개방성 관절내 분쇄 원위 요골 골절에 1차적 관혈적 정복술 및 금속판 내고정 수술

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Primary Open Reduction and Plate Fixation in Open Comminuted Intra-Articular Distal Radius Fracture

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Purpose: There are no standard surgical treatments for open distal radius fractures (DRFs), and the fracture fixator is chosen by the surgeon’s own experience. This study compared the outcomes of open reduction and volar locking plating (OR VLP) between closed and open AO-OTA type C3 DRFs.

Materials and Methods: Patient data were retrospectively collected between January 2010 and December 2018. Only patients aged >18 years with AO-OTA C3 DRFs were included. After further exclusion, the patients with DRFs were divided into two groups: 13 patients with open DRFs in Group 1 and 203 patients with closed DRFs in Group 2. Data on the patient characteristics and treatment-related factors were further investigated. For the radiological evaluation, the radial height, volar height, and volar tilt were measured based on the final plain radiography, and the union time was measured. The wrist range of motion (ROM), pain visual analogue scale score, and modified Mayo wrist score for function were measured at the final outpatient follow-up. Finally, the complications associated with OR VLP fixation were investigated.

Results: In the demographic comparison, the patients with open fractures were older (mean age, 62 years) than those with closed fractures (mean age, 57 years), without a statistically significant difference. The patients with open DRFs had longer antibiotic therapy and hospital stay durations. Although they presented a higher radial inclination, with statistical significance, the clinical implication was low with a mean difference of 3°. No significant differences were observed for the remaining radiological parameters, wrist ROM, and functional scores. An open DRF did not increase the complication rates, including deep infection.

Conclusion: Depending on the expertise of the operating surgeon, the primary OR VLP fixation in open intra-articular comminuted DRF did not increase the incidence of deep infections and yielded similar outcomes to a closed intra-articular comminuted DRF.

Key Words: Distal radius, Open fracture, Open reduction and internal fixation, Volar locking plate
Introduction

Distal radius fractures (DRFs) have been reported as the most common upper extremity and open fractures, reported in approximately 5% to 6% of all fractures.\textsuperscript{1-4} Although most DRF management strategies involve nonoperative methods, a significant trend toward surgical treatment has been noted,\textsuperscript{5,6} largely explained by the introduction of volar locking plate (VLP) fixation, which is associated with advantages such as stable fixation, short immobilization period, and few complications.\textsuperscript{7-9}

In open DRFs, there is no consensus regarding operative treatment modalities, and the effectiveness of surgical fixation and its timing have been controversial and are based on the surgeon’s preference.\textsuperscript{10,11} Infection after open DRFs is a primary concern for determining the appropriate treatment methods. Instead of applying an external fixator for definitive or staged operation, some surgeons prefer immediate open reduction and internal fixation (ORIF) for open DRFs.\textsuperscript{4,10,12-14} Kurylo et al.\textsuperscript{13} reported that the initial plating might be safer at the initial debridement regardless of debridement timing regardless of temporary external fixation with a staged conversion in Gustilo and Anderson (G–A) type I and II open DRFs.

Nevertheless, in open DRF with severe articular comminution, open reduction and VLP (OR VLP) fixation are challenging to perform in the initial setting.

This study aimed to compare the outcomes of OR VLP between closed and open AO Foundation and Orthopaedic Trauma Association (AO–OTA) type C3 DRFs. We hypothesized that treatment of open DRFs presents inferior results, including poor radiological and functional outcomes, and complications, including infections.

Materials and Methods

This retrospective single-center cohort study was approved by the local institutional review board (IRB No. CHAMC 2020–06–014–005), and patient consent was waived due to the retrospective nature of the study. Patient data were collected at CHA Bundang Medical Center between January 1, 2010 and December 31, 2018.

An expert hand surgeon, according to previously defined levels of experience, performed all the surgeries.\textsuperscript{15} During the procedure, the surgeon performed VLP fixation for DRFs using a modified Henry approach to the fractured distal radius between the flexor carpi radialis and the tendons of the brachioradialis. The inserted VLP from only one manufacturer (DePuy Synthes Co., Solothurn, Switzerland) was used, but different types of plates were used depending on the fracture patterns as per the surgeon’s discretion.

1. Patient selection and group allocation

We included a total of 1,059 patients with DRFs surgically treated during the study period, with age >18 years. Among them, 72 patients (6.8%) reported open fractures, and the remaining reported closed fractures (987 patients).

