Research article

Effect of delayed distal radius fracture fixation on the difficulty of surgical operation

Pobe Luangjarmekorn a,*, Saowabhak Nitayavardhana b, Vanasiri Kuptniratsaikul a, Kawee Pataradool a, Pravit Kitidumrongsook a

a Department of Orthopaedics, Faculty of Medicine, Chulalongkorn University, King Chulalongkorn Memorial Hospital, Bangkok, Thailand

HIGHLIGHTS

- This study analyzed the effects of delayed distal radius fracture fixation on intraoperative and postoperative outcomes.
- Early fixation within 10 days was associated with a significantly shorter operation, a lower bone grafting rate and fewer additional incisions.
- For each day of delay, the operation time increased by 2.17 min, and the rate of both bone grafting and additional incisions increased by 8% each.
- Postoperative radiographic parameters, postoperative pain and wrist range of motion were significantly better in the early fixation group.
- We suggest that distal radius fracture fixation be performed as early as possible to reduce surgical complexity and improve postoperative outcomes.

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ABSTRACT

Purpose: The effect of delayed distal radius fracture (DRF) fixation by volar locking plates (VLPs) on the operative time, rate of bone graft use and need for additional surgical incisions was analyzed. Short- and mid-term outcomes were compared between early and delayed DRF fixation.

Methods: A retrospective cohort review of DRFs treated with VLPs was performed. The effects of delayed fixation were analyzed by 1) comparing intraoperative and radiographic parameters and follow-up outcomes between early fixation (EF, 1–10 days) and late fixation (LF, ≥11 days), 2) predicting the prolonged operative time using linear regression analysis, and 3) predicting the rate of bone graft use and additional incision using odds ratios.

Results: Of 104 patients, 51 and 53 were in the EF and LF groups, respectively. EF showed a significantly shorter operative time, lower rate of bone grafting and fewer additional incisions (94.80 vs. 123 minutes, 3.92% vs. 26.18% and 2% vs. 20.45%, respectively). Radiographic parameters, immediate postoperative pain and wrist range of motion were significantly better in the EF group. However, the visual analog scale (VAS) pain and Patient-Rated Wrist Evaluation (PRWE) scores were not different at the 12-month follow-up. For every day of delay, the operation was prolonged by 2.17 min, the rate of bone grafting increased by 8%, and the chance of additional incisions increased by 8%.

Conclusion: Delayed DRF fixation affects intraoperative and postoperative outcomes. We encourage internal fixation for DRFs as early as possible to reduce surgical complexity and improve postoperative outcomes.

Introduction

Distal radius fractures (DRFs) are one of the most frequent fractures encountered by orthopedic surgeons, with an incidence of 19.50–32 per 10,000 person-years [1, 2]. The majority of these fractures are caused by low-energy injury, with 66%–77% being related to a fall from standing height, corresponding to osteoporosis [3, 4, 5]. Unstable DRFs require open reduction and internal fixation (ORIF) to obtain good hand-and-wrist functions. The use of volar locking plates (VLPs) has become increasingly popularized and has shown advantages in providing rigid fixation, maintaining fracture reduction, facilitating early mobilization, and decreasing the complications associated with other types of fixation [6, 7].

The optimal timing for internal fixation among patients with DRFs had yet to be determined. Early surgery shows superior outcomes and is recommended in most cases [8, 9, 10, 11]. However, some studies have shown that delayed fixation affects only short-term outcomes and is...
indistinguishable in long-term functional results [12, 13]. Moreover, there is no information about the effect of delayed fracture fixation on the difficulty of intraoperative surgical operation and acute postoperative periods.

The present investigation was designed to test the hypothesis that delayed fixation of DRFs results in greater surgical difficulty. The purpose of this study was to show the effect of delayed DRF fixation with VLPs that is complicated intraoperatively in terms of (1) the operative time, (2) the need for bone grafting and (3) the need for additional surgical incisions. This study also compared the short- and mid-term outcomes of patients who were treated by early versus delayed DRF fixation.

Materials and methods

This retrospective cohort review evaluated patients who had DRFs and were treated with VLPs from January 2011–February 2018 at a single institution. The inclusion criteria were as follows: (1) patients diagnosed with a DRF resulting from a ground-level fall with outstretched hands, (2) age over 50 years old, and (3) treatment with VLP fixation. The exclusion criteria were as follows: (1) surgery later than 60 days after the injury, (2) bilateral DRFs, (3) associated ulnar styloid fracture and (4) multiple associated fractures that prolonged the hospital stay. This study was approved by the Institutional Review Board (Certificate of approval No. 186/2020, IRB No. 012/63).

