Surgical Treatment of Distal Radial Fractures with External Fixation Versus Volar Locking Plate

A Multicenter Randomized Controlled Trial

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Background: The use of volar locking plate fixation (VLP) for unstable extra-articular distal radial fractures has increased in the last decades. External fixation (EF) is less frequently used. This change of surgical approach has only to some extent been evidence-based.

Methods: In this multicenter, randomized controlled trial, we compared VLP and EF in patients between 18 and 70 years of age who had a displaced extra-articular distal radial fracture (OTA/AO type A3). The patients were examined at 6 weeks, 3 months, and 1 year postoperatively. The primary outcome measure was the Patient-Rated Wrist/Hand Evaluation score (PRWHE). Secondary outcomes were the shortened version of the Disabilities of the Arm, Shoulder and Hand (QuickDASH), pain score on a visual analog scale (VAS), and radiographic measurements. Range of motion, grip strength, finger stiffness, complications, and reoperations were also recorded.

Results: One hundred and fifty-six patients were included. One hundred and forty-two (91%)—127 women (89%) and 15 men (11%)—completed 1 year of follow-up. Sixty-nine patients were treated with VLP and 73, with EF. The mean age was 56 years. At 6 weeks, the median PRWHE score was significantly higher in the EF group (44) compared with the VLP group (27) ($p < 0.001$). At 3 months and 1 year, the difference between groups was not significant. The median QuickDASH score was 27 in the VLP group and 43 in the EF group at 6 weeks ($p < 0.001$), and a significant difference persisted at 3 months ($p = 0.023$). The VLP group had superior results in terms pain during activity, wrist extension, and ulnar and radial deviation at 1 year, whereas the number of major complications was similar in the 2 groups.

Conclusions: Patients treated with VLP had earlier recovery of function compared with patients treated with EF. One year postoperatively, we found no significant functional difference.

Level of Evidence: Therapeutic Level I. See Instructions for Authors for a complete description of levels of evidence.

Distal radial fractures are the most common fractures of the upper extremity[1,2]. Surgical treatment is recommended for unstable fractures[3] and has undergone major changes in recent years[4-6]. External fixation (EF) and percutaneous pinning used to be the treatments of choice, but the use of volar locking plate fixation (VLP) has increased dramatically since its introduction. Several studies, including some randomized controlled trials (RCTs), have suggested that VLP is associated with faster functional recovery compared with EF, but long-term results seem to be similar for the 2 methods[7-17]. However, most RCTs have been based on a small number of patients and have included both intra-articular and extra-articular fractures. The results of several meta-analyses are not conclusive regarding which treatment should be recommended[18-23]. Differences in patient cohorts, fracture types, implants, and surgical methods as well as

Disclosure: One author (T.L.) received research funds from the public health system, Helse–Vest, Norway. The **Disclosure of Potential Conflicts of Interest** forms are provided with the online version of the article (http://links.lww.com/JBJS/G260).

A **data-sharing statement** is provided with the online version of the article (http://links.lww.com/JBJS/G261).

TABLE I Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Age 18-70 yr	Dementia
Displaced unstable extra-articular distal radial fracture	Severe mental illness
Substantial initial displacement, inadequate initial reduction, or loss of reduction within 2 wk after injury as defined by ≥1 of the following: • ≥10° dorsal angulation of the joint line • Ulnar variance of ≥2 mm • Dorsal comminution of the fracture area/loss of intact dorsal cortex	Drug abuse Congenital bone disease Previous wrist fracture on either side Open fracture Pathological fracture Patients living outside the Helse-Bergen area (catchment area)

limitations in follow-up may have contributed to this lack of conclusions. The aim of this large and carefully designed RCT was to determine whether EF or VLP provides superior outcomes for treatment of displaced extra-articular distal radial fractures.

Materials and Methods

Design

This was a multicenter RCT with 2 parallel treatment arms.

Ethics

The study was conducted according to the Declaration of Helsinki. It was registered in ClinicalTrials.gov (ID: NCT01904084).

