Comparison of medium-term results of minimally invasive plating osteosynthesis and open reduction and internal fixation for mid-distal humeral shaft fractures

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To the Editor: There is controversy in the literature on the benefits of open reduction and internal fixation (ORIF) and minimally invasive plating osteosynthesis (MIPO) for mid-distal humeral shaft fractures.[1] ORIF has the advantages of anatomical reduction, strong fixation, and little impact on the function of the elbow and shoulder joints. Nevertheless, it has some disadvantages, including the need for a large incision and more dissection of soft tissues, interrupting blood supply to the fracture site, resulting in difficulties in healing and an increased risk of bone non-union, and a high risk of iatrogenic radial nerve injury. In contrast, treatment of mid-distal humeral shaft fractures by MIPO has the advantages of less dissection of soft tissues, avoidance of exposure of the radial nerve, and a low risk of iatrogenic radial nerve palsy. This study aimed to compare the medium-term safety and effectiveness of MIPO and conventional ORIF in the treatment of mid-distal humeral shaft fractures.

This nested case-control study was performed at the Seventh Medical Center of Chinese People's Liberation Army (PLA) General Hospital and Beijing Chaoyang Hospital. The nesting method has been described in detail elsewhere.[2] All the mid-distal humeral shaft fractures treated between January 2012 and December 2016 were eligible for the study and were enrolled. The inclusion criteria were patients aged 18 to 60 years with an acute displaced mid-distal humeral shaft fracture who experienced at least 3 years of post-operative follow-up. Those suffering from intra-articular fractures of the elbow, vascular insufficiency, pathological fracture, and multiple or open fractures were excluded. The included patients were divided according to whether they underwent MIPO or ORIF with plating (the MIPO and ORIF operation procedures were described in Supplementary Figures 1 and 2, http://links.lww.com/CM9/B239). Those who underwent MIPO were then matched for gender and age (±3 years) with those who underwent ORIF at a ratio of 1:2. All cases were evaluated at the first, third, sixth, and 12th months post-operatively and 3rd to 5th years thereafter. Their medical records and radiographs obtained during hospitalization and follow-up after discharge were reviewed. This study protocol was approved by the Research Ethics Committees of the Seventh Medical Center of Chinese PLA General Hospital (No. 2018-21) and Beijing Chaoyang Hospital (No. 2019-310) and all enrolled patients have signed the informed consent.

The primary outcome compared was the overall major complications, including iatrogenic radial nerve palsy, infection, myositis ossificans, and bone non-union. The secondary outcomes were the recovery of shoulder and elbow joint function evaluated by the University of California at Los Angeles (UCLA) scoring system and Mayo Elbow Performance Score (MEPS).

All statistical analyses were performed using SPSS version 23.0 (IBM Corp., Armonk, NY, USA) and GraphPad Prism version 8.3.1 (GraphPad Software, San Diego, CA, USA). Continuous variables were described as mean ± standard deviation and compared using the paired *t*-test when the normal distribution was met, otherwise the paired nonparametric test was used; while categorical variables were described as number (percentage) and compared using the McNemar's test. Survival analysis was performed using the Kaplan–Meier method, in which the total major complication rate was the outcome variable and the time interval between the day of surgery and the onset of the complication was the "time to event". The Mantel–Haenszel test was used to estimate hazard

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Table 1: Comparison of the baseline characteristics of 28 MIPO cases and their 56 matched ORIF cases with mid-distal humeral shaft fracture.

Characteristics	MIPO ($n = 28$)	ORIF ($n = 56$)	χ^2	*P* values
Male	18 (64.3)	36 (64.3)	–	–
Age (years)	36.0 ± 12.3	36.8 ± 11.8	–	–
Injury causes			1.08	0.783
Wrestling	10 (35.7)	23 (41.1)		
Throwing	9 (32.1)	17 (30.3)		
Fall	6 (21.4)	9 (16.1)		
Car accident	3 (10.7)	7 (12.5)		
OTA classification			6.66	0.353
A1	13 (46.4)	29 (51.8)		
A2	1 (3.6)	3 (5.4)		
A3	0 (0)	2 (3.6)		
B1	12 (42.9)	18 (32.1)		
B2	0 (0)	1 (1.8)		
B3	1 (3.6)	0 (0)		
C1	1 (3.6)	3 (5.4)		
Preoperative radial nerve injury	4 (14.3)	7 (12.5)	0.06	0.801

Data are expressed as *n* (%) or mean ± standard deviation. MIPO: Minimally invasive plating osteosynthesis; ORIF: Open reduction and internal fixation; OTA: Orthopaedic Trauma Association; –: Not applicable.

ratio (HR) of total major complications. A *P*-value of <0.05 was considered statistically significant.

Between January 2012 and December 2016, 216 patients with mid-distal humeral shaft fracture underwent orthopedic surgery at either of the participating institutions. According to the matching method, 28 patients were divided into the MIPO group and 56 into the ORIF group. The baseline characteristics were listed in Table 1.

