Evaluation of the results of anterior minimally invasive plate osteosynthesis in treating humeral shaft fractures

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Received: 9 October 2021
Revised: 1 December 2021
Accepted: 12 February 2022
Published: 31 May 2022

The Egyptian Orthopaedic Journal 2022, 57:79–84

Background
The advantages of minimally invasive plate osteosynthesis (MIPO) are less soft tissue dissection and less blood loss with excellent results. This study aims to assess the outcomes of MIPO in treating humeral shaft fractures.
Patients and methods
Anterior MIPO was performed on 30 patients from March 2017 to January 2019. The inclusion criteria for this prospective study included a fracture located at the middle third of the humeral shaft, a fracture with polytrauma, and fractures with early conservative treatment failure. Type A fracture was the most common according to the AO-OTA classification (13 cases), followed by type B (11 cases) and type C (six cases). The space between biceps and brachialis was identified, and a locking compression plate or limited contact dynamic compression plate was used. The minimum follow-up period was 1 year. The outcome measurements included fracture union, alignment, infection, range of motion, functional assessment as per the University of California at Los Angeles shoulder score, and elbow function as evaluated using the Mayo elbow performance index.
Results
The mean operation time was 90.30 min (range, 80–180 min), and mean radiation exposure was 204 s (range, 110—420 s). All fractures united. The mean fracture union time was 15.3 weeks (range, 10–18 weeks). There was no incidence of implant failures. The mean University of California at Los Angeles end-result score was 34 points (range, 32–35). The mean Mayo elbow performance index was 98 points (range, 90–100). The mean range of motion was 135° (range, 100–140°). The functional outcome was satisfactory.
Conclusion
MIPO is an excellent method for treating humeral shaft fractures. It might decrease the perioperative complications with a reduced operation time.

Keywords:
humerus, minimally invasive plate osteosynthesis, shaft fractures

Egypt Orthop J 57:79–84

1110-1148

Introduction

Minimally invasive modalities of treatment are popular in modern surgery. They have the advantage of low morbidity and give fast recovery and ideal return to work and daily living activities [1].

Evidence shows the superiority of biological fixation over stable mechanical fixation [2]. Minimally invasive plating osteosynthesis (MIPO) offers an excellent choice. This procedure has ideal advantages, including safeguarding of the biological environment, less soft tissue dissection, as well as less blood loss. These preferences demonstrate that MIPO is better than conventional plating osteosynthesis [3–7].

The purpose of this study was to evaluate the results of MIPO in treating patients with humeral shaft fractures.

Patients and methods

A total of 30 patients were enlisted in a prospective case series study after obtaining an informed written consent from all patients. We prepared for this study after the approval of the local ethical committee. The patients were treated with MIPO in the period between March 2017 and January 2019. The inclusion criteria for this prospective clinical series included a fracture located at the middle third of the humeral shaft, a fracture with polytrauma, and fractures with failure of early conservative treatment (Fig. 1). The exclusion criteria included pathologic fractures, open fractures, and fractures associated with radial nerve injuries.

Figure 1

Preoperative anteroposterior (a) and lateral (b) radiographs of a 40-year-old male who sustained a right humeral shaft fracture after a fall while walking showing a transverse fracture in the middle third of the humeral shaft.

Table 1 Patient demographics

Variables	Number
Patients	30
Age (years old, mean)	38.2 years (range 22–64)
Sex	
Male	22
Female	8
AO-OTA classification	
Type A	13
Type B	11
Type C	6

The mechanism of injury was a motor vehicle accident in 19 patients and a fall in 11 patients. Two patients had associated injuries, including a pelvic fracture, and an undisplaced distal radial fracture, which were treated conservatively. There were 22 males and eight females, with a mean age of 38.2 years (22–64).

Sites and patterns of fractures are listed in Table 1. AO/OTA classification was used, which is arranged in order of increasing severity as per the fracture complexities (type A-simple, type B-wedge, and type C-comminuted). Type A fracture was the most common (13 cases), followed by type B (11 cases) and type C (six cases). A locking compression plate or limited contact dynamic compression plate was used.

Surgical technique

The operative technique was similar to that previously described in literature [4]. Obtaining closed reduction by manual traction under image intensifier control was the most important step in the whole procedure. Under image intensifier control, the operation was carried out in a supine position under general anesthesia, with abduction of the involved arm to 90°. The forearm was kept in supination intraoperatively, accordingly radial nerve was not at risk.

