN.

Although MIPO has been successfully applied for femoral and tibial fractures for nearly 20 years,^{14,15} its use in humeral fracture was not reported until 2005 owing to the fear of injury to the radial nerve. At that time, Apivatthakakul et al. initially performed an anatomic cadaveric study to prove the safety and feasibility of MIPO for humeral shaft fracture.¹⁶ Thereafter, the effectiveness and safety of MIPO for the treatment of distal humeral fracture were further confirmed in the short-term clinical results of several case series.^{5,6,10,17-23}

Some comparative studies have also determined the advantages of MIPO for the treatment of humeral shaft fracture in short-term follow-up. Matsunaga et al. performed a clinical trial to verify clinical and radiographic outcomes between patients who had been treated with MIPO and nonoperation with a functional brace and found that MIPO had a statistically significant advantage with respect to joint function score.²⁴ An et al. retrospectively analyzed 33 cases with mid-distal humeral shaft fractures treated with MIPO and ORIF. Their results showed that MIPO can reduce the incidence of iatrogenic radial nerve injury (0% vs. 31.3%).²⁵ Oh et al. compared the clinical efficacy of MIPO (n = 29) and ORIF (n = 30) in the treatment of humeral shaft fractures, and found that the average operation time in MIPO group was shorter than that in ORIF group (110 min vs. 169 min, $P < 0.05$). They believe that MIPO potentially reduces the complications with a shortened operation time.²⁶ Our study yielded similar clinical results.

Malunion is a more common complication reported in treating humeral shaft fracture.^{5,19,27} Li et al. compared the degree of poor rotation and shoulder joint function after treatment of humeral shaft fracture with ORIF and IMN, and found that there was no poor rotation in patients receiving ORIF treatment, but the rate of poor rotation in IMN group was 27.2%, which led to the reduction of shoulder joint range of motion.²⁸ Wang et al. Prospectively divided 53 patients with humeral shaft fractures into MIPO group or ORIF group. The incidence of postoperative malrotation in MIPO group was significantly increased (40.9% vs. 0%; $P < 0.01$), which was related to shoulder joint degeneration.²⁹ In this study, no patient in the MIPO group showed malunion. This may be because the locking compression plate (LCP) was contoured to conform to the anterolateral surface of the mid-distal humerus, possibly reducing the incidence of malunion and making fracture reduction more convenient.

Our study proved that the MIPO group had statistically significantly better functional outcomes than the ORIF group in midterm follow-up. We believe that the advantages of MIPO in the optimal safety profile and gaining strong fixation without damaging the surrounding soft tissue were the foundation of

obtaining good joint function. Mahajan et al. evaluated the efficacy of MIPO in the treatment of middle humeral fractures in patients mainly engaged in overhead shoulder movement (athletes and manual workers), and found that most patients had good functional results, which was similar to our clinical results.³⁰

Our study had three limitations. First, the LCP in the MIPO group was contoured to conform to the anterolateral surface of the mid-distal humerus, which can reduce the strength of the plate, although we did not find any cases of failure of internal fixation. Therefore, a new anatomical plate designed for this area is needed. Second, the number of patients included is relatively small, because it is difficult to recruit hundreds of patients with such fractures in clinical practice. We designed the case-match controlled study to reduce type II error. Second, the number of patients was relatively small because it was difficult to enroll hundreds of patients in clinical practice. Therefore, we designed a case-match controlled study to reduce type II error. Lastly, this study was carried out at two centers and there might be a bias on the surgical technique and functional assessment. In the research preparation stage, we developed standard surgical procedures and all surgeons had vast experience to minimize potential bias.

Conclusions

This study demonstrates that MIPO has a statistically significant clinical benefit over ORIF, including better shoulder and elbow joint function, with few overall major complications after at least 3 years of postoperative follow-up. MIPO is a safe and effective technique for treating mid-distal humeral shaft fractures.

Declarations

Ethics approval and consent to participate

Consent for publication

Signed informed consent for publication was obtained from all authors.

Availability of data and materials

The data and materials used and/or analyzed during the current study are not publicly available but available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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None

Authors' contributions

Study Design: LL, BY. Data Collection: JG, HZ, YC. Statistical Analysis: ZL. Data Interpretation: ZL. Manuscript Preparation: YH.

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Figures

Figure 1

A 19 years old male whose right upper limb was injured by throwing underwent MIPO with LCP. A. Preoperative radiography showing the middle-distal humeral shaft fracture with OTA classification of B1. B. The LCP was contoured to conform to the anterolateral surface of the mid-distal humerus. C. Two small incisions can be observed on the anterior of the right upper limb. D. Six-month postoperative radiography showing the union of the fracture. E. One-year postoperative radiography showing that the internal fixation was removed. F-G. The patient obtained normal elbow function at 3 years postoperatively.

Figure 2

A 23 years old female whose left upper limb was injured by car accident underwent ORIF using a DCP. A. Preoperative radiography showing the middle-distal humeral shaft fracture with OTA classification of A1. B-C. Postoperative radiography showing that the fracture is fixed at the rear. D-E. Five-month postoperative radiography showing union of the fracture. F-G. The patient had normal elbow function at 3 years postoperatively.

A — MIPO — ORIF

B — MIPO — ORIF

Figure 3

Survival analysis and cumulative complication incidence curves showed the total major complication rate was highly significantly lower in MIPO group than in ORIF group ($p=0.000$). A. Kaplan–Meier curves of major complications. B. Cumulative complication of subjects at risk.