Eligibility Criteria

Consecutive patients between 18 and 70 years of age presenting to Haukeland University Hospital and Voss Hospital from 2013 to 2017 with an isolated unilateral displaced extra-articular fracture of the distal part of the radius (OA/AO type A3)[24] were eligible for inclusion into the trial. Criteria for exclusion were

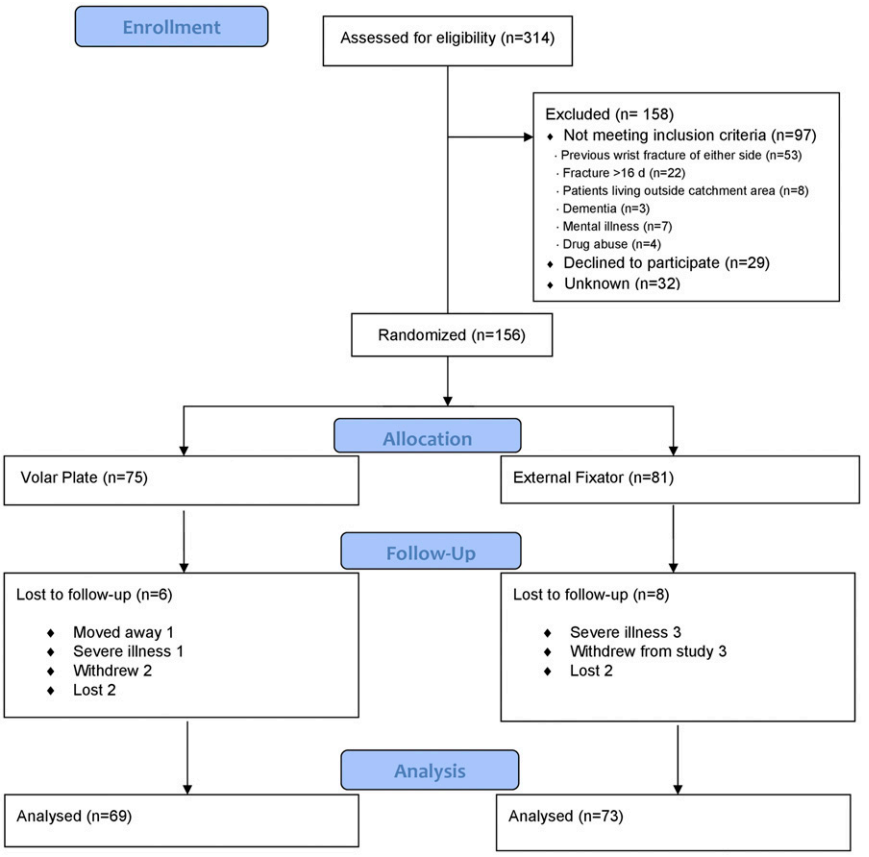

Fig. 1

CONSORT (Consolidated Standards of Reporting Trials) flow diagram for the study.

TABLE II Demographic Characteristics

	VLP	EF
No. of patients	75	81
Age* *(yr)*	56 (20-70)	57 (20-70)
Sex†		
Female	67 (43%)	73 (47%)
Male	8 (5%)	8 (5%)
Dominant side†		
Right	70 (46%)	68 (44%)
Left	4 (3%)	11 (7%)
Injured side†		
Right	33 (25%)	29 (22%)
Left	26 (19%)	46 (34%)
Dominant side injured†		
Yes	38 (24%)	30 (19%)
No	37 (24%)	51 (33%)
Pre-injury PROM‡		
PRWHE	0.85 ± 2.9	1.95 ± 6.4
QuickDASH	2.5 ± 5.6	2.7 ± 6.6

*The values are given as the mean and range. †The values are given as the number and the percentage of the total number in both groups combined with data on the variable. ‡The values are given as the mean and the standard deviation.

>16 days between the intervention and the injury, a previous fracture in the contralateral or ipsilateral wrist, an open fracture, mental illness, dementia, and severe drug abuse (Table I). Informed consent was obtained from all patients.

Randomization

The surgeon on call randomized the patients using sealed envelopes and block randomization designed by a statistician (Fig. 1). There was no significant difference in the demographics between the groups, or between patients who completed follow-up and those who did not (Tables II and III).