Indications for surgery in this study were (1) unacceptable radiographic parameters (radial height < 10 mm, radial inclination < 15°, articular stepping > 1 mm, ulnar variance > 2 mm, presence of dorsal tilt) and (2) unstable fracture patterns based on surgeon evaluation. All operations were performed by experienced orthopedic hand specialists. There were 3 primary surgeons in this study. All surgeons used the same protocol for fixation of the DRF, including the following aspects: (1) the volar approach with VLP fixation was primarily used; (2) a dorsal incision was added if the surgeon needed more room for fracture reduction or bone graft insertion; and (3) bone grafting from iliac crest was performed in cases in which the bone gap was presented after fracture reduction.

After the operation, a short-arm volar slab was applied. All patients were admitted after distal radius fixation. Six-pack hand exercises were encouraged to be started immediately after patients could move their fingers. Medications for pain control were short-course oral nonsteroidal anti-inflammatory drugs (NSAIDs), acetaminophen, and intermittent intravenous morphine as needed. Patients were allowed to be discharged after the pain improved, no postoperative complications were presented, and postoperative radiographs were checked and accepted by the surgeons. Patients were scheduled for follow-up at the 1st and 2nd weeks after surgery for wound checks and every 1, 3, 6, and 12 months for fracture evaluation and rehabilitation programs. The information collected and analyzed in this study included the following:

- **Preoperative:** Demographic data, type of DRF classified by AO/OTA classification from plain radiographs, duration from the time of injury to the performance of the surgical procedure;
- **Intraoperative:** Operative time (from skin incision to skin closure), surgical incision, bone graft use, and intraoperative complications;
- **Postoperative:** Radiologic parameters (radial height, radial inclination, articular stepping, ulnar variance, volar tilt), length of hospital stay, visual analog scale (VAS) pain score, range of wrist motion, grip strength and Patient-Rated Wrist Evaluation (PRWE) score at 1, 3, 6, and 12 months.

### Statistical analysis

Demographic data are reported as the mean, median and standard deviation. The effect of delayed timing of DRF fixation on the operation time, the probability of bone graft use and the probability of additional surgical incisions were determined by logistic and linear regressions. Increases in the operation time were predicted by the formula from the linear regression model. The odds ratio (OR) was used to predict the chance of bone graft use and additional incisions after a delayed time to surgical fixation. Subgroup analyses of each fracture type according to the AO/OTA classification are also reported.

The median cutoff point for time from injury to surgery was used to classify patients into 2 groups: early fixation (EF, 1–10 days) and late fixation (LF, 11 days and over). All data in these 2 groups were compared. Continuous data (operative time, radiographic parameters, VAS pain score, range of motion, grip strength and PRWE score) were analyzed using independent t tests. Categorical data (AO/OTA type, bone graft use, additional incisions, length of hospital stay) were analyzed using the chi-square test. Results were considered statistically significant if the p value was < 0.05.

### Results

There were 104 subjects enrolled in this study. The median time from injury to surgery was 11 days. The mean operative time for DRF fixation by VLPs in our study was 109 +/− 44.60 min. The overall rate of bone graft use was 12.50%, and the overall rate of additional dorsal incision was 9.62%. Classified by AO/OTA type, all 3 types showed no statistically significant difference in the operative time, rate of bone graft use, rate of additional incisions or length of hospital stay (Table 1).

From the logistic and linear regression model, delayed timing of DRF fixation showed an effect with a longer operative time, an increased rate

