Minimally invasive percutaneous plate osteosynthesis for distal radius fractures with metaphysio-diaphyseal comminution

Hosam Elsayed Farag[a], Ahmed Shawkat Rizk[b]

Departments of [a]Orthopedic, [b]Orthopaedics and Traumatology, Faculty of Medicine, Benha University, Benha, Egypt

Correspondence to Hosam Elsayed Farag, MD, Department of Orthopedic, Benha University, El-Shaheed Farid Nada Street, Benha, Qalyubia, Egypt. Tel: +20 100 295 3963; e-mail: hosamfaragortho@gmail.com

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Background
Distal radius fractures following high-energy trauma are common injuries, usually associated with metaphysio-diaphyseal comminution with marked soft tissue injury making effective treatment a real challenge with high risk of complications. Minimally invasive percutaneous plate osteosynthesis (MIPPO) is a fixation technique giving priority for soft tissues and vascularity of the bone fragments achieving a relatively stable fracture construct while preserving a biological environment insuring rapid bone healing. This study aims to evaluate the outcomes of the MIPPO technique for the treatment of distal radius fractures with metaphysio-diaphyseal comminution.
Patients and methods
This prospective, case series study comprised 11 cases of closed distal radial fractures with varying degrees of displacement and metaphysio-diaphyseal comminution following high-energy trauma. All fractures were treated by the MIPPO technique through two volar longitudinal incisions using a volar locking plate bridging the comminuted segment. The patients were followed up clinically and radiologically and the functional outcome was evaluated according to the Dienst wrist scoring system.
Results
All fractures united with a mean union time of 12.5±1.6 weeks (range, 11–16 weeks) with no reported loss of fixation with secondary displacement, implant failure, or deep wound infection. No cases needed any secondary surgical intervention to achieve union. The follow-up period extended for a mean duration of 16.7±3.2 months with satisfactory (excellent and good) clinical and radiological results compared with the other side achieved in all cases. The radiological results (radial inclination, radial height, and volar tilt) were excellent in eight cases and were good in three cases, but the clinical results (range of motion of the wrist and grip strength) were excellent in all the 11 studied cases.
Conclusion
The results are very satisfactory. MIPPO minimizes soft tissue compromise with preservation of vascularity of the comminuted fracture fragments, thus improving the healing rate, shortening the time for union with no need for initial or delayed bone grafting for such comminuted fractures with few potential complications.

Keywords:
distal radius fractures with metaphysio-diaphyseal comminution, minimally invasive percutaneous plate osteosynthesis, satisfactory results, volar locking compression plate

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Introduction

Distal radius fractures with highly comminuted metaphysio-diaphyseal segment represent a major problem even in the absence of articular surface involvement. Prober reduction with restoration of the radiological parameters and keeping such accepted reduction till consolidation and healing remain a major challenge for the surgeon. Whatever the selected method of treatment, the aim of the treatment is to obtain a painless, mobile wrist, and hand allowing return to activities with minimal risk for disability or future degenerative changes.

Different treatment options have been presented to treat such difficult injuries, distraction plate fixation [1,2], fixed angle volar plate fixation [3], long volar locking compression plate (LCP) fixation [4,5] and spanning or nonspanning external fixators. The long volar LCP plate were considered superior because it can allow simultaneous reduction of the articular surface and diaphyseal segment and facilitate earlier return to work and normal daily activities due to early mobilization [5]. However, traditional open reduction and internal fixation often results in extensive soft tissue dissection and periosteal injury and may be

associated with high rates of infection, delayed union, and nonunion [6,7].

Minimally invasive percutaneous plate osteosynthesis (MIPPO) is a fixation technique giving priority for soft tissues and vascularity of the bone fragments achieving a relatively stable fracture construct while preserving a biological environment insuring rapid bone healing. MIPPO can also lead to a reduction in complications caused by conventional treatment [8].

This study aimed to evaluate the outcomes of MIPPO technique for the treatment of distal radius fractures with metaphysio-diaphyseal comminution.

Patients and methods

This prospective, case series study was carried out in the Orthopedics Department of Benha University Hospital between June 2013 and March 2017.

The study included 11 cases in 11 different patients presented with closed, displaced distal radius fractures with long-segment metaphysio-diaphyseal comminution – a minimum of 5 cm of comminution proximal to the radial articular surface – with or without simple intra-articular extension to the radio-carpal and/or radio-ulnar joints (Fig. 1). Cases with open fractures, simple distal radial fractures without long-segment metaphysio-diaphyseal comminution, fractures with complex comminuted intra-articular fractures, patients with associated ipsilateral elbow or arm fractures and patients with neurovascular injuries of the forearm were excluded from this study.

Figure 1

Displaced distal radial fractures with marked metaphysio-diaphyseal comminution.

