Is single-stage minimally invasive plate fixation safe in open distal radius fractures with metadiaphyseal involvement?: Retrospective evaluation of 54 patients

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ABSTRACT

Objective: The aim of this study was to evaluate the safety and results of one-stage surgery in Gustilo grade 1 and 2 open distal radius fractures with metadiaphyseal involvement.

Methods: This retrospective study included 54 patients with AO-2R3 and metadiaphyseal involvement according to the AO fracture classification. All fractures were treated with a long volar plate using the minimally invasive plate osteosynthesis (MIPO) technique. The patients were divided into two groups as open fracture group (25 patients) and closed fracture group (29 patients), and the groups were compared for their union time and complications and functional and radiological results.

Results: There was no statistically significant difference between the groups in terms of clinical and radiographic results ($P > .05$ for both). The mean union time was 12.77 (range, 8-20) weeks in the open fracture group and 12.75 (range, 8-18) weeks in the closed fracture group. There was no statistically significant difference between the groups in terms of union time ($P > .05$). Moreover, there was no statistically significant difference between the two groups in terms of major and minor complications. All fractures healed without the need for bone and/or soft tissue grafts.

Conclusion: As a result of this study, using with long volar plate immediately minimally invasive plate osteosynthesis might be safely used as a single-stage definitive treatment for Gustilo grade 1 and 2 open distal radius fractures with metadiaphyseal involvement.

Level of Evidence: Level IV, Therapeutic Study

Introduction

The treatment of distal radius fractures (DRFs) with metadiaphyseal involvement remains a challenge.1,2,3 Especially these fractures, when associated with Gustilo–Anderson’s grade 1 and 2 open fractures, there is still no consensus on whether definitive treatment should be performed immediately.4,5 Although early debridement and immediate internal fixation is a common practice in open upper extremity fractures,6,7 there are publications stating that treatment with a progressive external fixator (EF) should be preferred due to the risk of deep infection.8,9,10

Another controversial issue is to decide whether to perform minimally invasive surgery or conventional surgery in DRFs with metadiaphyseal involvement. Although many publications are reporting good results with the conventional approach, it has been reported recently that the results of the MIPO approach are similar to the conventional approach.2,4,11-12 It is even said that the MIPO approach is both cost-effective and better in terms of patient satisfaction than the conventional approach.4,11 However, there is no study in the literature using the MIPO approach and long volar plate in open DRFs with metadiaphyseal involvement.

In this study, we aimed to evaluate the safety and results of using MIPO as a single-stage definitive treatment of open DRFs. For this purpose, we retrospectively reviewed patients who underwent MIPO long volar plate implantation as a 1-stage definitive treatment. Among these patients, we compared patients with Gustilo type 1 and 2 open fractures with those without open fractures in terms of complications and long-term outcomes.

Materials and Methods

This retrospective study was approved by the institutional review board of Health Science University, Ankara Numune Training and Research Hospital (25/05/2018, E-18-1839). All patients with metadiaphyseal involvement who underwent MIPO approach with the same length fixed-angle long volar plate (Zimmerbiomet® Anatomic Volar Plating System, Standard Extra Extended: 12 holes, 24.4 mm × 175.0 mm, Inc., Warsaw, Ind, USA) from 2013 to 2018 were reviewed retrospectively. All patients were consecutive patients. Patients aged 18-85 years, with at least 24 months of follow-up, who underwent single-stage surgery, and who were treated with long volar plate with the MIPO approach as definitive treatment were included in the study. Patients under the age of 18,
who did not undergo MIPO, who had open fractures accompanied by neurovascular injury, who had gunshot injuries, who had undergone 2 or more surgeries, who had previously undergone ipsilateral upper extremity surgery, who had refracture, who do not require the MIPO approach and use short plates, who had different fixation implants and had a follow-up period of less than 24 months were excluded from the study. Patients were divided into 2 groups according to whether there was Gustilo type 1 and 2 open fracture or not (group 1: patients with open fractures and group 2: patients with closed fractures). All fractures, according to the Arbeitsgemeinschaft für Osteosynthesefragen (AO) fracture classification, were recorded as 2R3B and 2R3C with metadiaphyseal involvement. Patients with accompanying ulna fractures were also recorded as 2U3 fractures according to the AO classification. The time (in hours) from the arrival of the patients to our hospital to the operating room was recorded as the time to definitive treatment.

