[Original]

Comparison of Functional Outcome Between Early and Delayed Internal Fixation Using Volar Locking Plate for Distal Radius Fractures

Kazuta YAMASHITA¹, Yukichi ZENKE^{2*}, Akinori SAKAI³, Toshihisa OSHIGE², Shiro MORITANI¹ and Takashi MAEHARA¹

¹ Department of Orthopaedic Surgery, Kagawa Rosai Hospital, Marugame-city Kagawa 763-0013, Japan

² Department of Orthopaedic Surgery, University Hospital of Occupational and Environmental Health, Japan. Yahatanishi-ku, Kitakyushu 807-8555, Japan

³ Department of Orthopaedic Surgery, School of Medicine, University of Occupational and Environmental Health, Japan. Yahatanishi-ku, Kitakyushu 807-8555, Japan

Abstract : The purpose of this study was to assess the effect of timing (Early (E) group vs Delayed (D) group) of internal fixation for distal radius fractures on forearm and wrist function in patients who underwent the surgery. The subjects were one hundred six patients who had extra-articular fractures of the dorsally displaced distal radius and were treated with a volar locking plate. The subjects were divided into two groups: E group (Operation on the day of injury or the next day, n = 76 ; and the D group (Operation at 7 days after injury or later, n = 30). Follow-up examinations conducted at 4, 12, and 48 weeks after surgery included measurements of wrist and forearm ranges of motion (ROM), measurement of grip strength (GS), Disability of the Arm, Shoulder and Hand score (DASH), and complications, retrospectively. The patients in both groups improved significantly with respect to ROM, GS, and DASH. At 4 weeks, the patients in the E group had better forearm motion, At 4 and 12 weeks, those who had undergone early surgery had significantly better wrist motion, GS and DASH. At 48 weeks, there were no differences between the groups in ROM, GS, or DASH. Patients with dorsally displaced extra-articular fractures of the distal radius can expect to have better short-term outcomes with early treatment, open reduction and internal fixation using a volar locking plates.

Keywords : distal radius fractures, volar locking plate, extra articular fracture, timing of surgery, functional outcome.

(Received November 11, 2014, accepted May 14, 2015)

Introduction

Extraarticular, dorsally displaced fractures with metaphyseal comminution are among the most common fractures of the distal radius, particularly in patients with osteoporosis[1]. Dorsal metaphyseal comminution renders most of these fractures unstable[2, 3], and misalignment after manipulative reduction and cast immobilization is common without surgical fixation[4]. Open reduction and volar plate and screw

fixation using distal locked screws has become a popular alternative for treatment of dorsally displaced fractures with dorsal metaphyseal comminution[5–8].

There have been no studies about the optimal timing of internal fixation for patients with distal radius fractures. This study was designed to test the hypothesis that wrist function and health status do differ between patients with early open reduction and volar plate fixation and those with delayed fixation for dorsally displaced extraarticular fractures of the distal radius. The

*Corresponding author: Yukichi ZENKE, Department of Orthopaedic Surgery, University Hospital of Occupational and Environmental Health, Japan. Yahatanishi-ku, Kitakyushu 807-8555, Japan. Tel:+81-93-691-7444, Fax: +81-93-692-0184, E-mail: ukichi.drz@gmail.com

purpose of the present study was to assess the effect of the timing of internal fixation on function in patients who underwent open reduction and internal fixation with a volar locking plate.

Patients and Methods

Between January 2006 and March 2011, 641 patients who sustained a distal radius fracture presented to our institution. A flow chart that shows how the patients were extracted from 641 patients and how the patients were enrolled into two groups was created. The flow chart about patient exclusion is shown in Fig. 1. We performed a retrospective cohort study using a database containing information about these cases. The inclusion criteria were female sex, age 50–80 years, closed fractures, open reduction and internal fixation with volar locking plate only, and no prior open reduction and internal fixation treatment of the wrist. Exclusion criteria included general or local conditions that adversely affected bone physiology (such as tumor, hyperparathyroidism, and osteogen-

esis imperfecta), polytrauma, history of drug or alcohol abuse, and dementia. Furthermore, we excluded intraarticular fractures of the distal radius because of the variety of implants.

Two of the authors classified the patients according to AO/OTA (Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association) Comprehensive classification of fractures and using standard posteroanterior and lateral radiographs[9]. The study was approved by the Ethics Review Committee, and consent was obtained from each patient.

