Original article

Minimally invasive percutaneous plate osteosynthesis for distal radius fractures with long-segment metadiaphyseal comminution

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A R T I C L E   I N F O

Article history:
Received 28 May 2015
Accepted 17 December 2015

Keywords:
Minimally invasive plate osteosynthesis
Volar locking compression plate
Distal radius fracture
Metadiaphyseal comminution

A B S T R A C T

Introduction: Distal radius fractures with both metaphyseal and diaphyseal comminution are commonly encountered injuries due to high-energy trauma. However, effectively treating patients with this disease remains challenging for the surgeon.

Hypothesis: The goal of this study was to evaluate the outcomes of minimally invasive percutaneous plate osteosynthesis (MIPPO) technique for distal radius fractures with long-segment metadiaphyseal comminution.

Materials and methods: Nine patients with distal radius fractures involving long-segment metadiaphyseal comminution were treated with MIPPO from June 2011 to May 2012. Radiograph index, the range of motion of the wrist and forearm, grip strength, the Disabilities of the Arm, Shoulder, and Hand (DASH) score were assessed at final follow-up. Additionally, time to bone healing, time to return to work or activity, and postoperative complications were also recorded.

Results: All nine fractures healed by 13 ± 1.3 weeks postoperatively. At an average follow-up of 15.9 ± 3.6 months, the radiographs revealed a mean radial inclination of 18.2 ± 2.7°, a mean volar tilt of 10.7 ± 3.2°, and a radial shortening of 2.3 ± 1.0 mm. Nine patients had excellent wrist function according to the DASH score, range of motion, and grip strength. Except one patient experienced delayed healing of the distal incision, no complications occurred. All patients resumed work or activity within 16.2 ± 1.9 weeks.

Discussion: Volar MIPPO is a safe and effective surgical treatment method for distal radius fractures with long-segment metadiaphyseal comminution, with few potential complications.

Type of study/level of evidence: Therapeutic IV.

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1. Introduction

Distal radius fractures with both metaphyseal and diaphyseal comminution are commonly encountered injuries as a result of high-energy trauma. These extensively comminuted fractures of the wrist complicate the proper reduction and restoration of anatomical alignment and thus remain a major clinical challenge for the surgeon. Currently, only a few treatment options have been entertained to treat these difficult fractures, including distraction plate fixation [1,2], fixed angle volar plate fixation [3] and long volar locking compression plate (LCP) fixation [4–6], among which the long volar LCP plate has gained favor 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 no demand of long period of immobilization [5]. However, the classic Henry approach usually requires pronator quadratus (PQ) muscle incision and extensive soft-tissue stripping over the metaphysis, which may devascularize the fracture fragments and consequently result in delayed healing [7]. Therefore, how to preserve an intact PQ muscle to provide better conditions for bone union is a hot research direction recently [8,9].

The minimally invasive percutaneous plate osteosynthesis (MIPPO) technique is one of the widely recommended techniques in which division of the PQ muscle was not involved, but a long LCP was inserted through two small incisions made on the volar side of distal forearm [10]. This procedure has been demonstrated to be more safe and effective for treatment of distal radial fractures [11–14], however, there are rare reports on the use of MIPPO for complex distal radius fractures involving both metaphyseal and diaphyseal comminution [15].

In addition, with regard to skin incisions, Imatani et al. [10] recommended two parallel, longitudinal incisions (3 cm), whereas Zenke et al. [11] recommended a distal transverse skin incision along the wrist skin crease and a proximal longitudinal incision.
Zenke injured was
2. (3)
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fractures, underlying seal surgery the involvement.

The purpose of this report was to describe this specific operative technique and to evaluate the clinical, radiographic, and functional outcomes of distal radius fractures with long-segment metaphyseal comminution in mainland Chinese patients. We hypothesize that volar MIPPO may be a safe and effective option for treating distal radius fractures with long-segment metaphyseal comminution.

2. Materials and methods

2.1. Patients

The study was approved by the Medical Ethics Committee of local hospital. All patients gave informed consent to allow their wrist images, clinical outcomes, and radiography data to be used for publication.

This retrospective study excluded patients presented with open fractures, simple distal radial fractures without long-segment metaphyseal comminution, and neurovascular injuries of the forearm. Nine patients who suffered closed displaced distal radius fractures with long-segment metaphyseal comminution at least 5 cm proximal to the radiocarpal articulation, with or without simple intra-articular fractures, were included from June 2011 to May 2012 and were treated with volar MIPPO in our hospital. Table 1 lists the demographic characteristics of the patients. The 5 women and 4 men had a mean age at surgery of 55.1 ± 9.7 years (range: 38–71 years). The mean time from injury to surgery was 7.3 ± 2.7 days (range: 5–14 days). According to the AO classification, there were 5 type 23-A3.3 and 4 type 23-C2.3. The causes of injury were road traffic accidents in 4 patients, work-related accidents in 4 patients and a simple falling from a height in 1 patient. The right wrist was injured in 6 patients and the left wrist was injured in 3 patients.