Surgical Technique

All patients were operated on by 2 surgeons participating in the study. Patients were operated on a standard radiolucent Mayo table. A tourniquet was used on all patients. In all patients, fixation was applied primarily to the DRF. In patients with only fragmented DRF and shortness, if the ulna fracture was relatively less fragmented, the ulna fracture was first fixed to provide length. Modified Henry’s approach was used in all patients for radius fracture fixation. In this approach, first starting with a longitudinal distal incision and reaching the distal part of the radius. Since the fracture had radiocarpal extension in all cases, a distal incision of 4-5 cm was planned for anatomical reduction. All fractures were reduced anatomically under fluoroscopy using indirect and direct methods. After the reduction was achieved with Kirschner wires and the reduction was checked under fluoroscopy, the proximal part of the radius was reached by making a proximal longitudinal incision and exploration. Proximal incision was planned as 3-4 cm on average to avoid iatrogenic vascular nerve injury. After the guide Kirschner wires were applied by sliding the plate over the bone and under the pronator quadratus muscle, the placement of the plate was checked with fluoroscopy. Then, fixation was applied (Figure 1A-H). After the control x-ray, if fixation to the ulna was needed, only cannulated screws were used in ulna styloid fractures, and low-profile tubular plates were used in distal ulna metaphysis or diaphysis fractures. Tourniquet was opened and bleeding was controlled and the surgery was finished by suturing the surgical incisions. Hemovac drain was not used for any patient.

If the wound is on the incision line, the distal incision was made approximately 2-4 cm longer. After the incision, careful debridement was performed, and the operation was continued through these incisions. If the wound was far from the incision line, the wound was first debrided, washed with saline, and sutured. Then distal and proximal incisions were made (Figure 2A-G). In addition, the patients in the closed group were given cefazolin 30 minutes before the tourniquet for preoperative prophylaxis, while the patients in the open group were given cefazolin prophylaxis both at their first visit to the emergency room and 30 minutes before the tourniquet. Antibiotic prophylaxis was terminated at the 24th hour for the patients in the closed

HIGHLIGHTS

- The ideal treatment of open distal radius fractures (DRFs) with metadiaphyseal involvement remains a matter of debate. This retrospective study, aimed to evaluate the safety and results of using MIPO as a single-stage definitive treatment for open DRFs.
- The results showed that treatment of distal radius fractures with metadiaphyseal involvement with the minimally invasive plate osteosynthesis (MIPO) approach gives good functional results with similar complication rate for both open and closed fractures.
- The results indicate that the MIPO approach can be used safely in Gustilo grade 1 and 2 open distal radius fractures with metadiaphyseal involvement.

Figure 1. A-H. Closed distal radius fracture with metadiaphyseal involvement in a 26-year-old male. (A) Preoperative anteroposterior x-ray. (B) Preoperative lateral x-ray. (C) Intraoperative view. (D) Distal and proximal incisions. (E). Postoperative second-year anteroposterior x-ray. (F) Postoperative second-year lateral x-ray. (G) Postoperative second-year supination image. (H) Postoperative second-year pronation image.
while the antibiotic prophylaxis of the patients in the open fracture group was continued until the postoperative 72nd hour. In addition, tetanus prophylaxis was applied to the open fracture group in the emergency department. The remaining procedures were the same in both groups.

Follow-up and clinical evaluation

The patients were evaluated clinically and radiographically at 3, 6, 12, and 48 weeks postoperatively. Bone union was defined as fracture healing in 3 cortices on anteroposterior and lateral radiographs and absence of pain at the fracture site on clinical examination. Complications were divided into major and minor. Complications requiring reoperation such as tendon rupture, tendon irritation, and deep infection were considered as major complications. Superficial infection and non-surgical wound problems were considered as minor complications.

In the controls of the patients who completed 2 years postoperatively, for the subjective clinical measurement was used the shortened version of the Disabilities of Arm, Shoulder, and Hand questionnaire (QuickDASH) score (range, 0-100). As objective outcomes, a Jamar® dynamometer (Lafayette Instrument Company, Lafayette, Ind, USA) was used to test grip strength, the wrist range of motion (ROM; flexion and extension) and forearm ROM (pronation and supination) were compared with the contralateral side using a standard goniometer. As radiographic measurements described by Medoff, radial tilt and volar tilt in degrees and ulnar variance in millimeters were used.

Statistical analysis

The IBM Statistical Package for the Social Sciences Statistics 22 (IBM SPSS) software was used in the statistical analysis of the results obtained in this study. The Shapiro–Wilk test was applied to the continuous variables, which were found to be in accordance with the normal distribution. As descriptive statistics, mean ± standard deviation for continuous variables and frequencies and percentages for categorical variables were given. One-way analysis of variance was used for the comparison of quantitative data and between groups for variables with a normal distribution. Qualitative data were compared with the use of a chi-square test. Statistical significance was set at $P < .05$.