There were four females and seven male cases, with a mean age at surgery of 41.5±6.7 years (range, 25–55 years). The causes of injury were road traffic accidents in nine patients, and a fall from a height in two patients. The right wrist was injured in six patients and the left wrist was injured in five patients. The injury/surgery interval ranged from 1 to 12 days with a mean duration of 6.6±2.7 days . The patients were evaluated clinically and radiologically before surgery and the fractures were classified based on plain radiography and computed tomography scans according to the AO/OTA classification. Nine fractures were of type 23-A3.3, while two were of type 23-C2.3 (Table 1). All cases were treated by the MIPPO technique through two volar longitudinal incisions using a volar locking plate bridging the comminuted segment. The patients were followed up clinically and radiologically and the functional outcome was evaluated according to the Dienst wrist scoring system [9].

Ethical standards

The procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national)

Table 1 Demographic data

Number	Age (years)	Sex	Injured hand	AO/OTA classification	Cause
1	25	Male	Right	23-A3.3	FFH
2	48	Male	Left	23-A3.3 +disrupted DRUJ	RTA
3	38	Male	Left	23-C2.3	RTA
4	55	Female	Right	23-A3.3	RTA
5	50	Female	Right	23-A3.3	RTA
6	55	Male	Left	23-A3.3	RTA
7	46	Male	Left	23-A3.3	FFH
8	40	Female	Left	23-C2.3 +disrupted DRUJ	RTA
9	35	Male	Right	23-A3.3	RTA
10	33	Female	Right	23-A3.3	RTA
11	49	Male	Right	23-A3.3	RTA

DRUJ, distal radio-ulnar joint; FFH, falling from height; RTA, road traffic accident.

and with the Helsinki Declaration of 1975, as revised in 2000 and 2008. All patients gave informed consent before inclusion in the study; the study was authorized by the institutional review board.

Operative technique

A radiolucent operative table and image intensifier are mandatory in performing this intervention. The procedure was done under general anesthesia, under tourniquet with the patients in the supine position.

A longitudinal volar incision was planned over the flexor carpi radialis started from the proximal wrist crease, which usually corresponds to the radio-carpal articulation, and extends proximally for 2–3 cm long (Fig. 2).

Developing the interval between the flexor carpi radialis laterally and the radial artery medially heralds deep dissection, whereas the flexor pollicis longus tendon was retracted medially exposing the pronator quadratus muscle. The pronator quadratus was longitudinally incised to expose the anterior cortex of the distal radius and a submuscular, extraperiosteal tunnel was made between the flexor pollicis longus muscle and the underlying periosteum.

The appropriate length of the plate was determined by placing the plate along the volar aspect of the forearm and adjusting it under the C-arm so that the distal end of the plate was 1 cm proximal to the joint line and the proximal end extended at least three screw holes beyond the proximal extent of the comminuted segment after restoration of the correct length of radius by a closed, indirect reduction using manual traction.

After selecting the appropriate length of the plate, a T-shaped LCP of an appropriate length was inserted through the incision and passed over the radius bridging the comminuted segment. Distal fixation with at least two screws secured the plate to the distal fragment before proximal fixation with at least three locking screws through a second, proximal 2–3 cm long longitudinal incision that was made along the medial border of the brachioradialis (Fig. 2), at the level of the proximal end of the plate after restoration of the correct alignment, length, and rotation of the radius by closed, indirect reduction using manual traction under image intensifier guidance. The incisions were closed in layers. Temporary ulno-radial K-wire holding the injured distal radio-ulnar joint was needed in two cases where the joint was disrupted due to the high-energy trauma.

Figure 2

The two separate longitudinal incisions with the plate slid extraperiosteally.

Postoperative care and follow-up

Fixation was protected in a below the elbow splints for 2 weeks postoperatively and active motion of all the unsplinted joints was encouraged from day 1 postoperatively. Radiological assessment was done at 2-week interval for detection of fixation loss or secondary displacement and evaluation of union progression. At the final follow-up, outcomes were evaluated as follows:

(1) Fracture was considered united once there was a bridging callus in three of the four cortices observed on the anteroposterior and lateral radiographs of the radius with absent fracture site tenderness and pain with movement.
(2) Quality of reduction was radiologically assessed by evaluating the radial inclination, volar tilt, and radial height in comparison with the other uninjured side.
(3) Range of motion at the wrist (flexion and extension) and forearm (pronation and supination) were compared with the other uninjured side and measured using the goniometer.
(4) Grip strength compared with the other uninjured side was tested by using a dynamometer.
(5) A yes/no question about satisfaction after surgery was a simple and reliable screening question assessing the efficacy of the procedure.
(6) Recording complications and when patients returned to their pre-injury level of activity and could have resumed their work.