2.2. Operative technique

At a mean of 7.3 ± 2.7 days (5 to 14 days) after injury, the surgery was performed by the same one senior orthopedic surgeon as described previously [13]. The patient was placed on a radiolucent operating table in the supine position under brachial plexus block. Two assistants pulled the patient’s forearm longitudinally, with the forearm in full pronation and the elbow flexed to 90°. Under the traction of the fracture site, manual reduction was performed by the surgeon. Once a satisfactory reduction was achieved under C-arm fluoroscopy guidance, one or two 1.5 mm kirschner wires were obliquely inserted to temporarily maintain the reduction, followed by placing the injured forearm in full supination with the shoulder abducted to 90°. A 2-cm long transverse incision was made at the proximal wrist crease (Fig. 1). Further dissection was performed in the interval between the flexor carpi radialis laterally and the radial artery medially. The flexor pollicis longus tendon was retracted medially to expose the PQ, portion of which was split longitudinally (less than 1.5 cm) to expose the anterior cortex of the distal radius. This incision was not necessary for patients with incomplete injury in the PQ. A submuscular extraperiosteal tunnel was made between the flexor pollicis longus muscle and the underlying peristeum. A 10- or 12-hole, 2.4-mm, precontoured, titanium T-shaped LCP (Synthes GmbH, Oberdorf, Switzerland) [4] was inserted through the transverse incision and passed over the fracture site and down to an additional, 2-cm longitudinal incision which was made along the medial border of the brachioradialis, approximately in the mid-forearm (Fig. 1). A 1.5-mm K-wire was then inserted through a distal screw drill guide in the plate to temporarily fix the plate (Fig. 2). The alignment, length, and rotation of the fracture were checked with the C-arm fluoroscopy, and any obvious deformity was corrected by manual manipulation. When the anatomical alignment was achieved, the brachioradialis and radial vessels were retracted laterally while the flexor carpi radialis (FCR) was retracted medially, followed by inserting another 1.5-mm K-wire through a proximal screw drill guide in the plate (Fig. 2). The alignment, length, and rotation of the fracture were confirmed again under anteroposterior and lateral fluoroscopic views. Two suitable locking screws were placed through the incisions distally and proximally. Then, the above 2 K-wires were removed, and other suitable locking screws were placed separately, with at least 3 screws in each end of the LCP. Care must be taken not to put the distal screws into the wrist joint. The incisions were closed in layers.

2.3. Postoperative care and follow-up

Postoperatively, neither a splint nor any other means were used to strengthen the fixation. Shoulder, elbow, and digit motions were
Table 1
Patient characteristics and surgical outcomes of 9 patients with distal radial fractures.

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Sex/age</th>
<th>Injured hand</th>
<th>AO class</th>
<th>Causes</th>
<th>Time from injury to surgery (d)</th>
<th>Surgery time (min)</th>
<th>Radiation time (min)</th>
<th>Blood loss (mL)</th>
<th>TUN (w)</th>
<th>FU (m)</th>
<th>Radiograph</th>
<th>Grip strength (%)</th>
<th>DASH score</th>
<th>Time to return to work or activity (w)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F/55</td>
<td>L</td>
<td>23C2.3</td>
<td>RTA</td>
<td>5</td>
<td>56</td>
<td>2</td>
<td>55</td>
<td>13</td>
<td>20</td>
<td>8</td>
<td>0</td>
<td>80/85</td>
<td>90/85</td>
</tr>
<tr>
<td>2</td>
<td>M/61</td>
<td>R</td>
<td>23A3.3</td>
<td>RTA</td>
<td>5</td>
<td>57</td>
<td>3</td>
<td>57</td>
<td>12</td>
<td>13</td>
<td>15</td>
<td>5</td>
<td>70/65</td>
<td>85/85</td>
</tr>
<tr>
<td>3</td>
<td>F/38</td>
<td>L</td>
<td>23C2.3</td>
<td>WRA</td>
<td>14</td>
<td>97</td>
<td>5</td>
<td>140</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>5</td>
<td>70/70</td>
<td>85/85</td>
</tr>
<tr>
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<td>WRA</td>
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<td>62</td>
<td>4</td>
<td>95</td>
<td>13</td>
<td>14</td>
<td>19</td>
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</tr>
<tr>
<td>6</td>
<td>M/49</td>
<td>R</td>
<td>23A3.3</td>
<td>WRA</td>
<td>6</td>
<td>71</td>
<td>3</td>
<td>85</td>
<td>12</td>
<td>12</td>
<td>16</td>
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</tr>
<tr>
<td>7</td>
<td>M/50</td>
<td>R</td>
<td>23A3.3</td>
<td>RTA</td>
<td>7</td>
<td>63</td>
<td>3</td>
<td>83</td>
<td>14</td>
<td>21</td>
<td>22</td>
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</tr>
<tr>
<td>8</td>
<td>F/65</td>
<td>R</td>
<td>23A3.3</td>
<td>RTA</td>
<td>7</td>
<td>80</td>
<td>3</td>
<td>70</td>
<td>12</td>
<td>18</td>
<td>14</td>
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<tr>
<td>9</td>
<td>M/55</td>
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<td>23C2.3</td>
<td>WRA</td>
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<td>100</td>
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<td>13</td>
<td>19</td>
<td>10</td>
<td>70/70</td>
<td>70/75</td>
</tr>
</tbody>
</table>