Among the patients with open fractures, according to the AO–OTA classification, we only included those with type C3 (23 patients) featuring complete articular fractures with comminution. Considering articular comminution, the fractures were classified as G–A type III, regardless of the external wound size.\textsuperscript{10} We excluded open type IIIB fractures requiring additional soft tissue management and IIIC fractures requiring vascular repair. Patients who were treated with external fixation devices were excluded because severe intra–articular comminution made it difficult to perform OR VLP fixation. Finally, we obtained 13 patients who were treated with primary OR VLP fixation in Group 1. They were also followed up for over 6 months. Antibiotics were administered from the onset of the initial injury until the signs of infection disappeared after OR VLP fixation. During the operation, the open wound was debrided and closed primarily.

In patients with closed fractures, 238 patients (24.1%) were classified with AO–OTA type C3 from the overall 987 patients. We excluded patients treated with other treatment modalities, including K–wire or screw fixation, dorsal plating, and external fixator. Patients lost to outpatient follow-up before bony union were also excluded, finally allocating 203 patients in Group 2 (Fig. 1).
2. Data investigation

Two orthopedic surgeons collected the data during the study period. Data on patient characteristics such as age, sex, side of the fractured arm, and multiple fractures were investigated.

In the operation-related data survey, we investigated the time interval (in hours) recorded between the first occurrence of injury and operation. The operation time excluding operations for multiple fractures was also assessed. The overall antibiotic treatment duration was surveyed. Finally, we examined the length of hospital stay.

For radiological evaluation, data on the distal ulnar fractures were recorded. We measured the radial height, volar height, and volar titling based on the final plain radiograph. We also investigated union time, which is defined as the presence of bony trabeculae crossing the fracture site in at least three of the four cortices on anteroposterior (AP) and lateral plain radiography images using the PACS software (Maroview®; Infinitt Healthcare Co., Seoul, Korea).

We investigated the wrist range of motion (ROM), which was the final score before the final outpatient follow-up. The measured ROM includes volar flexion, dorsiflexion, ulnar deviation, and radial deviation. We also investigated the pain visual analogue scale (VAS) score and modified Mayo wrist score (MMWS) for function at the final outpatient follow-up. Finally, we investigated the following complications as associated with OR VLP fixation: (1) tendon injury: flexor and extensor tendon injuries; (2) fixation and instrument related: reduction loss after VLP fixation, instrument breakage, screw penetration into the radial carpal joint, and reoperation for implant removal; (3) nonunion; and (4) deep infection. Uncontrolled infection requiring incision and debridement was regarded as a deep infection.

3. Statistical analyses

The data are presented as mean values for continuous variables or numbers with percentages for categorical variables. Because the number of cases in the experimental group was small, a nonparametric test was used. Fisher’s exact test was used to compare the categorical variables, and the Wilcoxon rank-sum test was used for comparison of the continuous variables between the groups, presenting the median values and interquartile ranges in tables. A p-
value of <0.05 was considered statistically significant. The statistical analysis was performed using the R software (ver. 3.1.0).

### Results

Fig. 1 presents the flowchart of patient selection for Group 1 (13 patients, open fracture) and Group 2 (203 patients, closed fracture). The patients with open fractures were older (mean age, 62 years) than those with closed fractures (mean age, 57 years), without statistical significance. We found no significant differences between the two groups in terms of sex, fractured arm, and combined distal ulnar fracture (Table 1). In open fracture patients, the initial open wound varied from a pin-point open wound to a wound 5 cm in length. The primary OR VLP fixation was performed within 12 hours in 3 patients, 24 hours in 4 patients, 2 days in 1 patient, 1 week in 3 patients, and over a week in 2 patients due to unstable conditions from multiple fractures and brain injury. By contrast, the mean operation duration from the onset of the initial fracture was 4 days in Group 2.

Although we found no significant difference in the duration of operation between the groups, Group 1 presented longer antibiotic therapy and hospital stay durations with a statistically significant difference (Table 1). The total outpatient follow-up duration did not differ between the groups.

### 1. Treatment outcome comparison

When comparing the radiological outcomes, only radial inclination was significantly different, with mean values of 23.2° and 20.4° between groups 1 and 2, respectively. There was no significant difference in terms of radial height, volar tilting, and union time between the groups (Table 2). We obtained 12 and 172 DRF medical recordings depicting wrist ROM before the end of treatment; however, all ROM in all directions showed no significant difference.
between the groups.

The final mean pain VAS score was 0.7 in Group 1 (12 of 13 DRFs overall) and 0.2 in Group 2 (152 of 203 DRFs overall), with no statistically significant difference (p=0.469). In the comparisons of the MMWS and grade, we found no significant differences, with mean scores of 83.6 and 84.1 score in groups 1 and 2, respectively.

2. Complications

None of the complications showed significantly different incidence rates between the groups. While no tendon injury occurred in Group 1, two cases of flexor pollicis longus tendon rupture and two cases of extensor pollicis longus tendon rupture were reported in Group 2. After VLP fixation, one each in both groups showed a reduction loss. One case of joint penetration after VLP was reported in Group 2. Four patients underwent implant removal in Group 1 (30.8%) compared with 68 cases in Group 2 (33.5%), with no statistically significant difference (p>0.999). None of the cases presented nonunion or deep infection in both groups.