Results

A total of 59 patients were evaluated. In group 1, 3 (5.1%) patients (2 patients discontinued follow-up and 1 patient died) and 2 (3.4%) patients (2 patients discontinued follow-up) in group 2 were excluded from the study. A total of 54 (91.5%) patients were included in the study. Twenty-five (43.1%) patients in group 1 and 29 (53.7%) patients in group 2 were evaluated. According to Gustilo open fracture classification in group 1, 11 (44%) of 25 patients were grade 1 and 14 (56%) of 25 patients were grade 2. The follow-up period was 39.68 ± 12.51 months (range, 24-62 months) in group 1 and 36.87 ± 11.16 months (25-56 months) in group 2. Demographic information and follow-up time were shown in Table 1. There was no statistically significant deviation.
difference between the groups in terms of age, gender, fracture classification, additional ulnar fracture, and follow-up time (P > 0.05 for all).

The mean QuickDASH score was 23.44/100 (SD ±19.66) in group 1 and 18.89/100 (SD ±13.74) in group 2. The results comparing the operated extremity with the contralateral extremity performed with a Jamar dynamometer were as follows for group 1 and group 2, respectively. Mean grip strength was 70% and 73%, mean flexion was 77.81 ± 17.35° and 76.83 ± 17.11°, mean extension was 77.36 ± 16.38° and 72.45 ± 17.44°, mean supination was 77.95 ± 15.89° and 67.16 ± 13.04°, mean pronation was 68.50 ± 16.83° and 67.54 ± 16.18°. There was no statistically significant difference between the 2 groups in terms of both subjective and objective results (P > 0.05 for all) (Table 2).

Radiographic analysis of group 1 and group 2, respectively, were as follows: mean radial tilt was 13.40 ± 6.47° and 12.87 ± 4.61°, mean volar tilt was 6.36 ± 4.43° and 6.16 ± 4.06°, and mean ulnar variance was 0.50 ± 2.48 and 0.58 ± 2.46. There was no statistically significant difference between the 2 groups in terms of all radiographic measurements (P > 0.05 for all) (Table 3).

Two major complications (1 tendon irritation in group 1 and 1 deep infection in group 2) that required re-operation were treated with the removal of the plate. Two of the minor complications had superficial site infections (1 patient in each group) that were treated with oral antibiotics (Table 4). All fractures healed successfully without any need for bone grafting or soft tissue coverage.

### Discussion

It is still controversial whether definitive treatment will be gradual in open DRFs and which surgical approach will be chosen. In our study, we compared Gustilo grade 1 and 2 open fractures and closed fractures in DRFs with metadiaphyseal involvement, in which we applied a long volar plate with a single-stage MIPO approach. The most important finding of this study is that the results of the single-stage MIPO approach in open fracture are similar to the closed fractures, in which we apply the same approach, both clinically and radiologically. In addition, this study is the first and only study in the literature to both report and compare the results of open and closed DRFs with metadiaphyseal involvement.

There are limited studies in the literature comparing the conventional and MIPO approach in DRFs. Zhang et al. evaluated a total of 157 patients (MIPO: 83, conventional: 74) with DRF and found that patients who underwent the MIPO approach had better pronation and cosmetic scores. Zenke et al. evaluated a total of 66 patients (MIPO: 30, conventional: 36) with DRF and reported that there was no statistical difference between the results, both functionally and radiologically. In another study, Chen et al. compared a total of 34 patients (MIPO: 21, conventional: 13) with metadiaphyseal DRFs who applied MIPO and the conventional approach in their study. As a result, although they found the functional and radiological results to be similar, they recommended the conventional approach in the case of intra-articular extension. Pire et al. in their study, compared a total of 31 patients (MIPO: 15, conventional: 16) with metadiaphyseal DRFs and reported that the MIPO approach is more advantageous in terms of cosmetic and economic aspects. However, none of these studies included patients with open fractures. In our study, a total of 54 patients (open fracture group: 25; closed fracture group: 29) who had DRF with metadiaphyseal involvement and underwent long volar plate with the MIPO approach were included in the study and the results of these patients were compared. As a result, clinical and radiological results and complication rates were found to be statistically similar in both groups in which the same approach was applied (P > 0.05).

