


# Postoperative early and proactive grip strength training program for distal radius fractures promotes earlier recovery of grip strength

## A retrospective study

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### Abstract

The use of volar locking plates (VLPs) for distal radius fractures has remarkably improved clinical outcomes; however, there are some reports of delayed recovery of grip strength. Since January 2019, we have been conducting an early and proactive grip strength training program (EGTP). In this program, 20 minutes of grip strength training—using a gripper with a load of 0.7 kg—was initiated from 2 weeks after surgery; the load was then gradually increased. From 6 weeks postsurgery, daily home grip strength training was performed using a gripper with a load of 5 kg, provided to the patient.

We investigated whether the introduction of the EGTP could lead to earlier recovery of grip strength. We also examined whether the EGTP caused postoperative correction loss at the fractured site, or contributed to the early improvement of wrist function.

Thirty-nine patients who underwent surgery using VLPs for distal radius fractures were included in this study; 20 followed the EGTP (EGTP group) and 19 patients did not (NGTP group). For these patients, grip strength and range of motion of the wrist joint were evaluated both 3 and 6 months postoperatively. The Quick Disabilities of the Arm, Shoulder, and Hand (qDASH) scores were also evaluated 6 months postoperatively. Additionally, corrective losses of radial inclination (RI), palmar tilt (PT), and ulnar variance (UV)—occurring from immediately postsurgery to 6 months after surgery—were evaluated.

At both 3 and 6 months postoperatively, the grip strength of the EGTP group was significantly higher than that of the NGTP group. Regarding range of motion, only palmar flexion was significantly improved in the EGTP group at 3 months postoperatively. Conversely, no differences in corrective losses of RI, PT, and UV, or in qDASH scores, were observed between the two groups.

The results of this study suggest that the EGTP can provide early recovery of grip strength and palmar flexion of the wrist without causing corrective loss at the fracture site.

**Abbreviations:** ADL = activities of daily life, EGTP = early and proactive grip strength program, NGTP = nonearly and proactive grip strength program, OT = occupational therapists, PT = palmar tilt, qDASH = the Quick Disabilities of the Arm, Shoulder, and Hand, RI = radial inclination, UV = ulnar variance, VLP = Volar locking plate.

**Keywords:** distal radius fracture, grip strength, gripper, rehabilitation, volar locking plate

## 1. Introduction

Various surgical techniques have been used to treat distal radius fractures; however, since the introduction of volar locking plates (VLPs), outcomes have improved dramatically.<sup>[1,2]</sup> With the use of VLPs, postoperative correction loss is less likely to occur, even if range of motion exercises are performed early in the

postoperative period; a good range of motion can therefore be obtained earlier.<sup>[2]</sup> Nevertheless, there are some reports of delayed recovery regarding grip strength.<sup>[3–5]</sup> This is because unlike range of motion exercises, grip strength training—which places more stress on the fracture site—tends to be initiated later. Furthermore, there are few reports of well-planned grip strength

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training programs that begin early after surgery for distal radius fractures. It was therefore speculated that the muscle strength related to grip strength would decrease by the time proactive grip strength training was initiated, and would take a long time to recover. We hypothesized that if patients follow a proactive grip strength training program from the early postoperative period, a satisfactory grip strength may be acquired sooner.

In January 2019, our institution initiated an early and proactive grip strength training program (EGTP). In this ongoing program, training with a light-load gripper is initiated during the early postoperative period of VLP fixation for distal radius fractures; the load is then gradually increased according to the bone fusion status. In this study, we investigated whether the introduction of the EGTP lead to earlier acquisition of satisfactory grip strength by comparing the recovery of grip strength with that in patients before the introduction of the EGTP. We also examined whether the EGTP caused postoperative corrective loss at the fractured site, or contributed to early improvement of wrist function.