Interventions

All 40 surgeons involved had performed at least 5 procedures with each technique, either independently or with experienced supervision, before participating in the study. Operations were standardized regarding anesthesia, implants, surgical techniques, and fluoroscopic guidance.

In the EF group, 1 proximal dorsoradial incision and 2 incisions on the second metacarpal were used to insert the 4 apex pins of a Hoffmann Compact T2 external fixator (Stryker). Rods and blocks were mounted, and the fracture was reduced. Supplementary Kirschner wires were not used. At 6 weeks, the EF was removed at the outpatient clinic.

The VLP (DVR; DePuy) was inserted through the Henry distal volar approach. To improve exposure distally, a short oblique incision was made over the flexor crease. The pronator quadratus was lifted subperiosteally and was reattached after plate fixation; the distal radioulnar joint was then tested. A dorsal splint was applied and was removed within a few days.

Patients were advised to mobilize the wrist as tolerated, with no weight-bearing for 6 weeks.

Outcome Measures

Primary Outcomes

The Patient-Rated Wrist/Hand Evaluation (PRWHE) scores at 6 weeks, 3 months, and 1 year postoperatively were primary outcomes[25]. This patient-reported score rates wrist function in 2 equally weighted sections addressing pain and limitations in the activities of daily living. The score ranges from 0 to 100, with 100 being the worst score[25]. The minimum clinically important difference (MCID) in this score for patients with a distal radial fracture is 11.5 points[26]. We defined full recovery as a difference in the PRWHE score of <11.5 points compared with the preoperative score.

Secondary Outcomes

Secondary outcomes were the scores on the shortened version of the Disabilities of the Arm, Shoulder and Hand (QuickDASH) questionnaire, pain as measured with a visual analog scale (VAS), and radiographic measurements.

The QuickDASH is a standardized self-administered questionnaire using 11 items to measure function and disabilities in persons with musculoskeletal disorders of the upper limb; the score ranges from 0 to 100, with 100 indicating greater disability[27,28]. The PRWHE and QuickDASH questionnaires are cross-culturally validated to Norwegian[29,30].

Pain at rest and during activity was measured using a VAS ranging from 0 to 100, with 100 being the worst result[31].

Radiographs of the wrist were standardized. Posteroanterior views were obtained with the shoulder in 90° of abduction, the elbow in 90° of flexion, and the wrist in neutral. Lateral views were obtained with the shoulder in an adducted position, the elbow in

TABLE III Demographic Characteristics of Patients Who Did and Did Not Complete 1-Year Follow-up

	Completed 1-Year Follow-up	
	Yes	No
No. of patients	142	14
Mean age *(yr)*	56.2	57.7
Female sex*	128 (90%)	12 (86%)
Currently employed*	95 (67%)	9 (64%)
Pre-injury PROM†		
PRWHE	1.2 ± 4.6	5.2 ± 10.2
QuickDASH	2.5 ± 5.6	3.7 ± 10

*The values are given as the number and the percentage of the total number in the "yes" or "no" group. †The values are given as the mean and the standard deviation.

TABLE IV PROMs at Follow-up

	Median (Interquartile Range)		
	VLP	EF	P Value*
PRWHE			
6 wk (n = 148)	27 (12-38.5)	43.5 (34.5-56.6)	**<0.001**
3 mo (n = 148)	11.5 (1.6-20.9)	13.8 (4.8-29.1)	0.069
1 yr (n = 142)	1.3 (0-6.8)	2.3 (0-10.8)	0.233
QuickDASH			
6 wk (n = 148)	27.3 (15.9-38.6)	43.2 (33.0-53.4)	**<0.001**
3 mo (n = 148)	11.4 (2.3-20.5)	15.9 (4.5-29.6)	**0.023**
1 yr (n = 142)	2.3 (0-9.1)	2.3 (0-11.4)	0.357
Pain at rest			
6 wk (n = 148)	0 (0-11.3)	0 (0-20)	0.498
3 mo (n = 148)	0 (0-7.5)	0 (0-5)	0.868
1 yr (n = 142)	0 (0-0)	0 (0-0)	0.201
Pain during daily activity			
6 wk (n = 148)	22.5 (10-40)	30 (10-50)	0.449
3 mo (n = 148)	10 (0-27.5)	20 (10-30)	**0.022**
1 yr (n = 142)	0 (0-7.5)	0 (0-10)	**0.034**

*Significant values ($p < 0.05$) are in bold.