RTA: road traffic accidents; WRA: work-related accidents; FFH: falling from height; TUN: time until union; FU: follow-up; RI: radial inclination; PT: volar tilt; RS: radial shortening; F: flexion; E: extension; P: pronation; S: supination; DASH: Disabilities of the Arm, Shoulder, and Hand.
encouraged at 2 or 3 days after surgery without any weight-bearing activities. All patients were followed with clinical and radiographic examination in 3- or 4-week intervals. When a callus appeared, the patients were asked to perform more active exercises.

At the final follow-up, a different senior surgeon, who had not participated in the treatment of these patients, evaluated the outcomes as following:

- the bone healing time was determined by the presence of bridging calluses in 3 of the 4 cortices observed on the anteroposterior and lateral radiographs of the radius. Delayed union was defined as lack of any healing on plain radiographs within four months. Nonunion was defined as lack of any healing on plain radiographs within six months;
- the degree of fracture deformity was assessed by measurements of radial inclination, volar tilt, and radial shortening based on the anteroposterior and lateral projection radiographs taken;
- the range of motion at the wrist and forearm (extension and flexion of the wrist joint, pronation and supination of the forearm) was measured by using a standard goniometer;
- grip strength was tested by using the Jamar dynamometer (Sammons Preston, IL, USA) and expressed as the percent of the contralateral uninjured side;
- the Disabilities of the Arm, Shoulder, and Hand (DASH) score was used to quantify disabilities related to the upper extremity, with a score ranging from 0 points (no disability) to 100 points (maximum disability);
- patient satisfaction was assessed by simply asking patients if they were satisfied with the result (yes/no);
- in addition, the operative time (min, recorded from the first skin incision to the last suture), radiation time (min, provided by the fluoroscopic apparatus for each procedure), blood loss (mL, estimated according to both the weight of blood on surgical swabs and the volume of flushing solution), complications, and the time to resumption of work were all recorded.

3. Results

All the patients underwent the MIPPO surgery successfully, with the average operative time of 69.6 ± 13.7 min, radiation time of 3.3 ± 1.0 min, and blood loss of 85 ± 25.7 mL. The surgery outcomes were displayed in Table 1. All 9 fractures healed by 13 ± 1.3 weeks postoperatively (range: 12–16 weeks). After an average of 15.9 ± 3.6 months’ follow-up, all patients had achieved perfect finger range of motion, with the mean motion as follows: 76.7 ± 7.1° of extension (range: 65–85°), 76.1 ± 9.3° of flexion (range: 60–90°), 78.9 ± 10.5° of pronation (range: 65–90°), and 80.6 ± 9.2° of supination (range: 65–90°). Radial inclination, volar tilt, and radial shortening on the radiographs obtained at the final follow-up examination were 18.2 ± 2.7°, 10.7 ± 3.2°, and 2.3 ± 1.0 mm, respectively. The average grip strength was 89 ± 4.1% compared with the patient’s unaffected wrist at final evaluation (range: 83–95%). Our functional results seemed to be well achieved with a low DASH score of 5.8 ± 0.9. Except one patient (case 3) experienced delayed healing of the distal wrist crease incision, no case of reduction loss, implant failure, deep infection, tendon or neurological injury had been recorded. Only two patients insisted to removing the plate which was performed along with the same minimally invasive incisions as above, not requiring additional extension of incision. All patients considered themselves fully satisfied with the results and resumed work or activity within approximately 16.2 ± 1.9 weeks. A typical case (case 1) was demonstrated in Fig. 3A–D.