## 2. Materials and methods

This retrospective study (case–control study) was conducted with approval from the institution’s ethical review committee, and informed consent for publication of this article was obtained from the patients. We conducted a retrospective, comparative study to evaluate the efficacy of the EGTP for the recovery of grip strength after surgery for distal radius fractures. The inclusion criteria for this study were: patients who underwent fixation with VLPs for distal radius fractures between January 2015 and February 2022, as well as postoperative rehabilitation under the supervision of occupational therapists (OT); assessment of grip strength and wrist range of motion at 3 and 6 months postoperatively; a Quick Disabilities of the Arm, Shoulder, and Hand (qDASH) score at 6 months postoperatively; plain radiographs of the wrist at the time of injury, immediately after surgery, and at 6 months postoperatively; and computed tomography at the time of injury. Exclusion criteria were concomitant injuries around the wrist, and the use of external fixators that would affect grip strength. We analyzed data from 50 patients. Of these 50 patients, 45 met the inclusion criteria, and of these 45 patients, 6 were excluded based on the exclusion criteria. As a result, 39 patients who underwent VLP fixation for distal radius fractures met the criteria. Of these patients, 19 patients who underwent surgery between January 2015 and December 2018 did not follow the EGTP (NGTP group; before the initiation of EGTP), while 20 patients who underwent surgery after January 2019 followed the EGTP (EGTP group; after the initiation of EGTP).

### 2.1. Surgery

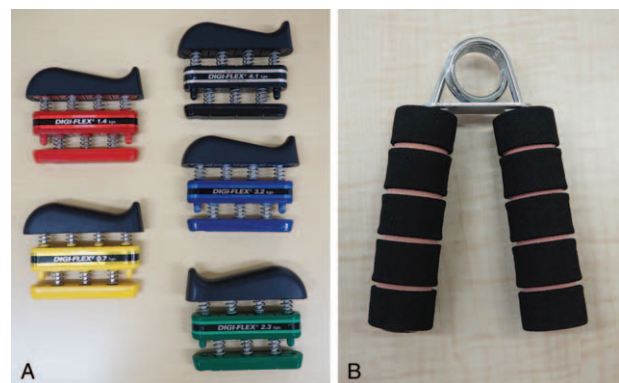
Surgery for distal radius fractures were performed using the standard VLP fixation technique with the transflexor carpi radialis approach. The VLPs used were: 10 HYBRIX or HYBRIX-D (Mizuho Medical Co, Ltd., Tokyo, Japan), 5 DVR (Zimmer Biomet, Warsaw, IN), 1 VariAx (Stryker Corporation, Kalamazoo, MI), and 1 VA LCP (DePuy Synthes, Raynham, MA) in the NGTP group; and 19 HYBRIX or HYBRIX-D, and 1 DVR in the EGTP group. After surgery, a plastic brace was attached to the wrist joint for 1 to 2 weeks and

removed during rehabilitation. Surgeries were performed by two experienced hand surgeons (Y.K. and K.Y.).

### 2.2. Rehabilitation

Rehabilitation began the day after surgery in both groups, with active assistive range of motion exercises of the wrist joint performed according to the postoperative pain status; towel squeezing and silicone putty compression training were also prescribed 3 weeks postoperatively as part of the usual grip strength training program at the hospital. Additionally, the EGTP—performed using a DigiFlex Exercise System (DIGIFLEX, New York)—was followed by patients in the EGTP group.

The DigiFlex system is a grip strength training device comprising five grippers, ranging from 0.7 to 4.1 kg (1.5–9 lbs); three of these grippers—with loads of 0.7, 1.4, and 2.3 kg—were used in this study (Fig. 1). In the EGTP group, grip strength training using a gripper with a load of 0.7 kg (1.5 lbs) was initiated on postoperative day 14 under the supervision of an OT; training then shifted to use of a gripper with a load of 1.4 kg (3 lbs) on day 21, and 2.3 kg (5 lbs) on day 28. Grip strength training was conducted once a day for 20 minutes during hospitalization. After discharge, training was conducted two to three times a week for 20 minutes per session, in addition to the usual range of motion exercises of the joints and grip strength training. From the 42nd day after surgery, grippers with a load of 5 kg (11 lbs) were lent to the patients; they were instructed to train twice a day at home for 20 minutes per session. The implementation status of the training was confirmed by the OT when they visited the hospital, and the training method was simultaneously re-explained. For grip strength training in the NGTP group, participants were instructed to perform towel or sponge grasping at home; however, they were not given detailed instructions regarding the frequency and duration of the sessions. Usual range of motion exercises of the joints, as well as grip strength training, were also provided under OT supervision two to three times a week after discharge. For both groups, activities of daily life (ADL) and sports activities were allowed without any restrictions from postoperative day 56. Details regarding the rehabilitation programs are presented in Table 1.



**Figure 1.** Grippers used in early and proactive grip strength training program. (A) Digi-Flex Exercise System. (B) Gripper with a load of 5 kg, used for home training.