Cefuroxime 1.5 g intravenous antibiotic prophylaxis was injected. Two small incisions were made on the anterior side of the arm, proximal and distal to the fracture site. The sensory branch of the musculocutaneous nerve was usually identified and secured after retracting the biceps muscle. A blunt dissection was used to split the brachialis muscle. A submuscular extraperiosteal tunnel was created between the brachial muscle and the underlying periosteum with a narrow periosteal elevator inserted first from the proximal entry point distally and a while later from the distal incision proximally. A straight, noncontoured, long, narrow, locking compression plate or limited contact dynamic compression plate was used. It was inserted through this tunnel from the proximal incision, passing the fracture site and down to the distal incision.

Rotational and angular deviations were restored by traction, and confirmation of the reduction was done with a contact between the fragments of at least 50% in both anteroposterior and lateral planes. Furthermore, the 'cortical step sign' or incongruity of cortical widths on either side of the fracture, as described by Krettek *et al.* [8] was used to look for any rotational malalignment.

At least three screws and six cortices were prepared for each of the principal fragments of the fracture to prevent future malalignment (Fig. 2). The radial nerve was not exposed during the entire procedure. The wound was closed in the standard style. No drain tube was used.

Postoperatively a long arm splint was applied for 2 weeks. Range-of-motion (ROM) exercises of the shoulder, elbow, fingers, and wrist were gently started usually 3–5 days after surgery. After 2 weeks, the stitches were removed. For the initial 3 months after surgery, all patients were followed up at 4-week

Figure 2

Postoperative radiographs show good fracture reduction and alignment. The patient was treated with minimally invasive plate osteosynthesis (MIPO) with an anterior locking plate.

intervals and at 8-week intervals for the following 3 months after the operation. The ranges of motion of the shoulders and elbows were documented. Radiographs of the operated arm were performed at a 4–6-week interval until bony union was achieved. More active exercises were started when callus appeared.

All data were recorded: the operative time, intraoperative duration of radiation exposure (in seconds), fracture union time, perioperative and late complications, and shoulder and elbow function. Clinical union was defined as the absence of pain or tenderness at the fracture site. Radiographic union was defined as the presence of a bridging callus in three of the four cortices on the anteroposterior and lateral radiographs of the humerus.

Superficial infection was characterized as an infection of the superficial soft tissues that was responsive to a short course of oral antibiotics, whereas deep infection was characterized as an infection of the deep soft tissues encompassing the implant with positive deep tissue tests at the time of implant removal whenever done, as well as proof of underlying osteomyelitis.

The University of California Los Angeles scoring system [9] was used to assess shoulder function. The parameters included pain (10 points), motion (10 points), function (10 points), and patient satisfaction (five points). Subjective rules comprise 15 points of a total of 35 points, and the findings on assessment involve the remaining 20 points. The scores were then divided into excellent (34–35 points), good (29–33 points), fair (21–28 points), and poor (0–20 points). Mayo elbow performance index was used to evaluate elbow function [10], which evaluates patients on a 100-point scale concerning pain (45 points), range of motion (20 points), stability (10 points), and function (25 points). The joint function is categorized as excellent (>90 points), good (75–89 points), fair (60–74 points), or poor (<59 points). For the assessment of the shoulder ROM, external and internal rotation and forward elevation were evaluated with the shoulder abducted, and flexion and extension angles of the elbow joint were measured.

Results

The mean period of follow-up was 16.9 months (range, 12–22 months). The mean duration of injury was 4.59 days (range, 2–8 days). The mean operation time was 90.30 min (range, 80–180 min). No autogenous bone grafting was used for any case.

All fractures united during the follow-up period (Fig. 3). The mean time for fracture union was 15.3 weeks (range, 10–18 weeks). There was no iatrogenic radial nerve palsy.

One patient developed a superficial infection in the distal incision 2 weeks after the original operation and was treated successfully with local wound care and oral antibiotics (500 mg of flucloxacillin three times a day for 2 weeks). There was no incidence of implant failures. The implants were removed in two cases without complications. A total of 27 patients returned to their original jobs. Moreover, 22 patients had returned to their preinjury daily activities and sports.