90° of flexion, and the wrist in neutral; if necessary, the beam was angled to visualize the radiocarpal joint. All values for the involved side were compared with those for the contralateral side.

We assessed volar tilt, radial inclination, radial height, ulnar variance, and the presence of an ulnar styloid fracture[32]. Initially, radiographs of 10 randomly selected patients were reviewed independently by 3 experienced radiologists and 1 orthopaedic surgeon. The results were assessed to check for comparability of the accuracy of measurements by calculating the intraclass correlation coefficient (ICC) according to guidelines given by Koo and Li[33]. The other radiographs were divided into 4 equal groups, each assessed by 1 of the same 4 interpreters.

Range of Motion, Grip Strength, Finger Stiffness, Complications, and Reoperations

Range of motion, grip strength, finger stiffness, complications, and reoperations were also recorded.

We measured range of motion with a goniometer and grip strength with a dynamometer (Jamar). Measurements on the uninjured side served as preinjury (baseline) values. The grip strength on the nondominant side was adjusted down by 10% for right-handed patients[34], whereas left-handed patients were assumed to have equal grip strength on both sides[35,36].

Finger stiffness was assessed according to the fingertips-to-palm distance when the patient attempted to make a fist (normal = fingertips touch the palm, moderate stiffness = 0 to 2 cm between the fingertips and palm, and severe stiffness = more than 2 cm between the fingertips and palm).

We classified complications leading to a reoperation, permanent nerve injury, or persistently reduced function such as chronic regional pain syndrome (CRPS) (Budapest criteria[37]) as major complications. We defined complications as minor if they were transient or not affecting the patient's final result. Patients with CRPS were treated by a dedicated team, and the treatment included advanced physical therapy and pain management.

Evaluation and Follow-up

Clinical evaluation and trial documentation were carried out at 5 visits: baseline; the time of intervention; and 6 weeks, 3 months, and 1 year postoperatively. One hundred and forty-two patients (91%) completed the 1-year follow-up; 14 were lost to follow-up (Fig. 1).

Statistical Analysis

Sample Size and Power Calculation

A block randomization was performed by a biostatistician.

Functional results based on the PRWHE score at 6 weeks, 3 months, and 1 year postoperatively were the primary outcomes.

The significance level (α) was set at 0.05. With a test strength ($1 - \beta$) of 80% and a standard deviation of 21, 70 patients were needed in each group to show a clinically relevant difference of 11.5 points[38]. Assuming a follow-up rate of 90%, we intended to include 160 patients.

The nonparametric independent-samples Mann-Whitney U test was used to identify differences in patient-reported outcomes