**Table 1**  
Schedule of grip strength training.

	Nonearly grip strength training	Early grip strength training
2 weeks ~	–	(At hospital) <b>Gripper with a load of 0.7 kg (1.5 lbs)</b>
3 weeks ~	(At hospital) Compression of silicon putty Towel squeeze	(At hospital) Compression of silicon putty Towel squeeze <b>Gripper with a load of 1.4 kg (3 lbs)</b>
4 weeks ~	(At hospital) Compression of silicon putty Towel squeeze	(At hospital) Compression of silicon putty Towel squeeze <b>Gripper with a load of 2.3 kg (5 lbs)</b>
6 weeks ~	(At hospital) Compression of silicon putty Towel squeeze (At home) Towel or sponge grasping	(At hospital) Compression of silicon putty Towel squeeze 7 (At home) <b>Gripper with a load of 5 kg (11 lbs)</b>

### 2.3. Outcome evaluation

Demographic data, cause of injury, grip strength, range of motion of the wrist joints, and qDASH scores were extracted from the electronic medical records of the patients. Grip strength was evaluated using a Smedley-type hand dynamometer (GRIP-D; Takei Scientific Instruments Co, Ltd, Niigata, Japan). Ranges of motion of the wrist joint were evaluated in dorsiflexion, palmar flexion, pronation, and supination angles using a standard goniometer (Todai-shiki goniometer; Matsuyoshi & Co, Ltd, Tokyo, Japan). Grip strength and range of motion were evaluated at 3 and 6 months after surgery, while the qDASH scores were evaluated 6 months after surgery.

### 2.4. Radiographic evaluation

Plain radiographs and CT images at the time of injury were used to evaluate fracture type (AO-OTA classification). Additionally, radial inclination (RI), palmar tilt (PT), and ulnar variance (UV) were evaluated using plain radiographs immediately after surgery, as well as 6 months postoperatively. These evaluations were performed using the measurement tools included in the PACS system (SYNAPSE; FUJIFILM Medical Systems, Tokyo, Japan). The corrective losses of RI, PT, and UV—that occurred from immediately after surgery to 6 months after surgery (values immediately after surgery—values at 6 months after surgery)—were evaluated. Radiological measurements were performed by the same experienced surgeon (K.Y.).

### 2.5. Statistical analysis

The Student's *t* test was performed to compare the clinical and radiographic outcomes between the two groups. The level of significance was set at  $P \leq .05$ . For grip strength and range of motion, the difference in mean ratios to the healthy side was compared between the two groups. For qDASH and radiological outcomes, the difference in mean values was compared between

**Table 2**  
Demographic data of participating patients.

	Nonearly grip strength training	Early grip strength training
Number of patients	19	20
Mean age (years)	70.3 (range, 33–81)	68.8 (range, 37–86)
Sex (M/F)	2/17	1/19
AO/OTA type (A/B/C)	7/0/12	5/0/15
Cause of injury (n)		
Fall from standing	15	15
Fall from height	3	2
Bicycle or motor vehicle accident	1	3

the two groups. All statistical analysis were performed by JMP Pro 15 (SAS Institute Inc, USA).

## 3. Results

The NGTP group included 2 males and 17 female patients, with a mean age of 70.3 years; the EGTP group included 1 male and 19 female patients, with a mean age of 68.8 years. Basic demographic information, types of fractures, and causes of injuries are summarized in Table 2.

### 3.1. Clinical outcomes

At 3 months postoperatively, the mean proportions of grip strength compared with the healthy side were 73.6% and 82.5% in the NGTP and EGTP groups, respectively. At 6 months postoperatively, the mean proportions for grip strength compared with the healthy side were 79.7% and 91.6% in the NGTP and EGTP groups, respectively. At both 3 and 6 months postoperatively, the mean proportions for grip strength compared with the healthy side was significantly higher in the EGTP group than the NGTP group ( $P=.03$  and  $P=.002$ , respectively).

At 3 months postoperatively, the mean range of motion compared with the healthy side was significantly higher in the EGTP group than in the NTGP group; however, this was only