Results

All fractures united in a mean time of 12.5±1.6 weeks (range, 11–16 weeks) with no cases needed any secondary intervention to achieve union. The radiological results (radial inclination, radial height, and volar tilt) were excellent in eight cases and were

good with loss of the volar tilt or reversal to dorsal tilt with improper restoration of the radial height in three cases (Fig. 3and Table 2) with no reported loss of fixation with progressive, late displacement, or implant failure in any case throughout the follow-up period that extended for a mean duration of 16.7±3.2.

Satisfactory clinical results (wrist motion and grip strength) were achieved in all cases with the mean range of extension, flexion, pronation, and supination being 78.6±5.1°, 77.3±8.2°, 79.4±9.6°, and 80.1±7.8°, respectively (Table 2). No cases had deep infection, tendon, or neurovascular injuries and all patients considered themselves fully satisfied with the results and resumed work or activity within ~17.3±1.7 weeks. Surprisingly, the clinical results did not strictly coincide with the radiological results. The three cases with good – not excellent – radiological results (with loss of volar tilt and/or radial shortening compared with the other uninjured side) showed excellent clinical results (wrist motion and grip strength) in the last follow-up. This could be explained by minimal dissection during plating using the MIPPO technique and encouraging the patients to start active, full joint motion for all the unsplinted joints from day 1 and wrist motion from day 14 postoperatively.

Among the 11 cases studied, two had disrupted distal radio-ulnar joint. In these two cases, temporary ulno-radial K-wires were inserted holding the reduced joint in full supination after the fracture had been reduced and fixed. These transfixing K-wires hindered active pronation/supination in the first, four postoperative weeks and these wires were protected in above the

Figure 3

(a, b) A displaced, extra-articular distal radial fractures with metaphysio-diaphyseal comminution; (c) immediate postoperative radiography showing fixation of the fracture by an improperly contoured volar locking plate bridging the comminution with improper restoration of volar tilt; (d) last follow-up radiography showing complete union of the fracture with loss of volar tilt implying a good radiological result.

Table 2 Postoperative follow up data

Number	Union time (weak)	Follow up time (month)	ROM F/E	ROM S/P	RI	VT	RS (MM)	Grip strength (%)	Time to return to work (week)
1	12	18	75/70	80/75	18	Reversed – 5	2	81	16
2	13	20	80/80	80/75	16	10	3	85	19
3	12	17	80/85	85/90	17	11	0	90	16
4	12	16	75/80	80/75	20	10	2	80	16
5	13	18	70/75	80/85	21	Reversed – 3	4	83	17
6	14	20	80/80	80/80	19	12	0	83	18
7	12	16	75/75	80/80	20	10	0	87	15
8	15	18	80/80	85/80	18	Lost 0	3	89	19
9	13	20	85/80	80/80	16	13	2	90	17
10	14	20	85/80	80/75	22	10	0	95	18
11	15	18	80/85	85/90	17	12	0	86	15

E, extension; F, flexion; P, pronation; RI, radial inclination; ROM, range of movement; RS, radial shortening; S, supination; VT, volar tilt.

elbow casts unlike the other nine cases in which fixation was protected in a below the elbow splint for only 2 weeks. These two cases regained a very satisfactory functional range of motion and grip strength after a relatively longer period of rehabilitation and took a longer time to return to their work compared with the other nine cases.

Discussion

MIPPO is a method of biological fixation. Biological fixation can be defined as a method of fixation of fractures in which greater importance is given to the soft tissues and vascularity of bone during a surgical intervention to ensure continued vitality of the individual fragments and to achieve improved fracture healing by bridging callus instead of primary bone healing found in rigidly fixed fractures [10].

MIPPO improves the rate of fracture healing with decreased incidence of nonunion, decreases the need for either primary or delayed bone grafting, decreases the incidence of infection, and decreases the incidence of refracture after plate removal because of callus formation [11,12].

MIPPO was applied for comminuted fractures affecting the long bones of the lower limb with satisfactory clinical outcomes. The technique is also applicable to selected simple fractures [13,14]; more recently, its use has also been expanded for the fixation of upper extremity fractures [15–18].

This study highlighted the MIPPO technique for fixation of 11 distal radial fractures with more than 5 cm long metaphysio-diaphyseal comminution through two small, volar incisions using the volar locking plates.

Both the distal and the proximal incisions were vertically oriented and the length of the distal incision was determined by the distance from the main fracture line to the articular surface of the distal radius.

The first work on MIPPO for fixation of distal radius fractures with metaphyseal comminution was reported in 2005 when Imatani *et al.* [19] treated five patients through two longitudinal incisions (3 cm) on the volar side of the distal forearm through which reduction and fixation were done.