During medium-term follow-up, the overall major complication rate was 0% (0/28) in the MIPO group and 28.6% (16/56) in the ORIF group. The difference was significant ($\chi^2 = 10.37$, $P < 0.001$). The analysis on the cumulative incidence curves for complications showed that the total major complication rate was significantly lower in the MIPO group (HR 0.20, 95% confidence interval [CI] 0.07–0.56; $P < 0.001$, Mantel–Haenszel test) [Supplementary Figure 3, http://links.lww.com/CM9/B239].

There were no cases of iatrogenic nerve injury in the MIPO group and four cases (7.1%) in the ORIF group ($\chi^2 = 0.12$, $P = 0.357$). Among the four patients, two recovered within 4 weeks after surgery without intervention; another two did not recover within six months, and the radial nerve exploration on them revealed that the nerve of one patient was severed and that of the other was pressed under the plate. There were no deep infections in the MIPO group; however, there were three cases (5.4%) in the ORIF group, all of which were treated with intravenous antibiotic therapy. The between-group difference was not statistically significant ($\chi^2 = 0.16$, $P = 0.600$).

There was significant between-group difference in time to bone union (6.2 ± 1.6 [ranged 4.0–9.0] months in the MIPO group *vs.* 6.0 ± 3.3 [ranged 3.0–20.0] months in the ORIF group; $z = -2.46$, $P = 0.014$). Three patients (5.4%) in the ORIF group had bone non-union, which was managed by removing the soft tissue at the fracture end and internal fixation was performed again with bone graft. The between-group difference was not statistically significant ($\chi^2 = 1.57$, $P = 0.600$). Myositis ossificans was detected in four patients (7.1%) in the ORIF group and none in the MIPO group ($\chi^2 = 2.12$, $P = 0.357$). One case required release at the elbow joint to improve elbow function.

The plate was removed without the occurrence of complications in 20 patients in the MIPO group and 14 in the ORIF group. Two cases in the ORIF group suffered from complications (intra-operative radial nerve injury in one case and post-operative fracture for the second time in the other case). The complication rate was not significantly different between the two groups ($\chi^2 = 1.03$, $P = 0.584$).

The mean UCLA score was significantly higher in the MIPO group than that in the ORIF group (34.4 ± 1.7 *vs.* 31.2 ± 3.9, $P < 0.001$) at the last follow-up. Twenty-seven patients in MIPO group had an excellent outcome and one (3.6%) had a poor result. Thirty-five patients (62.5%) in the ORIF group had an excellent outcome, 14 (25.0%) had a good outcome, and 7 (12.5%) had a poor outcome. The post-operative UCLA values were significantly higher in the MIPO group when compared with that of the ORIF group ($P = 0.003$). Similar results were observed for MEPS at the last follow-up.

This study compared the medium-term results of MIPO with those of ORIF when treating mid-distal humeral shaft fractures. Our main finding showed that there was a statistically significant between-group difference in the overall major complication rate, with a hazard ratio of 0.20. Several comparative studies have investigated the short-term advantages of MIPO in terms of avoiding complications in patients with humeral shaft fractures.[3] which are consistent with our present findings.

In this study, the recovery of post-operative shoulder and elbow joint functions was better in patients who underwent MIPO than those who underwent ORIF. Our findings in this regard are similar to those of Mahajan *et al*[4] who evaluated the efficacy of MIPO in middle humeral fracture patients regularly performed overhead shoulder movements, such as athletes and manual workers, and found that most patients had good functional results. We attribute the good joint function achieved by MIPO to the ability of this procedure to obtain strong fixation without damaging the surrounding soft tissues.

In the mid-distal humerus, the bone is irregularly bent and there is a 20° to 30° intorsion in the junction between the middle and distal humeral shaft. The MIPO plate is usually pre-contoured to allow better attachment. However, up until now, most studies have used straight plates, which can result in poor fracture reduction and malunion.[5] None of the patients in our MIPO group showed malunion because the locking compression plate was contoured to conform to the anterolateral surface of the mid-distal humerus.

The strength of this investigation is the nested case-control study design, whereby patients who underwent MIPO were strictly matched with those who underwent ORIF. However, the study has some limitations. First, the population size was relatively small. However, in clinical practice, it is difficult to enroll large numbers of patients for this type of studies. Second, the included patients were recruited from two centers, and the possibility of a confounding effect in terms of surgical technique and functional assessment cannot be excluded. In the future study, a multi-center randomized controlled trial is needed for further verification.

To conclude, MIPO has significant clinical advantages in comparison with ORIF, including few major complications and better shoulder and elbow joint function recovery during at least three years of post-operative follow-up. MIPO is a safe and effective technique in treating mid-distal humeral shaft fractures.

Conflicts of interest

None.

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