| Table 1. Demographic data of the 104 patients in this series. |
|-----------------------------------------------|
| Number of cases (%)  | Total | AO/OTA type |
|---------------------|-------|
|                     |       | A     | B     | C     | p value |
| Days until surgery | Median | 11 (100%) | 10 (24.04%) | 13 (10.58%) | 11 (65.38%) | 0.83 |
| (days)              | (Range) | (1–49) | (3–44) | (1–49) | (1–46) |
| Operative time      | Mean   | 109 (+/- SD) | 106 (+/- 44.60) | 108 (+/- 34.90) | 110 (+/- 49.90) | 0.89 |
| (minutes)           |        | (+/- 44.60) | (+/- 34.90) | (+/- 49.90) | (+/- 47.40) |
| Bone graft use      | %      | 12.50% | 12.00% | 0.00% | 14.71% | 0.54 |
| (cases)             | (13/104) | (3/25) | (0/11) | (10/68) | |
| Additional incisions| %      | 9.62% | 12.00% | 0.00% | 10.29% | 0.77 |
| (cases)             | (10/104) | (3/25) | (0/11) | (7/68) |
| Length of stay      | Mean   | 2.17 (+/- SD) | 2.24 (+/- 0.09) | 2.09 (+/- 0.28) | 2.16 (+/- 0.09) | 0.81 |
| (days)              |        | (+/- 0.09) | (+/- 0.28) | (+/- 0.09) | (+/- 0.10) |
of bone graft use and an increased chance of additional dorsal incision during DRF fixation (Figures 1A-1C). The predicted operative time can be estimated by linear regression with the following formula:

\[
\text{Predicted operative time (minutes)} = 2.17 \times (\text{days of surgical delay}) + 76.99 \text{ minutes}
\]

delay, the odds of bone grafting and additional incisions increased by 8% (OR: 1.08, 95% confidence interval [CI] 1.03-1.13). From this information, we can estimate the effect of delayed surgery as follows: for every 5, 7 and 10 days of surgical delay, the operative time increased by approximately 11, 15 and 22 min, and the rate of bone graft use and additional incisions increased by 1.46, 1.70 and 2.14 times, respectively (Table 2).

We found that delayed surgery increased the operation time for all types of fractures as classified by the AO/OTA system (Figure 2A). In terms of bone graft use, delayed fixation of type C DRFs tended to show a greater effect on increasing the probability of bone grafting than that of type A DRFs. In terms of additional surgical incisions, delayed surgery for type A DRFs showed a slightly greater effect on increasing the probability of additional surgical incisions than type C DRFs (Figures 2B and 2C). Moreover, we found that all 11 cases of type B DRFs could be treated by using only a single volar incision, with no need for bone grafting, even though delayed surgery was performed (Table 1).

The most common cause of delayed surgery in our study was waiting for late displacement after acceptable initial reduction (25/53, 47.17%), followed by late hospital visits (7/53, 13.21%), patients changing their decision from conservative treatment (6/53, 11.32%), patients who were lost to follow-up and returned with residual pain (4/53, 7.55%), unavailability of operating rooms (3/53, 5.66%), self-removal of the splint and return with progressive pain and displacement (2/53, 3.77%) and unstable medical conditions (1/53, 1.89%).

To compare the effect of delayed surgery for DRFs between EF and LF, the median time to surgery (11 days) was used to classify the patients into EF (1–10 days) and LF (11 days or more) groups. As a result, there were 51 patients in the EF group and 53 patients in the LF group. These two groups were similar in terms of baseline characteristics, including age, male-to-female ratio, hand side and distribution of the AO/OTA fracture classification. Compared with the LF group, the EF group had a significantly shorter operative time, lower rate of bone graft use and lower chance of additional incisions (operative time: 94.8 vs. 123 minutes, rate of bone graft use: 3.92% vs. 26.18%, rate of additional incisions: 2% vs. 20.45%, respectively, p < 0.05). The postoperative X-ray alignment was also significantly different for all parameters (except articular stepping). Overall acceptable alignment after surgery was achieved in 96.08% (49/51 cases) of patients in the EF group and 66.08% (35/53 cases) of patients in the LF group (statistically significant, p < 0.05). The immediate postoperative VAS pain score was significantly higher in the LF group. However, the length of hospital stay was similar in both groups (Table 3).

The outcomes of treatment and follow-up are shown in Table 4. We found that the EF group showed a better range of motion than the LF group (statistically significant in protonation/supination at 1 month, more flexion and protonation at 3 months, more protonation/supination at 6 months and better flexion and protonation at the 1-year follow-up). However, the pain score and functional score (PRWE) were not different between the groups (Table 4).

**Discussion**

Currently, fixation of DRFs by VLPs is an increasingly popular choice of treatment with promising results [14, 15]. However, the optimal
Timing for surgery has not been clearly established. Recommended by the British Society for Surgery of the Hand (BSSH) and National Institute for Health and Care Excellence (NICE), surgical intervention should be performed within 72 h of injury for intra-articular fractures and within 1 week for extra-articular DRFs [10, 11]. However, the effect of delayed surgery is not clearly understood.