**Table 3**  
Physical findings and qDASH score.

	Nonearly grip strength training	Early grip strength training
Ratio of grip strength to healthy side (%), mean $\pm$ SD		
At 3 months after surgery	73.6 $\pm$ 11.0	82.5 $\pm$ 14.0*
At 6 months after surgery	79.7 $\pm$ 12.2	91.9 $\pm$ 9.6**
Ratio of range of motion to healthy side (%), mean $\pm$ SD		
Dorsiflexion 3 mo.	89.7 $\pm$ 10.7	90.2 $\pm$ 6.6
Palmar flexion 3 mo.	84.2 $\pm$ 13.3	93.0 $\pm$ 6.8*
Pronation 3 mo.	93.7 $\pm$ 7.0	96.9 $\pm$ 5.4
Supination 3 mo.	94.9 $\pm$ 6.8	95.7 $\pm$ 6.2
Dorsiflexion 6 mo.	98.6 $\pm$ 4.2	98.1 $\pm$ 7.2
Palmar flexion 6 mo.	95.8 $\pm$ 9.8	95.8 $\pm$ 6.6
Pronation 6 mo.	96.4 $\pm$ 7.4	98.8 $\pm$ 3.6
Supination 6 mo.	97.6 $\pm$ 7.3	97.9 $\pm$ 4.3
qDASH 6 mo. (point), mean $\pm$ SD	9.7 $\pm$ 13.8	8.7 $\pm$ 11.0

qDASH=quick disabilities of the arm, shoulder, and hand.

\*  $P < .05$ .

\*\*  $P < .01$  compared with the value of Nonearly grip strength training group.

observed for palmar flexion. At 6 months postoperatively, the significant difference in palmar flexion had already disappeared, and there was no significant difference between the two groups for all ranges of motion.

The mean qDASH score at 6 months postoperatively was 9.7 points in the NGTP group and 8.7 points in the EGTP group, with a slightly lower trend observed in the EGTP group. Nevertheless, there were no statistically significant differences between the two groups. Details regarding grip strength, range of motion, and qDASH scores are shown in Table 3.

### 3.2. Radiographic outcomes

Immediately after surgery, the RI, PT, and UV were 23.1°, 13.7°, and 1.0 mm in the NGTP group, and 22.5°, 12.4°, and 0.7 mm in the EGTP group, respectively. At 6 months postoperatively, the RI, PT, and UV were 22.4°, 13.5°, and 1.3 mm in the NGTP group, and 22.1°, 12.2°, and 1.0 mm in the EGTP group, respectively. There were no statistically significant differences between the two groups for any parameters. The mean postoperative corrective losses for RI, PT, and UV were 0.8°, 0.2°, and -0.3 mm in the NGTP group, and 0.4°, 0.2°, and -0.3 mm in the EGTP group, respectively, with no statistically significant differences between the two groups. The radiographic outcomes are shown in Table 4.

## 4. Discussion and conclusions

Surgery for distal radius fractures have been performed in several ways, including pinning, external fixation, and dorsal plate fixation.<sup>[6–8]</sup> Recently, the use of VLPs for the treatment of distal radius fractures has dramatically improved clinical outcomes.<sup>[1,9,10]</sup> By firmly supporting the joint surface with a locking screw, the VLP prevents redisplacement of the reduced bone fragments—even with early range of motion exercise—resulting in a good range of motion and improved ADL.<sup>[2]</sup> However, some studies have reported that recovery of grip strength tends to be slower than recovery of range of motion.<sup>[3–5]</sup> Lee et al reported that the grip strength at 6 months after fixation with the VLP was 67% that of the healthy side.<sup>[11]</sup> Additionally, several reports suggest that reduced grip strength after a distal radius fracture makes it difficult to use the hands during many daily activities<sup>[12,13]</sup>; therefore, recovery from this loss of grip

strength is a major issue during rehabilitation. Still, although many studies involving the use of VLPs for distal radius fractures have reported on the clinical outcomes—including grip strength—few reports have discussed effective rehabilitation procedures for postoperative grip strength recovery.<sup>[14–18]</sup> As previously mentioned, the treatment outcomes for distal radius fractures have significantly improved in recent years. To achieve better functional recovery in the future, we believe that it is important to recover grip strength, as well as range of motion, as quickly as possible.

Several problems can be considered reasons for the delay in the recovery of grip strength; the first is immobilization and disuse caused by splint immobilization from the time of injury, until the postoperative period. Second, there is a time lag before the initiation of grip strength training due to the fear of redisplacement of the fracture site, which may be caused by excessive loads applied to the fracture site. Regarding the effects of immobilization, Dekkers reported that immobilization with plastic or fiberglass casts resulted in marked functional decline and reduced grip strength.<sup>[19]</sup> Miles also reported that immobilization in a cast for 9 days lead to muscle weakness in the wrist.<sup>[20]</sup> It is also known that once muscle strength is lost, it is difficult to regain; some reports even suggest that recovery is delayed, especially in women.<sup>[21]</sup> Since distal radius fractures are a commonly occurring trauma—especially in elderly women—it is important to suppress muscle wasting as much as possible via the early initiation of grip strength training. We therefore believe that if grip strength training (with a small load that does not affect the fracture site) is performed early after surgery, with the load gradually increased according to the state of bone healing, the decline in grip strength can be minimized. Thereby, the subsequent recovery of grip strength can be achieved earlier.