There are studies in the literature showing that the MIPO approach can be safely applied in both open and closed fractures in long bone

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### Table 2. Comparison of clinic outcomes between groups at last follow-up

| Variable | Open fracture group (n = 25) | Closed fracture group (n = 29) | P** |
|----------|----------------------------|-----------------------------|-----|
| Mean QuickDASH score (points) (range, 0-100) | 23.44 ± 19.66 | 18.89 ± 13.74 | 0.365 |

DASH: disabilities of the arm, shoulder, and hand. ROM, range of motion.

**Values are expressed as mean ± SD.

**P**-values represent the outcomes comparisons between the affected wrist and uninjured extremity.

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### Table 3. Comparison of radiographic outcomes between groups at last follow-up

| Variable | Open fracture group (n = 25) | Closed fracture group (n = 29) | P |
|----------|----------------------------|-----------------------------|---|
| Mean radial tilt (°) (range) | 13.40 ± 6.47 (range, 8 to 20) | 12.87 ± 4.61 (range, 8 to 19) | 0.747 |
| Mean volar tilt (°) (range) | 6.36 ± 4.43 (range, −9 to 14) | 6.16 ± 4.06 (range, −9 to 14) | 0.076 |
| Mean ulnar variance (mm) (range) | 0.50 ± 2.48 (range, −5 to +4) | 0.58 ± 2.46 (range, −4 to +6) | 0.910 |

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### Table 4. Postoperative complications in groups

| Variable | Open fracture group (n = 25) | Closed fracture group (n = 29) |
|----------|----------------------------|-------------------------------|
| Tendon irritation | Major | Minor | Major | Minor |
| 1 (4.0%) | 0 | 1 (4.0%) | 1 (3.5%) | 1 (3.5%) |
| Infection | 0 | 0 | 0 | 0 |
| Total | 2 (8.0%) | 2 (6.9%) |
fractures.20 Recently, publications on the safety of single-stage surgery in low-grade open DRFs are increasing. Kaufman et al.1 evaluated 21 patients with open DRF. They reported that single-stage early debridement and open reduction internal fixation had good functional results and low major complication rates. Kurylo et al.20 retrospectively studied 32 patients with open DRF. As a treatment, they applied EF in 20 patients, plate in 7 patients, and applied EF and then plate in 5 patients in 2 stages. As a result, they did not encounter infection in grade 1 and 2 open fractures. They also stated that EF application may increase secondary complications. Glueck et al.21 retrospectively evaluated 42 patients with open fractures. They reported that the infection and complication rates were very low in patients with small wounds with no contamination. In our study, we preferred single-staged definitive treatment with a long volar plate using MIPO for Gustilo grade 1 and 2 open DRFs with metadiaphyseal involvement. In the current study, a total of 2 (3.7%) major complications were seen in 54 patients (1 tendon irritation in group 1 and 1 deep infection in group 2) and plate removal was required. The minor complications of superficial site infections were seen in a total of 2 (3.7%) patients (1 patient in each group), which resolved with oral antibiotics. Complication and reoperation rates were found similar for both groups (P < .05).

In our study, the mean time to surgery for patients with open fractures was 6.90 ± 2.28 hours (range, 3-10) while it was 20.58 ± 6.61 hours (range, 10-36) in the group with closed fractures. Patients with open fractures were operated on in a statistically significant shorter time (P < .05). We think that this situation contributed to the similarity of infection rates for both groups. In terms of union time, the mean time to union was 12.77 ± 3.23 (range, 8-20) weeks in group 1 and 12.75 ± 2.67 (range, 8-18) weeks in group 2. While there was no statistically significant difference between the 2 groups, the results were similar to the studies in the literature.1,2

Our study has some limitations. The first is that this study is a retrospective study. The second limitation is that patients with open fractures have to be operated on as early as possible, as suggested in the literature, and the difference in this duration between groups may affect the infection rates. Another limitation is that although there was no significant difference in the number of patients with ulna fracture in both groups, ulna fracture may negatively affect functional results. Finally, although long-term results are more important, the lack of early term functional and radiological results of the patients can also be considered as a limitation.

In conclusion, as a result of our study, the clinical and radiological results and complication rates of the single-stage MIPO approach of Gustilo grade 1 and 2 open DRFs with metadiaphyseal involvement were found to be similar to those of closed fractures in which the same approach was applied. The MIPO approach can be used safely in Grade 1 and 2 open DRFs with metadiaphyseal involvement.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of Health Science University, Ankara Numune Training and Research Hospital [E18-1839 date:25/05/2018].

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