The results of shoulder and elbow joint function were excellent. At the latest visit, the mean active anterior forward flexion of the affected shoulder was 160° (range, 140–170°). The mean University of California at Los Angeles end-result score was 34 points (range, 32–35 points). The mean Mayo elbow performance index was 98 points (range, 90–100 points). The mean ROM was 135° (range, 100–140°). The results of patients are summarized in Table 2.

Figure 3

Follow-up anteroposterior (a) and lateral (b) radiographs at 1 year showing radiologic union. The patient had a complete functional recovery.

Table 2 The overall results

Variables	Number
Operative demographics	
Operation duration (min)	90.30 (mean)
Radiation exposure (s)	204 (mean)
Autogenous bone graft	None
Time to union (weeks)	15.3 (mean)
Union rate from AO-OTA classification	
Type A	13/13
Type B	11/11
Type C	6/6
Functional outcome	
UCLA shoulder score (points)	34 (mean)
MEPI (points)	98 (mean)
ROM (deg.)	135 (mean)
Iatrogenic radial nerve palsy	0/30
Nonunion	0/30
Implant removal	2/30
Superficial infection	1/30

MEPI, Mayo elbow performance index; ROM, range of motion; UCLA, University of California at Los Angeles.

Discussion

Different strategies are utilized to treat fractures of the humeral shaft. Large numbers of fractures can be successfully treated conservatively [11,12]. At the point when operative treatment is obligatory, plate osteosynthesis with open reduction has offered a viable outcome [13–15], with the advantages of anatomical fracture reduction. Other advantages include less interference with elbow and shoulder function [13,16]. The disadvantages of this technique include extensive soft tissue stripping as well as interruption of the periosteal blood supply, which increase the prospects of nonunion. Other disadvantages include iatrogenic radial nerve injuries, deep infection, and cosmetic problems [17,18].

Intramedullary nailing is a good alternative and gives excellent bone healing, due to its biomechanical favorable circumstances and the closed nature of the insertion procedure [19,20].

MIPO is an arising procedure for the management of humeral shaft fractures. The MIPO approach requires a shorter operative time but is technically demanding [3,21].

One of the chief advantages of MIPO is that it protects the biological environment of fracture sites with respect to the soft tissue and the periosteal circulation, and accordingly, it promotes fracture healing. All cases accomplished primary bony union and it agrees with different studies on MIPO [7]. In the current study, the high union rate was ascribed to the minimal surgical trauma to the soft tissues, and the internal fixator mechanism of this sort of fixation.

The MIPO technique is typically used to treat shaft fractures and metaphyseal fractures in osteoporotic patients, which can be treated with indirect reduction as anatomical reduction is not needed, and for multi-fragmentary fractures, which can be treated with bridging plate fixation. However, the MIPO method can likewise be used for simple shaft fractures [21,22].

In the current study, we assessed the union rate and time as per the fracture classification, which were good, generally because of the biological advantage of MIPO with respect to the intact periosteum and periosteal vessels. All simple fractures (type A) united. Appropriately, we expect that MIPO might be an effective technique for treating humeral fractures, regardless of their fracture classification.

Postoperative infection rates are lower in MIPO than in conventional ORIF in light of the fact that the blood supply to the bone and nearby soft tissues can be safeguarded by the MIPO strategy. Additionally, the frequencies of postoperative infections after MIPO are

less violent and are simpler to be managed than those after ordinary ORIF [17]. This was discovered to be the case in the current study, as just a single patient developed a superficial infection and was effectively managed with local wound care and oral antibiotics.

Autogenous iliac bone unions may have significant morbidity (up to 44%) at the donor site [23]. Our findings confirm that MIPO prevents the need for bone grafts with a high union rate.

Malalignment was not seen in the current study, although it was a regular complication of MIPO when used to treat fractures of long bones, which agreed with previous studies [7,22]. Then again, a long time for fluoroscopic control is needed for MIPO to have a satisfactory alignment. This may reflect the generally long radiation exposure time.

Kobayashi *et al.* [24] revealed that MIPO of humeral shaft fractures demonstrated an early recovery of the shoulder and elbow joints with satisfactory functional results. Numerous reports of MIPO for humeral shaft fractures have demonstrated great ROM of contiguous joints [4,21,25,26].