Initially, all displaced fractures were managed with closed reduction and application of a sugar-tong splint. Informed consent about the surgical method, outcome and usual complications was obtained before surgery, and trained interviewers obtained baseline demographic data including baseline Disability of the Arm, Shoulder and Hand (DASH) score, indicating similar preinjury functional status and injury information. A series of standard radiographs was made at the time of the initial injury, including posteroanterior and lateral views of the affected and contralateral wrists. Mea-

Fig. 1. The flow chart of distal radius fracture patients selection. The flow chart shows how the patients were extracted from 641 patients and how the patients were enrolled into two groups. AO: Arbeitsgemeinschaft für Osteosynthesefragen, ORIF: Open Reduction and Internal Fixation.

surements of radial inclination ($^{\circ}$), volar tilt ($^{\circ}$), and ulnar variance (mm) were recorded for each radiograph. Open reduction and plate application were accomplished through an extended flexor carpi radialis approach [10, 11]. All fractures were reduced via an open approach and were stabilized with a locked precontoured volar plate (the Volar Distal Radius Plating System; Stellar plate, Japan Universal Technologies, Inc, Tokyo, Japan). All patients who had a concomitant fracture of the distal aspect of the ulna, which involved an avulsion of the tip of the ulnar styloid process or a fracture of the base of the styloid process, had not had an ancillary surgery for the distal aspect of the ulna. No patients had a postoperative splint applied, and all were allowed free movement of their wrists and fingers, as much as pain would allow.

We identified all the patients who had an extraarticular, dorsally displaced fracture treated with a volar locking plate and who had been followed up for at least 12 months. We defined the early fixation group as patients treated with open reduction and volar plate fixation within 1 day of injury, and the delayed fixation group was patients treated 7 or more days after injury. In this study, we excluded the middle group because it was a comparative study for early and delayed. It was fixed automatically as the operation day in the schedule of the operating room, regardless of our intention.

Evaluation

All the patients were followed up at 2, 4, 8, 12, 24, and 48 weeks by their treating surgeon, and all data were collected by an independent, trained researcher at each follow-up visit. All the patients participated in a formal outpatient therapy program that emphasized the active and passive range of finger motion, wrist motion, and forearm motion.

Follow-up examinations conducted at 4, 12 and 48 weeks included measurement of wrist and forearm ranges of motion (made by 2 independent, trained researchers) using a goniometer, measurement of grip strength (kg) using a dynamometer, and measurement of functional outcome with the DASH questionnaire [12]. Grip strength of the uninjured side was used as a control adjust for hand dominance [13]

Radiographic Evaluation

Radiographs were evaluated at each visit for loss of reduction. A trained research associate under the direction of the treating surgeon measured radial inclination, volar tilt, and ulnar variance according to the standardized techniques described by Kreder *et al* [14].

Early Fixation Group

The group that underwent surgery within 1 day of injury included 76 women, with an average age of 67 years (range, 51–80). All initial injuries were due to a fall from standing height. The right wrist was involved in 36 patients (including 34 with right dominance) and the left was involved in 40 patients (including 1 with left dominance). The operation was done within 24 hours. According to the Comprehensive Classification of Fractures, 32 fractures were Type A2 and 44 were Type A3. A total of 35 patients had a concomitant fracture at the distal ulna: at the tip of the ulnar styloid process ($n=20$) or the base of the ulnar styloid process ($n=15$). There were no additional injuries to the ipsilateral upper extremity. The average follow-up duration was 17 months (range, 12–22 months) (Table 1).

Delayed Fixation Group

Patients who underwent surgery at 7 days after injury or later included 30 women, with an average age of 67 years (range, 51–79 years). All initial injuries were due to a fall from standing height. The right wrist was involved in 15 patients (14 with right dominance) and the left in 15 patients (1 with left dominance). The mean time between injury and index procedure was 8 days (range, 7–12 days). According to the Comprehensive Classification of Fractures, 12 fractures were Type A2 and 18 were Type A3. A total of 18 patients had a concomitant fracture at the distal ulna: at the tip of the ulnar styloid process ($n=8$) or at the base of the ulnar styloid process ($n=10$). There were no additional injuries to the ipsilateral upper extremity. The average follow-up period was 18 months (range, 12–26 months) (Table 1).

