

# Is there a correlation between functional results and radiographic findings in patients with distal radius fracture A0 type A3 treated with volar locking plate or external fixator?

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**Purpose:** The aim of this study was to test the hypothesis that precise restoration of distal radius fractures is correlated to better patient-reported outcome.

**Methods:** The correlation between radiographic results and functional outcome was explored in 156 patients with extra-articular distal radius fractures included in a multicenter, randomized controlled trial comparing 2 surgical interventions, Volar Locking Plate or External Fixator. The primary functional outcome was the Patient Rated Wrist and Hand Evaluation score (PRWHE). Radiographically we assessed volar tilt, radial inclination, radial height, ulnar variance, and the presence of ulnar styloid fracture. The Pearson correlation analysis was used to estimate correlations between parameters.

**Results:** At 1-year follow-up the mean difference in radiographic findings compared with the uninjured side (min, max) was: reduced volar tilt 5.3° (−15°, 25°), reduced radial inclination 2.3° (−6°, 12°), radial height 1.3 mm (−4 mm, 7 mm), and ulnar variance −0.5 mm (−6 mm, 3 mm). Overall, we found no correlation between radiographic parameters and the PRWHE at 1-year follow-up within the whole group, regardless of which treatment was chosen. At the time of injury 53% (N=80) had sustained an additional ulnar styloid fracture. After 1 year this fracture was still radiographically present in 31% (N=43) of the patients. No correlation between PRWHE score and the presence of an ulnar styloid fracture at 1-year follow-up was found.

**Conclusions:** We found no correlation between functional outcome (PRWHE) and radiographic findings after 1 year in patients operated on with a Volar Locking Plate or External Fixator. Patient-specific factors were more important than radiographic measurements in this study group.

Level of evidence: Therapeutic Level 2

Trial registration: Norway: National Committee for Medical and Health Research Ethics 213/555

ClinicalTrials.gov ID: NCT01904084

Randomization of first patient: 02.09.2013

**Keywords:** displaced extra-articular fracture, distal radius fracture, external fixation, PRWHE, radiographic measurements, volar locking plate

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## 1. Introduction

A fracture of the distal radius (DRF) is the most common fracture in adults.<sup>[1,2]</sup> Surgical fixation is recommended in severely displaced fractures.<sup>[3]</sup> Volar locking plate (VLP) and external fixation (EF) are 2 of the most commonly used methods for treating DRF.<sup>[4–8]</sup> The goal of the operation is to restore the normal anatomy and a mobile, pain-free wrist without functional limitations. The correlation between the degree of radiographic deformity and functional outcome of the fracture however is controversial.<sup>[3,9–13]</sup> We therefore conducted a study alongside a RCT to assess the relationship between radiological findings and functional outcome.<sup>[14]</sup>

## 2. Methods and design

### 2.1. Design

This was a prospective follow-up study. The patients included participated in a RCT comparing 2 surgical interventions in

patients who had sustained an extra-articular distal radius fracture. Consecutive patients aged 18 to 70 years presenting to the orthopedic department with an isolated unilateral dorsally displaced unstable extra-articular fracture of the distal radius (OTA/AO 23 A3), according to the judgement of the surgeon on call, were eligible for inclusion into the trial.<sup>[15]</sup> Patients were included in the study if they received treatment within 16 days of their injury. Patients had the meaning of the trial and the consequences explained to them, and all patients signed a consent form prior to inclusion.

Exclusion criteria were previously fractured contra- or ipsilateral hand, open fractures, mental illness, dementia, and severe drug abuse.

During the inclusion period, 314 patients with A3 fractures between the age 18 and 70 years were assessed for eligibility. Out of these, 158 patients were excluded because of the following:

- Not meeting inclusion criteria (n=97)
  - Previous wrist fracture of either side (inclusive childhood fractures) (n=53)
  - Fracture >16 days (n=22)
  - Patients living outside catchment area (n=8)
  - Dementia (n=3)
  - Mental illness (n=7)
  - Drug abuse (n=4)
- Declined to participate (n=29)
- Unknown (n=32)

Of 156 primary included patients, 142 (91%) completed 1-year follow-up, among whom 73 were allocated to external fixator and 69 to volar plate. Patient characteristics are shown in Table 1. Forty different doctors were involved as primary surgeons, while the 1-year follow-up visit was performed by the authors. We analyzed the follow-up data 1 year after inclusion of the last patient.

## 2.2. Ethics

The study was conducted according to the Declaration of Helsinki and approved by the Regional Ethics Committee of Western Norway (ref 2013/555) and the local data protection

officer. The trial was registered at ClinicalTrials.gov (NCT01904084). Written informed consent was obtained from all patients.

## 2.3. Intervention

Implants were standardized to either Hoffman Compact T2 external fixator or DVR/DePuy volar locking plate. All the surgeons involved (n=40) had experience with both procedures. They should have performed a minimum of 5 procedures of both techniques, independently or with experienced supervision, before participating in the study. All operations were performed with brachial plexus block or general anesthesia and fluoroscopic guidance. Operating techniques were standardized and all patients were admitted and treated as inpatients. The external fixator was removed after 6 weeks at the out-patient clinic. In the VLP group, a dorsal splint was applied until the patient had regained control of the arm after having the plexus block. The splint was removed before being discharged from the hospital. The patient was advised to move the wrist with a free range of motion but not to apply any weight for the first 6 weeks.