These findings are reliable with previous reports on plating techniques. It is better to insert three bicortical screws into the distal fragment to permit fast recovery of the operated limb for everyday living activities and to prevent rotational malalignment. Moreover, as the plate is locked, this will add to the stability of the fixation [24]. Despite the fact that MIPO and nailing do not need fracture site exposure, MIPO may be better than nailing at diminishing functional disabilities.

One of the other advantages of MIPO is that the radial nerve does not need to be typically dissected, although it is exceptionally fundamental to be carefully exposed and protected during the entire method of open reduction and plating fixation. Neither the fracture sites nor the radial nerve should be explored during performing the MIPO method using an anteriorly situated plate to treat fractures of the humeral shaft [25].

The used plate should be sufficiently long to bridge the fracture over the danger zone of the radial nerve [27]. The anterior humeral MIPO technique, which is suitable for mid-third humeral shaft fractures, is favored in light of the fact that the radial nerve does not need to be exposed. The radial nerve is not in danger as long as the forearm is supinated intraoperatively when the anterior approach is utilized and no screws are inserted into the humeral shaft where the radial nerve passes through the spiral groove [7]. During the screw insertion, anterior drilling at the middle third of the humeral shaft should be carefully performed to prevent excessively deep insertion of the screws. The anatomic location of the nerve needs to be a primary concern to protect the nerve from being harmed. According to Apivatthakakul *et al.* [3], exactly when a plate is put on the anterior aspect of the humeral shaft, the mean distance from the nearest portion of the plate to the radial nerve is 3.2 mm. The brachialis muscle that covers a huge segment of the anteriorly situated plate guards the radial nerve from being hurt when a plate is embedded submuscularly through two minor incisions on the front aspect of the arm away from the fracture site. Pospula and Abu Noor [25] documented just one case of iatrogenic radial nerve injury when the MIPO procedure was utilized to treat 12 cases of humeral shaft fractures, whereas Ji *et al.* [7] revealed one case in 23 humeral shaft fractures.

Livani *et al.* [6] reported great results in 35 patients with mid-distal humeral shaft fractures with no iatrogenic radial nerve injuries. Additionally, the clinical findings described in the current study show no event of iatrogenic palsies of the radial nerve, which is consistent with that of previous series [4,6]; this can clarify the predominance of MIPO over the conventional procedure. Consequently, we believe that humeral MIPO is a safe procedure with respect to the radial nerve.

This study has some limitations, such as the small number of patients and the lack of a control group. It would be beneficial for future studies to include a larger number of patients, which would assist with approving the anterior MIPO for treatment of humeral fractures conclusively.

The protocol used in the present study seemed to be effective for enrolled patients for the treatment of humeral shaft fractures. The strengths of this study are based on its original prospective, randomized design. In addition, stringent patient inclusion criteria were used.

Conclusion

MIPO can effectively treat fractures of the middle third of the humeral shaft. It can achieve excellent radiological and functional results while reducing the operative time and perioperative complications.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

References

1 Garnavos C, Lasanianos N, Kanakaris NK, Arnaoutoglouc, Papathanasopoulou V, Xenakis T, *et al.* A new modular nail for the diaphyseal fractures of the humerus. Injury 2009; 40:604–610.

2 Baumgaertel F, Buhl M, Rahn B. Fracture healing in biological plate osteosynthesis. Injury 1998; 29(suppl 2):C3–C6.

3 Apivatthakakul T, Arpornchayanon O, Bavornratanavech S. Minimally invasive plate osteosynthesis (MIPO) of the humeral shaft fracture. Is it possible? A cadaveric study and preliminary report. Injury 2005; 36:530–538.

4 Zhiquan A, Bingfang Z, Yeming W, Chi Z, Peiyan H, *et al.* Minimally invasive plating osteosynthesis (MIPO) of middle and distal third humeral shaft fractures. J Orthop Trauma 2007; 21:628–633.

5 Ziran BH, Belangero W, Livani B, Pesantez R. Percutaneous plating of the humerus with locked plating: technique and case report. J Trauma Inj Infect Crit Care 2007; 63:205–210.

6 Livani B, Belangero W, de Medeiros RC. Fractures of the distal third of the humerus with palsy of the radial nerve management using minimally-invasive percutaneous plate osteosyhthesis. J Bone Joint Surg Br 2006; 88:1625–1628.