TABLE V Functional Outcomes at Follow-up

	Mean ± Standard Deviation (% of Value for Uninjured Side)		
	VLP	EF	P Value*
Wrist flexion *(°)*			
6 wk (n = 148)	49 ± 15 (68.6%)	39 ± 17 (54.8%)	**<0.001**
3 mo (n = 148)	62 ± 11 (87.4%)	57 ± 12 (80.6%)	**0.009**
1 yr (n = 142)	69 ± 9 (97.0%)	66 ± 9 (94.0%)	0.66
Wrist extension *(°)*			
6 wk (n = 148)	43 ± 16 (62.0%)	3 ± 24 (3.8%)	**<0.001**
3 mo (n = 148)	58 ± 15 (83.4%)	51 ± 16 (78.2%)	**0.004**
1 yr (n = 142)	64 ± 13 (93.2%)	59 ± 11 (91.0%)	**0.013**
Supination *(°)*			
6 wk (n = 148)	63 ± 23 (74.1%)	37 ± 27 (42.5%)	**<0.001**
3 mo (n = 148)	75 ± 15 (89.4%)	69 ± 18 (80.7%)	**0.034**
1 yr (n = 142)	83 ± 8 (99.4%)	79 ± 13 (92%)	0.18
Pronation *(°)*			
6 wk (n = 148)	74 ± 11 (87.7%)	61 ± 18 (14.3%)	**<0.001**
3 mo (n = 148)	81 ± 8 (96.0%)	78 ± 12 (92.5%)	0.070
1 yr (n = 142)	84 ± 6 (98.9%)	82 ± 9 (97.5%)	0.318
Ulnar deviation *(°)*			
6 wk (n = 148)	30 ± 10 (70.6%)	23 ± 9 (60.0%)	**<0.001**
3 mo (n = 148)	36 ± 9 (87.4%)	31 ± 9 (81.7%)	**0.001**
1 yr (n = 142)	40 ± 9 (97.0%)	37 ± 9 (95.5%)	**0.017**
Radial deviation *(°)*			
6 wk (n = 148)	16 ± 10 (65.5%)	−1.9 ± 11 (−11.7%)	**<0.001**
3 mo (n = 148)	21 ± 8 (90.0%)	14 ± 8 (73.7%)	**<0.001**
1 yr (n = 142)	23 ± 7 (98.7%)	20 ± 8 (103.8%)	**0.037**
Grip strength *(kg)*			
6 wk (n = 148)	10.9 ± 6.5 (41.7%)	1.01 ± 2.37 (3.8%)	**<0.001**
3 mo (n = 148)	19 ± 7.3 (72.9%)	12 ± 8.2 (46.8%)	**<0.001**
1 yr (n = 142)	24.8 ± 7.6 (95.4%)	21.8 ± 8.1 (88.4%)	0.085

*Significant values ($p < 0.05$) are in bold.

measure (PROM) data (PRWHE, QuickDASH, and VAS scores). Other continuous variables were analyzed using the Student t test. We used the chi-square test for categorical variables.

All analyses were based on the intention-to-treat principle.

SPSS version 26.0 (IBM) was used for all statistical analyses.

Results

The outcomes are presented in Tables IV, V, VI, and VII.

Primary Outcome

At 6 weeks postoperatively, there was a significant difference in PRWHE scores ($p < 0.001$) in favor of VLP. The differences were not significant at 3 months ($p = 0.069$) or 1 year ($p = 0.233$) (Fig. 2).

At 6 weeks, 23% of the patients in the VLP group and 6% in the EF group had full recovery. At 3 months, 58% in the VLP group and 47% in the EF group had full recovery. At the time of final follow-up, the percentages were 81% in the VLP group and 79% in the EF group. However, 10 patients in the EF group had a PRWHE score of ≥25 (range, 25 to 68), indicating a major disability. Only 3 patients in the VLP group had such a high score.

Secondary Outcomes

The QuickDASH scores were better in the VLP group than in the EF group at 6 weeks ($p < 0.001$) and 3 months ($p = 0.023$). We found no significant difference between groups at 1 year ($p = 0.36$).

There was no significant difference in pain at rest between the VLP and EF groups at any time point. Pain during activity was similar between groups at 6 weeks, but patients