Compared with the classic approach for open reduction and internal fixation that involves complete stripping of the pronator quadratus muscle with potential damage to the blood supply of the distal end of the radius – especially in the presence of comminution –leading to poor conditions for bone union and function recovery. MIPPO markedly preserves the pronator quadratus muscle with less stripping with more preservation of the blood supply for the distal radius and also allows better and faster restoration of postoperative pronation and supination of the forearm [20,21]. However, the striking concern while using the MIPPO technique is damage of the important anatomical structures during the procedure such as the radial artery, the median nerve, and/or its palmar cutaneous branch [22].

In a more recent study done by Wei and colleagues addressing MIPPO for fixation of distal radius fractures with long-segment metadiaphyseal comminution, they used a 2-cm long transverse incision made at the proximal wrist crease aiming at

providing more protection to the structures at risk during the MIPPO such as the radial artery, the median nerve, and the palmar cutaneous branch of the median nerve [22].

Volar plating was reported to be more superior compared with dorsally applied plates as it could avoid tendon irritation or attrition of the extensor tendons that usually occurred with dorsal platting. In addition, the volar cortex of the distal radius allows easy and more accurate placement of the plate being a wide and a flat surface compared with the dorsal cortex of the distal radius [23–25]. Moreover, volar locking plate was biomechanically superior compared with the dorsal locking plate [26].

Our results regarding the union time, the radiological results, the functional results, and the occurrence of complications were comparable to what was reported by Lee *et al.* [4] and Wei *et al.* [22]. We had no reported cases of neurological or vascular injuries, deep infection, loss of fixation, or implant failure.

Absence of neurovascular injuries in spite of the limited exposure could be explained by being familiar with the anatomy and vital structures at risk in that part of the distal forearm during the more commonly used standard Hennery's approach. The golden rule was to proceed for deep dissection directly through the bed of the flexor carpi radialis tendon to be safe from both the radial artery laterally and the median nerve and its palmar cutaneous branch medially. This coincides with and was supported by what was presented by McCann and colleagues. It has been reported that the flexor pollicis longus tendon was 7.4±1.46 mm from the radial artery and 7.01 ±2.37 mm from the median nerve [27] based on evaluating wrist MRIs of 100 patients.

The unrestored volar tilt and/or minimal radial shortening that were reported in three cases compared with the other uninjured side were detected in the immediate postoperative radiography, not detected or progressed late in the follow-up denoting that it was a reduction problem rather than an inefficient fixation with secondary displacement. The nonanatomical reduction with improper restoration of the volar tilt reported in these three cases was due to improper plate contouring – early in our learning curve – in one case (Fig. 3) and was due to marked comminution in the other two cases. Surprisingly, the clinical results did not strictly coincide with the radiological results. Volar tilt was lost in one case and was reversed in two cases (−3° and −5°). Such minimal changes were found to be ineffective when considering the functional outcome. These three cases showed excellent clinical results (wrist motion and grip strength) in the last follow-up.

Different studies reported that there is conflicting evidence on the impact of loss of normal palmar tilt on the functional outcome. Forward *et al.* [28] and Trumble *et al.* [29] have concluded that reduction of dorsal/palmar tilt was not associated with a better functional outcome, although Forward *et al.* [28] noted that dorsal angulation was associated with narrowing of the joint space and reduced grip strength.

Grewal and MacDermid [30] reported that the overall alignment of the fracture was considered unacceptable if the dorsal tilt was more than 10°, if the radial inclination was less than 15°, or if there was more than or equal to 3 mm of positive ulnar variance and malalignment of the distal radius beyond theses limits which was associated with a higher risk of poor outcome, but they reported that the impact diminished with advancing age. McQueen and Caspers [31] reported that malunion with dorsal tilt more than or equal to 12° was clearly associated with significant functional limitation.

We had radial shortening between 2 and 4 mm in six cases that was found to be noneffective when considering the functional outcome. Kelly *et al.* [32] concluded that up 5 mm of radial shortening –especially in elderly – may be accepted.

Indirect fracture reduction and biological fixation using a volar locking plate through a minimally invasive approach preserve the forearm musculature, acting as an internal splint surrounding the comminuted fragment ensuring a better blood supply to accelerate fracture union without the need for primary or delayed bone grafting, followed by early and progressive physiotherapy were the magic tools behind the satisfactory radiological and clinical results in this study.

The relatively small number of cases in this study with a relatively short-term follow-up period and the absence of control groups with another method of biological fixation like spanning and nonspanning fixators or using the same method of fixation through the classic open surgery through the standard Hennery's approach represent the limitations of this study; however, these limitations do not undermine the results achieved by this study.

Conclusion

Volar MIPPO for distal radius fractures with metaphysio-diaphyseal comminution could be a safe and effective surgical method of stabilization that can ensure a favorable mechanical and biological environment needed for fracture healing. MIPPO – using a mechanically superior locking plates – for such challenging fractures decreases the need for initial or delayed bone grafting and ensures a high union rate in a relatively short time with minimal complications, thus improving the functional outcome.

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Conflicts of interest

There are no conflicts of interest.

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