Table 1. Descriptive statistics for the extraarticular fractures treated by early fixation and delayed fixation

Factors of fact-find	Early Fixation	Delayed fixation	<i>P</i>
N	76	30	NS
Mean $\pm$ SD, age, y	67.5 $\pm$ 9.1	67.4 $\pm$ 8.3	0.45
Right dominance, n	72	29	NS
Left dominance, n	4	1	NS
Dominant hand fractured, n (%)	36 (46)	15 (50)	0.38
Nondominant hand fractured, n	40	15	NS
AO (A2: A3)	32: 44	12: 18	0.23
Mean $\pm$ SD, follow-up, mo	17.3 $\pm$ 3.3	18.6 $\pm$ 4.9	0.14

AO: Arbeitsgemeinschaft für Osteosynthesefragen, NS; No statistically significant differences, $P < 0.05$ were considered statistically significant, SD: standard deviation

Statistical Methods

Differences in demographic characteristics were assessed with chi-square tests, for categorical variables (hand dominance and fracture pattern); and Mann-Whitney *U* test, for continuous variables (age and follow-up duration). Differences in ranges of motion, radiographic measurements, and DASH score were assessed with Mann-Whitney *U* test. A *P* value less than 0.05 was considered statistically significant.

Results

One hundred six patients met the inclusion criteria. Seventy-six patients underwent surgery within 1 day of injury, and 30 underwent surgery at 7 days after injury or later. These groups had no demographic differences (hand dominance, fracture pattern, preexisting medical conditions, or follow-up duration). No differences in baseline DASH score were detected between the groups, indicating similar preinjury functional status.

Radiographic Evaluation

Good bone union and healing occurred in all 106 fractures. There were no significant differences in radial inclination, volar tilt, or ulnar variance at any follow-up time point (Fig. 2).

Ranges of Motion, Grip Strength, and DASH Score

The patients in both groups improved significantly with respect to ranges of motion, grip strength, and DASH score.

At the final follow-up time, no differences were seen in range of wrist motion, range of forearm motion, grip strength, or DASH score. At 4 weeks, the patients treated early had better wrist extension, flexion, supination, and pronation. At 12 weeks, the patients treated early had better wrist extension and flexion, but no differences in supination or pronation were observed. At 4 weeks, those who had undergone surgery early had significantly better grip strength, when controlling for the uninjured side. At 12 weeks, those who had undergone surgery early had significantly better grip strength. DASH score was significantly better in the early fixation group at 4 weeks and at 12 weeks (Table 2).

Complications

Complications are reported in Table 3. One patient (1.3%) in the early fixation group experienced a superficial infection, which was treated with antibiotics for 1 week. Another patient (1.3%) in the same group underwent an additional surgical procedure because the proximal cortical screw backed out. In the delayed fixation group, one patient (3.3%) experienced a rupture of the extensor pollicis longus tendon and one

Fig. 2. Radiographic Evaluation. There were no significant differences in radial inclination A, volar tilt B, or ulnar variance C at any follow-up time point.

—◆—: Early fixation n=76, -□-: Delayed fixation n=30

Table 2. Outcome of ranges of motion, grip strength, and DASH score

Factors of treatment	Mean $\pm$ Standard deviation		<i>P</i>
	Early fixation n=76	Delayed fixation n=30	
4 weeks			
Extension($^{\circ}$)	53.9 $\pm$ 14.1	42.5 $\pm$ 16.1	<0.01
Flexion($^{\circ}$)	60.6 $\pm$ 19.6	44.1 $\pm$ 18.7	<0.01
Supination($^{\circ}$)	80.8 $\pm$ 15.4	69.5 $\pm$ 23.9	<0.01
Pronation($^{\circ}$)	83.0 $\pm$ 13.4	70.7 $\pm$ 22.5	<0.01
Grip strength(%)	64.6 $\pm$ 17.2	41.9 $\pm$ 24.5	<0.01
DASH	17.2 $\pm$ 17.1	36.3 $\pm$ 17.9	<0.01
12weeks			
Extension($^{\circ}$)	67.6 $\pm$ 10.9	41.9 $\pm$ 13.3	0.01
Flexion($^{\circ}$)	73.4 $\pm$ 15.9	59.6 $\pm$ 20.1	0.01
Supination($^{\circ}$)	87.8 $\pm$ 5.9	85.8 $\pm$ 7.9	0.22
Pronation($^{\circ}$)	87.9 $\pm$ 5.6	86.0 $\pm$ 7.1	0.21
Grip strength(%)	80.6 $\pm$ 16.7	68.7 $\pm$ 18.5	0.03
DASH	4.9 $\pm$ 7.3	13.7 $\pm$ 13.3	0.04
48 weeks			
Extension($^{\circ}$)	70.6 $\pm$ 12.2	67.2 $\pm$ 10.4	0.09
Flexion($^{\circ}$)	78.2 $\pm$ 15.8	74.9 $\pm$ 12.3	0.10
Supination($^{\circ}$)	88.7 $\pm$ 5.9	87.2 $\pm$ 7.9	0.19
Pronation($^{\circ}$)	89.1 $\pm$ 2.7	85.2 $\pm$ 11.6	0.45
Grip strength(%)	87.6 $\pm$ 15.8	83.6 $\pm$ 11.5	0.11
DASH	1.1 $\pm$ 3.6	4.7 $\pm$ 8.8	0.07