TABLE VI Radiographic Results

	VLP	EF	P Value; ICC (95% CI)*
Volar tilt† *(°)*			
Prior to reduction	−22 ± 11.4	−20.4 ± 11	0.400; 0.95 (0.87-0.98)
Postoperative	6.3 ± 5.6	3.6 ± 5.5	**0.004**; 0.93 (0.83-0.97)
6 wk	6.1 ± 5.2	3.7 ± 5.5	**0.006**; 0.94 (0.86-0.98)
1 yr	5.5 ± 5.7 (4.8%)	4.6 ± 5.5 (5.7%)	0.342; 0.98 (0.95-0.99)
Radial inclination† *(°)*			
Prior to reduction	18 ± 6.2	18.5 ± 5.5	0.622; 0.93 (0.83-0.97)
Postoperative	22.5 ± 3.7	24.4 ± 3.6	**0.001**; 0.83 (0.62-0.93)
6 wk	23 ± 3.4	24 ± 3.3	0.062; 0.60 (0.31-0.83)
1 yr	23.2 ± 3.3 (2.9%)	24.2 ± 3.6 (1.8%)	0.102; 0.66 (0.37-0.87)
Radial height† *(mm)*			
Prior to reduction	6.7 ± 4.5	7 ± 3.8	0.701; 0.90 (0.76-0.96)
Postoperative	11 ± 2.6	11 ± 2.3	0.992; 0.88 (0.72-0.95)
6 wk	10.5 ± 2.4	10.3 ± 2.7	0.709; 0.88 (0.71-0.95)
1 yr	10.3 ± 2.6 (1.3%)	10.1 ± 2.7 (1.4%)	0.296; 0.89 (0.74-0.96)
Ulnar variance† *(mm)*			
Prior to reduction	2.5 ± 2.2	2.6 ± 2.6	0.911; 0.93 (0.84-0.98)
Postoperative	−0.2 ± 1.7	0.6 ± 1.6	**0.004**; 0.81 (0.60-0.93)
6 wk	0.7 ± 3.0	1.2 ± 1.8	0.278; 0.72 (0.45-0.88)
1 yr	0.8 ± 1.6 (−0.09%)	1.6 ± 1.9 (−0.8%)	**0.007**; 0.86 (0.68-0.95)
Ulnar styloid fracture prior to reduction‡	43 (58%)	37 (47%)	
Ulnar styloid nonunion at 1 yr‡	25 (37%)	18 (25%)	

*Significant values ($p < 0.05$) are in bold. ICC (95% CI) = intraclass correlation coefficient (95% confidence interval). With regard to the ICC, <0.50 = poor, between 0.50 and 0.75 = moderate, between 0.75 and 0.90 = good, and >0.90 = excellent. †The values are given as the mean and the standard deviation, with the percentage of the value for the uninjured side in parentheses in the "1 yr" row. ‡The values are given as the number and the percentage of the total number in the VLP or EF group.

with EF had significantly more pain at 3 months ($p = 0.022$) and 1 year ($p = 0.034$) (Table IV).

Radiographic measurements were similar between groups prior to reduction, but a higher percentage of patients in the VLP group had an ulnar styloid fracture (58% compared with 47% in the EF group). Correspondingly, we found nonunion of the ulnar styloid process in 37% of the VLP group compared with 25% of the EF group at 1 year. We found no significant difference regarding volar tilt, radial inclination, or radial height at 1 year. However, the ulnar variance was still smaller in the VLP group at 1 year (mean difference = −0.8 mm, $p = 0.007$), indicating a better length restoration (Table VI).

Range of Motion, Grip Strength, and Finger Stiffness

Patients treated with VLP had a better range of motion and grip strength at 6 weeks and 3 months than those in the EF group. At 1 year, they still had better wrist extension ($p = 0.013$), but they no longer had a statistically significant or clinically relevant difference in grip strength ($p = 0.085$). Patients treated with EF had more finger stiffness than the VLP group at 6 weeks and 3 months postoperatively; at 1 year, there was no difference between groups.

Complications and Reoperations

The number of major complications was 16 (23%) in the VLP group and 18 (25%) in the EF group, whereas 17 (25%) and 23 (32%) minor complications were recorded in the VLP and EF groups, respectively. A transient carpal tunnel syndrome was observed in 5 patients in the VLP group and 3 in the EF group. Three patients in the VLP group developed type-1 CRPS compared with 8 in the EF group. Six of these patients—1 in the VLP group and 5 in the EF group—had CRPS symptoms 1 year postoperatively (Table VII).

There were 4 reoperations in the EF group. Three were early crossovers due to insufficient fracture reduction. According to the intention-to-treat principle, these 3 patients were analyzed in the EF group. The remaining (late) reoperation was an arthroscopic repair of the triangular fibrocartilage complex (TFCC). There were 6 reoperations in the VLP group, including 5 late plate removals due to local pain (Table VII).