Discussion

We conducted a retrospective comparison study between open and closed AO-OTA C3 DRFs. In the demographic comparison, we found no significant difference despite the mean old age of patients with open fracture. Open DRF required longer antibiotic therapy and hospital stay durations. Although open DRF presented a higher radial inclination with statistical significance, the clinical implication was low. However, we found no significant differences in terms of the remaining radiological parameters, wrist ROM, and functional scores. The open DRF did not increase complication rates, including deep infection.

A meta-analysis compared ORIF with external fixation for unstable DRFs. Both ORIF and external fixation were found to be effective treatments for unstable DRFs. Compared with external fixation, ORIF provides reduced postoperative complication rates, lower DASH scores, and better restoration of volar tilt for the treatment of DRFs. However, in open fracture management, the appropriate modalities that should be applied are controversial, and there are few studies comparing the various treatment modalities because of the lack of experience that leads to a lack of treatment algorithms. In grading the severity of open fractures, the G–A open fracture grading system, considering the wound size and the patterns of both soft tissue and bony injuries, has been universally applied in orthopedic fractures and DRFs. However, the limitations of applying the G–A system in open DRFs were also addressed. Based on the decision tree for the comprehensive management of open DRFs suggested by Iorio et al., in the case of low-energy injuries, it was argued that marginal resection and internal fixation can be used to treat wounds, but serial marginal resection and temporary fixation may be required for high-energy injuries accompanied by contamination.

In G–A type I or II open DRFs, Kurylo et al. stated that primary plating might be safe at the initial debridement without the occurrence of infections. Subsequently, Kim and Park compared the treatment outcomes of G–A type I and II open DRFs with those of closed DRFs, in which both groups were treated with OR VLP fixation. The open DFR group presented inferior outcomes at 3 months, but the outcomes of open DRFs were comparable with those of closed DRFs at the 1-year assessment. Kaufman et al. prospectively studied the safety of immediate ORIF for open DRFs in the elderly aged >60 years. Among the 21 patients, one had deep infection and one had nonunion, with adequate functional outcomes, supporting the requirement for immediate OR VLP.

Previous studies provided many clues on the treatment of open DRFs, but studies are limited in that these were conducted among patients with various degrees of damage, mainly focusing on low-grade open fractures. Given the worse prognosis and higher incidence of complications as the severity of the fracture increases according to the G–A classification, primary OR VLP fixation is a debatable treatment modality for G–A type III DRFs. Nevertheless, Glueck et al. argued that infection occurs in proportion to the degree of wound contamination rather than the degree of injury and external wound size according to the
G–A classification by focusing on the rate of infection after injury. In our study, the open wound was debrided sufficiently and closed primarily. Nevertheless, for severely contaminated open comminuted DRFs that made the primary wound closure impossible after marginal resection, the authors also selected an external fixation device.

Depending on own particular soft tissue envelope, all long–bone open fractures have different risks of infection.\(^\text{21}\) Compared to thin soft tissue coverage of tibia anterior aspect, the distal radius surrounded by multiple flexor and extensor tendons as well as volar pronator quadratus muscles. Furthermore, presumably due to an increased blood supply, upper extremity fractures have a lower risk of infection than lower extremity fractures.\(^\text{22,23}\)

Finally, although the patients with open fractures had longer antibiotic therapy durations, the treatment outcome was not inferior to that in patients with open fracture DRFs or deep infections.

This study has several limitations. First, we only had 13 small cases of open AO-OTA C3 DRF with a retrospective design. The minimum follow–up period was at least 6 months; however, the median values were not long term with 8 and 9 months in each group, respectively. Furthermore, the operating author had >20 years of experience in performing hand surgeries, reporting an expert level based on the previously defined levels of experience.\(^\text{15}\) Applying VLP in intra–articular comminuted DRF might be challenging for surgeons with less experience. Therefore, we could not generalize our outcome to general practices managing open intra–articular comminuted DRF. The operating surgeon applied an external fixator if the comminution and displacement were so severe that the OR VLP fixation was extremely difficult in both groups, which was another limitation. Through a review of the literature, Iorio et al.\(^\text{10}\) stated that the basic principles of operative fixation should prevail in either closed or open injuries, with fixation chosen mainly on the basis of the fracture pattern as opposed to a scoring system.

### Conclusion

Depending on the expertise level of the operating surgeon, primary OR VLP fixation in open intra–articular comminuted DRFs did not increase the incidence of deep infection and yielded similar outcomes as in closed intra–articular comminuted DRFs.
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