At 4,12 and 48weeks, patients treated early had better ranges of motion, grip strength, and DASH score. DASH: the disability of the arm, shoulder and hand

Table 3. Patient complications

Early fixation n=76	Case	Delayed fixation n=30	Case
Superficial infection	1	Rupture of the extensor pollicis longus tendon	1
Backing out of proximal cortical screw	1	Numbness at the palmar branch of median nerve area	1
		Complex regional pain syndrome 1	2

(3.3%) experienced numbness at the palmar branch of the median nerve area, which was successfully treated with corticosteroid injections. Two patients (6.7%), who underwent surgery at day 7 and day 8, experienced complex regional pain syndrome 1, which was treated with physiotherapy and block anesthesia that was successful.

Discussion

The most important findings of our study are that

we found improved ranges of wrist and forearm motion, grip strength, and functional status at 4 weeks and 12 weeks with early operative treatment of displaced distal radial fractures compared with delayed operative treatment.

Abdelhady found that a one-week or two-week delay in timing of surgery [15], which was considered a negligible period, also has an impact on the final result. This delay mainly affects ROM and power to a lesser extent, and both are reflected in the total score. This is explained by a significant part of the repair phase oc-

curing during the preoperative period in the displaced position, which has a negative effect on the quality of muscle and tendon healing. There have been no studies about the optimal timing of internal fixation for patients with distal radius fracture. The present study is the first to propose an optimal time for internal fixation in patients with distal radius fracture.

However, we were unable to demonstrate statistically significant differences in ranges of wrist and forearm motion, grip strength, or functional status at the final follow-up between patients with early operative treatment and those with delayed operative treatment.

There are multiple reasons for good results with early operative treatment of displaced distal radial fractures. First, early internal fixation can promote early functional rehabilitation. Second, it may have a better effect on the psychological aspect of the patient's health because it reduces the time during which the patient must wear a splint that restricts the use of their hands. Mathews *et al* suggested that patients who undergo surgery experience acute psychological distress in the preoperative period [16]. These fears manifest themselves as uncertainty, loss of control, decreased self-esteem, and anticipation of postoperative pain. Furthermore, such psychological distress affects soft tissue swelling around the fracture, scar tissue formation, and local inflammatory cytokines at the wrist periarticular area. Sun *et al* found cytokine concentrations (TNF- α , IL-6, and IL-10) were independent predictors of adverse postoperative outcomes in elderly hip-fracture patients [17].

In our study, major complications did not occur in either group. Furthermore, there was no significant difference between groups in the incidence of complications. In the delayed fixation group, 2 patients experienced regional pain syndrome, whereas no patients in the early fixation group experienced regional pain syndrome. If the preoperative waiting period is too long, complex regional pain syndrome may occur.

One of the limitations of our study is that the sample was restricted to patients with extraarticular fractures. We excluded intraarticular fractures of the distal radius, because we treated them with various implants, such as polyaxial distal locking plate. To focus more specifically on the influence of the timing of surgery, we intentionally limited this study to a single common fracture (extraarticular, dorsally angulated with dorsal

comminution); this limits the generalizability of the results. Another limitation is that the reason for no significant differences with regard to clinical assessment at final follow-up could be due to the study under power. Therefore, large number of cases may be necessary to see a difference between groups.

In conclusion, our findings indicate that early internal fixation for distal radius fractures may provide better functional outcomes than delayed internal fixation.

Conflicts of Interest

We declare that we have no conflicts of interest in connection with this paper.