TABLE VII Complications at 1-Year Follow-up

	No. (%) of Patients		
	VLP (N = 69)	EF (N = 73)	P Value
Major complications*			
CRPS	3 (4%)	8 (11%)	0.14
CTS	5 (7%)	3 (4%)	0.49
Prolonged pain in wrist/hand	2 (3%)	2 (3%)	1.0
Deep infection		1 (1%)	1.0
Suboptimal osteosynthesis leading to secondary surgery	1 (1%)	3 (4%)	0.62
Plate removal	5 (7%)		0.025
Arthroscopic TFCC repair		1 (1%)	1.0
Total	16 (23%)	18 (25%)	0.83
Minor complications			
Superficial infection	1 (1%)	7 (10%)	0.063
Scar tissue problems	5 (7%)	6 (8%)	0.83
Paresthesia	4 (6%)	5 (7%)	1.0
Neuropathy	2 (3%)	2 (3%)	1.0
Other	5 (7%)	3 (4%)	0.49
Total	17 (25%)	23 (32%)	0.36

*CRPS = complex regional pain syndrome, CTS = carpal tunnel syndrome, and TFCC = triangular fibrocartilage complex.

Discussion

The PRWHE is the most sensitive outcome measure for patients with a wrist injury[25]. In our study, VLP resulted in a quicker recovery, with a better PRWHE score compared with EF at 6 weeks, but at 3 months and 1 year postoperatively we found no significant difference between groups. The difference in the percentage with full recovery in favor of the VLP group declined from 17% at 6 weeks to 11% at 3 months and

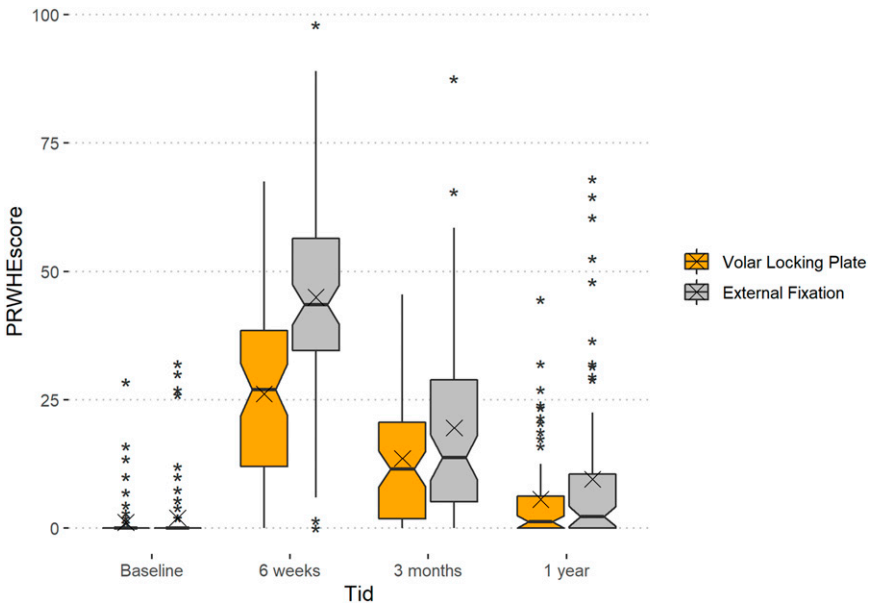

Fig. 2

The change in PRWHE score over time for patients with VLP (orange) and EF (grey). The top and bottom of each box denotes the interquartile range, the horizontal line within the box denotes the median, X denotes the mean, and * denotes outliers. An approximation of the 95% confidence interval is also included, represented by the notches around the median. Tid = Time.

finally to 2% at 1 year. This result resembles that of Wilcke et al.[15], who compared EF with VLP in 63 patients with an unstable extra-articular fracture and found that VLP was advantageous in terms of early rehabilitation but the outcomes were similar at 1 year.

The QuickDASH score was better in the VLP group than in the EF group at 6 weeks and 3 months but no longer at 1 year. Several studies support these findings[8,14,15]. Hammer et al. compared VLP with EF and additional Kirschner wires in 166 patients with an OTA/AO type-C fracture and came to the same conclusion[8]. Wilcke et al.[15] and Wei et al.[14] included fewer patients (63 and 46, respectively) than we did, but their results at 3 months were similar to ours. However, Karantana et al.[10], who compared VLP with conventional percutaneous methods in 130 patients, and Egol et al.[7], who compared VLP with EF with supplementary Kirschner wire fixation in 88 patients, found no difference between groups at 3 months. At 1 year, no difference between the groups was found in any of these studies[7,8,10,14,15].