There are few studies comparing early versus late treatment of DRFs. A previous retrospective study by Weil et al. compared patients with DRFs who underwent delayed fixation (>21 days) and acute fracture repair (<21 days). In this study, the researchers found that EF yielded a better DASH score but no differences in postoperative radiographic parameters at the 1-year follow-up [13]. A study by Ashdown et al. showed that surgical fixation of DRFs within 2 weeks reduces postoperative finger stiffness [8]. Another study by Sirnio et al. also showed that the early surgery group (within 1 week) had significantly superior DASH scores at the 2-year follow-up compared with the delayed surgery group [9]. A study by Yamashita et al. compared the early and delayed fixation of extra-articular DRFs, with a cutoff point of 7 days or later defined as delayed fixation. They found that both groups had the same postoperative radiographic parameters, but the EF group had a better range of motion, grip strength, and DASH score in the first 12 weeks. However, both groups showed no differences in all aspects at the 1-year follow-up [12]. In our study, we found that DRF fixation within 10 days yielded a better range of motion and radiographic parameters than delayed surgery, although the VAS pain score and PRWE functional score were not different at the 1-year follow-up. The better range of motion in some directions might be beneficial for patients in some special activities that require a greater range of motion. Moreover, better alignment is beneficial in terms of preventing degenerative osteoarthritis. However, longer follow-up periods might be required to demonstrate this effect. All of these findings encouraged us to perform early internal fixation of DRFs for a better chance of good radiographic and better clinical outcomes.

**Table 3. Details of the operation and postoperative results (n = 104).**

|                  | Early fixation (EF) | Late fixation (LF) | p value |
|------------------|---------------------|-------------------|---------|
| Total cases      | 51                  | 53                |         |
| Median time to surgery | 6                 | 17                |         |
| Age (F:M)       | 60.92 +/- 8.85     | 60.75 +/- 8.17    | 0.970   |
| Side of fracture|                     |                   |         |
| Dominant hand    | 25                  | 26                | 0.997   |
| Nondominant hand | 26                  | 27                |         |
| AO type          |                     |                   |         |
| A                | 14                  | 11                |         |
| B                | 5                   | 6                 |         |
| C                | 32                  | 36                | 0.723   |
| Bone graft use   | Yes                 | No                | 0.015*  |
| Incisions        |                     |                   |         |
| Single volar incision | 50                | 44                | 0.016*  |
| Additional dorsal incisions | 1 | 9 |         |
| Operative time   | 94.80 29.80         | 123 52            | 0.001*  |
| Length of stay (days) | 2.18           | 1.14              | 0.972   |
| VAS pain score D1 | 4.27             | 2.08              | 0.042*  |
| VAS pain score D2 | 1.56             | 1.20              | 0.002*  |
| Radial height    | 10.35              | 9.13              | 0.006*  |
| Radial inclination| 0.10              | 1.35              | 0.005*  |
| Volar tilt       | 7.38 3.62          | 4.83 4.87         | 0.003*  |
| Ulnar variance   | 0.24 0.657         | 0.962 1.13        | <.001   |
| Articular step   | 0.14 0.405         | 0.311 0.59        | 0.091   |
| Overall alignment| Acceptable         | Unacceptable      |         |
|                 | 49                  | 25                |         |
|                 | 35                  | 18                |         |

*Statistically significant (p < 0.05).
Another advantage of early DRF fixation was a reduction in the complexity of the surgical procedures and overall operative time. Earlier surgery should provide more benefits for the patient in terms of reducing the waiting time for bone healing, time in a cast, time of disability and overall morbidity rate. The easier procedure and shorter operation will reduce the cost of fracture treatment and be beneficial in terms of the overall operating room and hospital facility allocation. Moreover, the standard deviation of the operative time of the late fixation group was large due to the variety of operations in this group. Some cases in the late group may have used a short time to perform the surgery. However, most of the cases required a long operative time for surgery and less predictable time for the operation due to the difficulty of the delayed fracture and the variety of intraoperative problems during the surgery. Unpredictable operative time is also one of the problems in surgical schedule management in the operating room.

To the best of our knowledge, no study has provided information about the effect of delayed DRF fixation on the intraoperative and acute post-operative periods. In our study, EF of DRFs within 10 days had a significantly shorter operative time (94.80 vs. 123 minutes), a lower rate of bone graft use (3.92% vs. 26.18%) and a lower change of additional dorsal incision (2% vs. 20.45%). Moreover, in the subgroup analysis of our series, a total of 15 patients who underwent DRF fixation during days 1–5 after injury had no need for bone grafting or additional incisions. After analysis by linear regression and the OR, we found that for every day of delayed fixation, the possibility for bone graft use and the need for additional incisions both increased by 8%, and the operation was prolonged by 2.17 min.