References

1. Souer JS, Ring D, Matschke S, Audige L, Maren-Hubert M & Jupiter J (2010) : Comparison of functional outcome after volar plate fixation with 2.4-mm titanium versus 3.5-mm stainless-steel plate for extra-articular fracture of distal radius. *J Hand Surg Am* 35: 398-405
2. Lafontaine M, Delince P, Hardy D & Simons M (1989): Instability of fractures of the lower end of the radius: apropos of a series of 167 cases. *Acta Orthop Belg* 55: 203-216
3. Mackenney PJ, McQueen MM & Elton R (2006): Prediction of instability in distal radial fractures. *J Bone Joint Surg Am* 88: 1944-1951
4. Earnshaw SA, Aladin A, Surendran S & Moran CG (2002): Closed reduction of Colles fractures: comparison of manual manipulation and finger-trap traction: A prospective, randomized study. *J Bone Joint Surg Am* 84: 354-358
5. Willis AA, Kutsumi K, Zobitz ME & Cooney WP 3rd (2006): Internal fixation of dorsally displaced fractures of the distal part of the radius. a biomechanical analysis of volar plate fracture stability. *J Bone Joint Surg Am* 88: 2411-2417
6. Rozental TD & Blazar PE (2006): Functional outcome and complications after volar plating for dorsally displaced, unstable fractures of the distal radius. *J Hand Surg Am* 31: 359-365
7. Orbay JL & Fernandez DL (2004): Volar fixed-angle

- plate fixation for unstable distal radius fractures in the elderly patient. *J Hand Surg Am* 29: 96–102
8. Musgrave DS & Idler RS (2005): Volar fixation of dorsally displaced distal radius fractures using the 2.4-mm locking compression plates. *J Hand Surg Am* 30: 743–749
 9. Jupiter JB & Fernandez DL (1997): Comparative classification for fractures of the distal end of the radius. *J Hand Surg Am* 22: 563–571
 10. Orbay J, Badia A, Khoury RK, Gonzalez E & Indriago I (2004): Volar fixed-angle fixation of distal radius fractures: the DVR plate. *Tech Hand Up Extrem Surg* 8: 142–148
 11. Orbay JL, Touhami A & Orbay C (2005): Fixed angle fixation of distal radius fractures through a minimally invasive approach. *Tech Hand Up Extrem Surg* 9: 142–148
 12. Hudak PL, Amadio PC & Bombardier C (1996): Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected] The Upper Extremity Collaborative Group (UECG). *Am J Ind Med* 29: 602–608
 13. Mathiowetz V, Kashman N, Volland G, Weber K, Dowe M & Rogers S (1985): Grip and pinch strength: normative data for adults. *Arch Phys Med Rehabil* 66: 69–74
 14. Kreder HJ, Hanel DP, McKee M, Jupiter J, McGillivray G & Swiontkowski MF (1996): X-ray film measurements for healed distal radius fractures. *J Hand Surg Am* 21: 31–39
 15. Abdelhady AM (2013): Timing of shoulder arthroplasty in comminuted proximal humerus fracture, how much does it matter? *Eur J Orthop Surg Traumatol* 23: 515–519
 16. Mathews A & Ridgeway V (1981): Personality and surgical recovery: a review. *Br J Clin Psychol* 20: 243–260
 17. Sun T, Wang X, Liu Z, Chen X & Zhang J (2011): Plasma concentrations of pro- and anti-inflammatory cytokines and outcome prediction in elderly hip fracture patients. *Injury* 42: 707–713
-

橈骨遠位端骨折に対する掌側ロッキングプレートを用いた早期手術群と待機手術群の機能予後の比較検討

山下 一太¹, 善家 雄吉², 酒井 昭典³, 大茂 壽久², 森谷 史朗¹, 前原 孝¹

¹ 香川労災病院 整形外科

² 産業医科大学病院 整形外科

³ 産業医科大学 医学部 整形外科学

要 旨：本研究の目的は、橈骨遠位端骨折の受傷から手術までの期間(早期群vs待機群)が術後成績に影響を及ぼすか否かを明らかにすることである。背側転位型橈骨遠位端関節外骨折患者106症例のうち、受傷当日もしくは翌日に掌側ロッキングプレートを用いて観血的整復固定術を施行した76例を早期群、受傷後7日目以降に手術した30例を待機群とし、術後4週、12週、48週のそれぞれの時点での可動域、握力、Disability of the Arm, Shoulder and Hand (DASH) スコア、合併症について後ろ向きに調査した。両群の患者とも、可動域、握力、DASHスコアとも有意に改善した。術後48週時は、両群間に有意差を認めなかったが、早期群が待機群と比較して、術後4週は前腕・手関節可動域、握力、DASHスコア、術後12週は手関節可動域、握力、DASHスコアが有意に良好であった。手術した背側転位型橈骨遠位端関節外骨折において、受傷から手術までの待機期間が、術後早期の臨床成績に影響を及ぼす可能性が示唆された。

キーワード：橈骨遠位端骨折, 掌側ロッキングプレート, 関節外骨折, 手術時期, 機能的予後。