Interestingly, few investigators have reported specifically about pain apart from questions included in PROMs. Hammer et al. included a general question about pain and found no statistical difference between treatment methods[8]. In our study, we distinguished between pain at rest and pain during activity. We found no difference in pain at rest between groups, but patients with EF reported significantly more pain during activity at 3 months and 1 year.

Our evaluation demonstrated no significant difference in radiographic parameters between the groups at 1 year, with the exception of the failure of EF to maintain ulnar variance to the same extent as VLP, a result also found in other studies[8,10,11,15-17]. The difference between ulnar variance immediately postoperatively and at the later follow-up intervals even in the VLP group was an unexpected finding as studies[18-21,39,40] have shown generally no loss of reduction with VLP. Most likely, this is a result of posteroanterior radiographs made in slight supination at the immediate postoperative visit, due to postoperative pain, resulting in a negative ulnar variance, and in neutral rotation at the later follow-up examinations[41,42].

Patients treated with VLP had better recovery of wrist flexion and extension, forearm supination, wrist ulnar and radial deviation, grip strength, and finger stiffness at 3 months in our study. At 1 year, they still had better extension as well as ulnar and radial deviation, but wrist flexion, supination, grip strength, and finger stiffness no longer differed between the groups. The immobilization of the wrist with an external fixator may explain these early functional differences.

Early mobilization is a sound principle in orthopaedic rehabilitation, and the VLP group had an obvious advantage with regard to adhering to this principle as wrist movements could start immediately postoperatively. Patients in the EF group could not start full functional rehabilitation before removal of the EF 6 weeks postoperatively. In this group, initial weakness and stiffness gradually improved after removal of the EF. In line with other studies, our EF group still had poorer outcomes 1 year postoperatively with respect to extension as well as ulnar and radial deviation[7-10,12-16]. These results confirm the hypothesis that VLP fixation results in less loss of function and a better range of motion both short and long-term. However, this was not reflected in patient-rated scores 1 year postoperatively.

The total number of complications was similar in the 2 groups. We found a tendency toward more CRPS in the EF group (8 versus 3), but this was not a significant difference ($p = 0.14$). However, the power of the study may have been insufficient to detect a significant difference in the occurrence of this infrequent complication. Interestingly, Hammer et al. found the same tendency of CRPS to be related to EF (8 versus 3)[8]. Overdistraction using EF, resulting in reduced microcirculation with fibrosis and increased stiffness, might be an explanation for this, but the pathophysiology behind this complication is not fully understood. More research on this topic is called for. If additional research confirms an association between EF and CRPS, this could be a reason to favor VLP.

There were 6 reoperations in the VLP group compared with 4 in the EF group. Three of the 4 in the EF group and 1 of the 6 in the VLP group were early reoperations due to malreduction. One late reoperation, due to a TFCC rupture, was reported in the EF group and 5 late reoperations, all for implant removal due to persistent pain, were reported in the VLP group. Previous studies have demonstrated a plate removal rate between 6% and 21%[8,16], comparable with our rate of 7%. The patients in the present study were informed, when included in the trial, that plate removal usually is unnecessary. This might explain our relatively low removal rate.

The major strengths of this study are the large sample size and low number of patients lost to follow-up as well as the uniform type of fractures and surgical methods.

We recruited the patients from 2 hospitals and a large number of surgeons were involved in the primary treatment, yielding external validity of the results.

There are some limitations to our study. It was not blinded, and patients older than 70 years were not included. Also, because we only selected patients with an extra-articular fracture, the results cannot be generalized to distal radial fracture management overall. Follow-up was limited to 1 year.

Conclusions

Treating displaced extra-articular distal radial fractures (OTA/AO type A3) with VLP resulted in faster recovery compared with EF. Even though 1-year results were more similar between the groups, there may be a tendency toward a lower rate of CRPS, less pain during activity, and a better range of motion 1 year after VLP. Accordingly, our data support VLP as the first choice of treatment when an early return of wrist function is of major importance. ■

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