In the situation of delayed surgery, healing of the malposition of the DRF might cause difficulty of the operation due to 1) difficulty in identifying fracture sites because of fibrous or callus formation; 2) ill-defined fracture lines from the process of bone resorption; 3) difficulty in reduction due to circumferential callus formation and soft tissue adhesion; and 4) loss of the ligamentotaxis effect and fragment recoil during the process of fracture reduction. These effects caused the surgeon to perform additional, necessary operations, such as brachioradialis release, the extensile volar approach or additional dorsal incision for circumferential bone and soft tissue release, to achieve anatomical reduction. Moreover, loss of recoil and ligamentotaxis effects in late reduction usually caused void areas and required bone grafting. This situation occurred because multiple small comminuted fragments started to heal and did not move back into place, as occurred with the acute fracture. In more late-presenting cases in which the fractures were already united, the surgery was more difficult because the osteotomy had to be performed. All of these factors resulted in a longer operative time and worse fracture reduction compared to the corresponding outcomes in patients with early operative fixation.

In the past, waiting for definite instability or late displacement after initial acceptable reduction was a treatment option. However, information from our study showed that early surgical fixation resulted in better outcomes, fewer morbilities and less difficult procedures. Currently, we encourage surgeons to determine the need for surgical DRF fixation at the first visit to reduce the potential of delayed surgery. In our institute, active DRF patients with unacceptable alignment at the initial X-ray or DRF with potential instability (by Lafontaine’s criteria, Wristcalc calculation or Fernandez classification), even though they achieved acceptable alignment after reduction, were advised to receive surgical fixation as soon as possible. We reserved nonoperative treatment for DRFs in only the following cases: 1) nondisplaced or minimally displaced DRFs with acceptable alignment at the initial X-ray; 2) low-demand hand patients who accepted malposition of the wrist; 3) patients with severe medical conditions or high anesthetic risk for surgery; and 4) patients who refused surgery.

There are some limitations to this study. First, there were several surgeons involved in this study. Therefore, there were some differences in the details of the surgical procedure and intraoperative decisions even though all surgeons used the same type of instruments and the same principle for fixation. Second, there was a difference in the technical skill of the assistants in each surgery. Even though each surgery had the same number of assistants (2 assistants), the assistants varied from the orthopedic residents (PYGI-4) or the hand fellows. This point may influence the operative time. Third, this study did not assess the background factors related to the complications and medical history in the patients with DRF. The underlying diseases associated with bone quality and fragility may influence the clinical outcome of DRF fixation and may influence our results in this study.

Because of these limitations, the information from our regression model should be used with caution, and we recommend further research with larger sample sizes and more control variables for accurate interpretation of the effect of delayed surgery. Moreover, the gap between the cutoff value and the maximum number of days of delay in the delayed surgery group seems to be large in our study. Subgroup analysis by dividing the number of days, especially in the delayed surgery group, may be beneficial to show the clear effect of delayed surgery in future studies.

Conclusions

Delayed VLP fixation in DRF patients affects intraoperative and postoperative outcomes. Early surgical fixation within 10 days yields a significantly lower rate of bone grafting, better requirement for additional surgical incision, shorter operative time, better radiographic parameters and more preservation of wrist motion. For each day of delayed fixation, the possibility for bone grafting increased by 8%, the rate of additional incisions increased by 8%, and the operative duration increased by 2.17 min. Therefore, we encourage internal fixation for DRFs as early as possible to reduce the complexity of the operation and improve postoperative outcomes.
Declarations

Author contribution statement

Luangjarmekorn P, conceived and designed the experiments, performed the experiments, analyzed and interpreted the data, contributed reagents, materials, analysis tools or data, wrote the paper.

Nitayavardhana S, conceived and designed the experiments, performed the experiments, analyzed and interpreted the data, contributed reagents, materials, analysis tools or data, wrote the paper.

Pataradool K, contributed reagents, materials, analysis tools or data.

Kuptniratsaikul V, contributed reagents, materials, analysis tools or data.

Kitidumrongsook P, conceived and designed the experiment, contributed reagents, materials, analysis tools or data.

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Data availability statement

The authors do not have permission to share data.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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