In this study, we started with a gripper with a light load of 0.7 kg (1.5 lbs), initiated from 14 days after surgery; the load was gradually increased to minimize muscle weakness due to disuse. Additionally, to provide sufficient stimulation to the muscles, a training time of 20 minutes was set. The frequency of grip strength training was increased using a gripper for home self-training from 6 weeks after surgery, making the patient aware of the importance of grip strength recovery. This resulted in a significant recovery at 3 months postoperatively, compared with the recovery of patients in the NGTP group; this significant difference was maintained 6 months postoperatively. In some cases in the EGTP group, the grip strength of the affected side exceeded that of the healthy side. Nevertheless, although we believe that only a minor load was applied in the EGTP, there was a risk of excessive load to the fracture site, which would cause redisplacement; therefore, we also assessed whether the EGTP would result in corrective loss of the fracture site. Since there were no significant differences in postoperative correction loss of the fracture site between the two in groups the present study, we considered that the EGTP did not adversely affect the fracture site.

Grip strength was reported to correlate with the qDASH score<sup>[22–24]</sup>; however, in this study, there was no significant difference in the qDASH score between the EGTP group—in which grip strength recovered early—and the NGTP group. Lee et al reported that age correlated with grip strength.<sup>[11]</sup> One of the reasons for the lack of difference in qDASH scores between the two groups may be the wide age range of the patients in this study. Additionally, the difference in grip strength observed in

**Table 4**  
Radiographic measurement at 6 months after surgery.

Group	Nonearly grip strength training	Early grip strength training
Radial inclination (°), mean ± SD		
Immediately after surgery	23.1 ± 3.4	22.5 ± 3.7
At 6 months after surgery	22.4 ± 2.9	22.1 ± 3.8
Postoperative corrective loss	0.8 ± 2.4	0.4 ± 2.4
Palmar tilt (°), mean ± SD		
Immediately after surgery	13.7 ± 4.3	12.4 ± 3.3
At 6 months after surgery	13.5 ± 4.3	12.2 ± 4.3
Postoperative corrective loss	0.2 ± 2.7	0.2 ± 2.5
Ulnar variance (mm), mean ± SD		
Immediately after surgery	1.0 ± 1.4	0.7 ± 1.1
At 6 months after surgery	1.3 ± 1.1	1.0 ± 1.6
Postoperative corrective loss	-0.3 ± 0.85	-0.3 ± 1.1

this study may not be sufficient to affect upper limb function. In the future, if the rehabilitation procedure is improved to obtain further improvements in grip strength, a difference in the qDASH score may be observed.

Regarding range of motion, only palmar flexion was significantly improved in the EGTP group at 3 months. Since the finger and wrist flexor muscles are expected to be strengthened by grip strength training, early improvement in the strength of these flexor muscles may have resulted in the early improvement of palmar flexion in the wrist joint.

In this study, a special grip strength training device was used during the EGTP; to use this device, the patient must regularly visit the hospital for training. Several studies have reported that the effects of rehabilitation under OT supervision do not differ from those of patient-guided home rehabilitation regarding the postoperative treatment of distal radius fractures.<sup>[25–27]</sup> While there have been reports of home training methods related to grip strength—such as ball grasp training—the intensity of the grasp was not strictly set in these reports.<sup>[26,28,29]</sup> Additionally, it was reported that even when patients were instructed on how to train at home, proper training was no longer possible after two weeks.<sup>[30]</sup> We therefore believe that it is important for patients to receive regular training under the supervision of an OT, as well as regular self-training instruction by the OT.

This study has several limitations. First, this study had a retrospective, non-randomized design; larger-scale randomized controlled trials are therefore needed to further discuss the efficacy of EGTP and to minimize biases. Another limitation is the short follow-up period of 6 months; however, since this study design was designed to investigate whether grip strength was recovered earlier, we believed 6 months to be sufficient.

In summary, it was suggested that early and proactive grip strength training under strict planning after VLP fixation for distal radius fractures may result in earlier recovery of grip strength and palmar flexion of the wrist. Additionally, the present method of grip strength training could be performed safely without causing postoperative correction loss at the fracture site.

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