7 Ji F, Tong D, Tang H, Zhang Q, Li J, Wang Ql. Minimally invasive percutaneous plate osteosynthesis (MIPPO) technique applied in the treatment of humeral shaft distal fractures through a lateral approach. Int Orthop 2009; 33:543–547.

8 Krettek C, Schandelmaier P, Miclau T, Grün O, Tscherne H, *et al.* Intra operative control of axes, rotation and length in femoral and tibial fractures. Technical note. Injury 1998; 29(Suppl 3):C29–C39.

9 Ellman H, Hanker G, Bayer M. Repair of the rotator cuff. J Bone Joint Surg Am 1986; 68:1136–1144.

10 Gill DR, Morrey BF. The Coonrad-Morrey total elbow arthroplasty in patients who have rheumatoid arthritis. A ten to fifteen-year follow-up study. J Bone Joint Surg Am 1998; 80:1327–1335.

11 Ekholm R, Tidermark J, Törnkvist H, Adami J, Ponzer S. Outcome after closed functional treatment of humeral shaft fractures. J Orthop Trauma. 2006; 20:591–596.

12 Toivanen JA, Nieminen J, Laine HJ, *et al.* Functional treatment of closed humeral shaft fractures. Int Orthop 2005; 29:10–13.

13 Bhandari M, Devereaux PJ, McKee MD, Schemitsch EH. Compression plating versus intramedullary nailing of humeral shaft fractures: a meta-analysis. Acta Orthop 2006; 77:279–284.

14 McCormack RG, Brien D, Buckley RE, McKee MD, Powell J, Schemitsch EH. Fixation of fractures of the shaft of the humerus by dynamic compression plate or intramedullary nail. A prospective, randomized trial. J Bone Joint Surg Br 2000; 82:336–339.

15 Moyikoua A, Ebenga N, Pena-Pitra B. Recent fractures of the humeral shaft in adults. Role of surgical treatment using screwed plates. Apropos of 35 cases surgically treated. Rev Chir Orthop 1992; 78:23–27.

16 Niall DM, O'Mahony J, McElwain JP. Plating of humeral shaft fractures-has the pendulum swung back? Injury 2004; 35:580–586.

17 Anglen JO, Archdeacon MT, Cannada LK, Herscovici Jr D, Ostrum RF. Avoiding complications in the treatment of humeral fractures. Instr Course Lect 2009; 58:3–11.

18 Volgas DA, Stannard JP, Alonso JE. Nonunions of the humerus. Clin Orthop Relat Res 2004; 419:46–50.

19 Chen AL, Joseph TN, Wolinksy PR, Tejwani NC, Kummer FJ, Egol KA, *et al.* Fixation stability of comminuted humeral shaft fractures: locked intramedullary nailing versus plate fixation. J Trauma 2002; 53:733–737.

20 Lin J, Hou SM. Locked nailing of severely comminuted or segmental humeral fractures. Clin Orthop Relat Res 2003; 406:195–204.

21 Livani B, Belangero WD. Bridging plate osteosynthesis of humeral shaft fractures. Injury 2004; 35:587–595.

22 Jiang R, Luo CF, Zeng BF, Mei GH. Minimally invasive plating for complex humeral shaft fractures. Arch Orthop Trauma Surg 2007; 127:531–535.

23 Hierholzer C, Sama D, Toro JB, Peterson M, Helfet DL. Plate fixation of ununited humeral shaft fractures: effect of type of bone graft on healing. J Bone Joint Surg Am 2006; 88:1442–1447.

24 Kobayashi M, Watanabe Y, Matsushita T. Early full range of shoulder and elbow motion is possible after minimally invasive plate osteosynthesis for humeral shaft fractures. J Orthop Trauma 2010; 24:212–216.

25 Pospula W, Abu Noor T. Percutaneous fixation of comminuted fractures of the humerus: initial experience at Al Razi hospital, Kuwait. Med Princ Pract 2006; 15:423–426.

26 Mehraj M, Shah I, Mohd J, Rasool S. Early results of bridge plating of humerus diaphyseal fractures by MIPO technique. Orthop Traumatol Rehab 2019; 21:117–121.

27 Apivatthakakul T, Patiyasikan S, Luevitoonvechkit S. Danger zone for locking screw placement in minimally invasive plate osteosynthesis (MIPO) of humeral shaft fractures: a cadaveric study. Injury 2010; 41:169–172.