4. Discussion

This present study first reported the use of volar MIPPO via two small perpendicular incisions (2 cm) to treat distal radius fractures with long-segment metaphyseal and diaphyseal comminution (> 5 cm proximal to the radiocarpal articulation). As expected, the patients obtained excellent bone union and function recovery after volar MIPPO technique. Our outcome seemed to be slightly superior to those reported by Lee et al. [4] (average time to fracture union, 13 vs 16 weeks; DASH score, 5.8 vs 10.1), who performed open reduction and internal fixation with volar long LCP for distal radius fractures with metaphyseal extension. Open reduction involves incision of the skin and PQ muscle, damaging the blood supply to the distal end of the radius [16,17] and thereby leading to poor conditions for bone union and function recovery. However, closed reduction requires longitudinal traction and other manual manipulation. The forearm muscles around the fracture site facilitate traction, maintain reduction and act as an inner soft splint, which provides a better blood supply to accelerate bone healing. It is noteworthy that recent comparison studies conversely indicate that there were no significant differences in union time and functional outcome in patients undergoing MIPPO or conventional Henry’s approach [11,15]. We believe this may be attributed to limited fractures in these two literatures (Zenke et al., type 23-A and type 23-C [11]; Chen et al., type 22 with 23 [15]), further suggesting MIPPO technique may be more beneficial for extensive metaphyseal fractures of distal radius (such as type 23-A3.3 and type 23-C2.3).

The distinct concern with the use of MIPPO technique is damaging anatomical structures with the incision and the surgical approach, such as the radial artery, the median nerve, and the
palmar cutaneous branch of the median nerve (Fig. 4). McCann’s study on 100 cases used magnetic resonance imaging to show that the FCR tendon was 7.4 ± 1.46 mm from the radial artery and 7.01 ± 2.37 mm from the median nerve [18], indicating the safe margin is located 7 mm around the FCR tendon, which was strictly followed in our study, not exposing the radial artery and the median nerve. Anatomical studies demonstrated that the palmar cutaneous branch originated from the radial part of the median nerve and then perforated the fascia of the anterior forearm just proximal to the distal wrist crease after travelling alongside the median nerve between the tendons of the palmaris longus and the flexor carpi radialis, implying a longitudinal incision located on the ulnar side should be recommended to avoid injuries to the palmar cutaneous branch of median nerve [19,20]. Combining with the cosmetic requirement, we used a transverse distal incision at the proximal wrist crease which was only limited in full-thickness skin and the deep soft-tissue separation was still performed longitudinally. As anticipated, no injuries in the radial artery, median nerve or the volar cutaneous branch of the median nerve were observed in our clinical study.

Compared with dorsal non-locked plating, radial–ulnar dual-column locked plating, and locked intramedullary fixation, the volar locked plating seemed to have higher bending stiffness, bending strength, and resistance to 5 mm displacement [21] and therefore may be more suitable for reduction and fixation of fractures that involve both the diaphysis and the metaphysis of the distal part of the radius [4–6]. MIPPO is a newly developed surgical procedure and thereby the specialized volar locked plate for it has not been widely explored. Recently, the most volar locked plate is T-shaped and designed based on the anatomical characteristics of Western populations [4–6,22]. There are rare reports to develop anatomical plate systems for Asian [23], which may be an underlying study direction for us.

In addition, the titanium plates are less heavy and bulky and, therefore, there is no need for plate removal in most cases, decreasing the related complications, such as wound infection [24]. As expected, no case of deep infection had been recorded in our study. However, delayed healing (5 weeks) of the distal wrist crease incision was observed in 1 patient, which may be associated with unsatisfactory detumescence preoperatively and excessive traction of skin intraoperatively. We suggest a proper incision length and a reasonable operation time to allow for sufficient detumescence preoperatively would resolve this complication.

This study has several limitations. First limitation of the current study is the small number of cases for evaluation of MIPPO procedure due to the relative rarity of metadiaphyseal fractures. Second limitation was the short follow-up period. The small sample size and short follow-up may jointly influence the statistics of complications. The last limitation is the lack of a control treatment with Henry approach.

5. Conclusions

Volar MIPPO may be a safe and effective surgical treatment method for distal radius fractures with long-segment metadiaphyseal comminution. However, further study with increased number of patients, a control group, longer follow-up is still needed to verify the advantage of MIPPO.

Disclosure of interest

The authors declare that they have no competing interest.

References