## 2.4. Outcome measures

**2.4.1. Functional outcome measures.** The PRWHE (The Patient-Rated Wrist and Hand Evaluation), is a patient-reported outcome measuring wrist function in 2 (equally weighted) sections concerning the patients experience of pain and limitations in daily life activities, to give a score out of 100 (with 100 being the worst score).<sup>[16]</sup>

The PRWHE questionnaire has been cross-cultural validated to the Norwegian population.<sup>[17]</sup> The minimum clinically important difference for this score, in patients with distal radius fractures, is 11.5 points.<sup>[18]</sup> We defined patients reporting a difference in PRWHE score less than 11.5 points, compared with their preoperative score, as fully recovered.

**2.4.2. Method of radiographic measurements.** Radiographs of the wrist were obtained according to standardized clinical procedures:

Posterior-anterior (PA) views with the shoulder in 90° abduction, elbow in 90° flexion, and wrist in neutral position. Lateral views with the shoulder in adducted position and elbow in 90° flexion, and wrist in neutral position, if necessary the beam angled to visualize the radiocarpal joint.

All values for the involved side were compared with those for the contralateral side.

Radiographic findings were assessed as follows.

The long axis of the radius was defined as the line between the midpoint of the radius at 3 and 6 cm proximal to the radiocarpal joint (Figs. 1 and 2).

The volar tilt was defined as the angle between lines drawn perpendicular to the long axis of the radius and the distal joint surface of the radius using the lateral view. A positive angle denotes volar angulation and a negative angle dorsal angulation (Fig. 2).

The ulnar variance was defined on the PA view as the distance between 2 parallel lines drawn along the distal ulnar aspects of the radius and the distal cortical rim of the ulna, perpendicular to the long axis of the radius (Fig. 1A).

Radial height was measured on the PA view as the distance between 2 parallel lines drawn along the tip of the radial styloid and the distal cortical rim of the ulna, perpendicular to the long axis of radius (Fig. 1A).

**Table 1**

### Patient characteristics

Number of patients included	156
Mean age (min–max)	56 (20–70)
Sex	
Female	140 (90%)
Dominant side	
Right	138 (88%)
Dominant side injured	
Yes	68 (43%)
Implant	
External fixator	81 (52%)
Volar locking plate	75 (48%)
PRWHE preinjury <sup>†</sup>	1.4 ± 5.0
Radiology <sup>*</sup>	
Volar tilt (°) <sup>†</sup>	-21 ± 11
Radial inclination (°) <sup>†</sup>	18 ± 5.8
Radial height (mm) <sup>†</sup>	6.8 ± 4.2
Ulnar variance (mm) <sup>†</sup>	2.6 ± 2.4
Ulna fracture (N)	80 (52.2%)

PRWHE=Patient Rated Wrist and Hand Evaluation score (0–100).

<sup>\*</sup> Radiographic measurements of injured side prior to reduction.

<sup>†</sup> The values are given as the mean with standard deviation.



Figure 1. PA views of the wrist. PA=posterior-anterior.



Figure 2. Lateral views of the wrist.

Radial inclination was defined as the angle between a line drawn from the tip of the radial styloid to the medial edge of the articular corner of the radius and a line perpendicular to the long axis of the radius (Fig. 1B). An additional ulnar styloid fracture, if present, was registered (Fig. 1A).

All radiographs from 10 different randomly selected patients were reviewed independently by 3 radiologists and 1 orthopaedic surgeon. Previous studies have given a detailed description of these measurements.<sup>[3]</sup> 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.<sup>[19]</sup> An ICC of 0 indicates no agreement and an ICC of 1 indicates perfect agreement. The ICC was interpreted as good or excellent (ICC 0.75–0.98) with the exception of radial inclination at 6 weeks and 1 year (moderate ICC 0.60–0.66). The radiographs for the remaining patients were split into 4 equally sized groups and reviewed by one of the same 4 interpreters.

Sample size was guided by a previous study on inter- and intra-observer reliability of assessment of distal radial fractures. However, no power analysis was undertaken.<sup>[20]</sup>

## 2.5. Evaluation and follow-up

PRWHE was reported at the first examination after the injury according to wrist function prior to the injury and at 1-year follow-up.

Radiographs of both the injured and uninjured wrist were obtained at the first consultation after injury and radiographs of the injured wrist were obtained at 1-year follow-up.

## 2.6. Blinding

The interpreters of the radiographs were not the treating surgeon and were blinded to functional outcome but not to the method of treatment (as it would show on the radiographs).

## 2.7. Statistical analysis

Data from all the outcome measures were summarized using means and standard deviations (given in parenthesis). A Pearson correlation was calculated for radiological parameters and patient reported outcome (PRWHE). The strength of the correlations was interpreted as: negligible ( $r=0.00-0.3$ ), weak ( $r=0.31-0.5$ ), moderate ( $r=0.51-0.70$ ), strong ( $r=0.71-0.90$ ), and almost perfect ( $r=0.91-1.00$ ).<sup>[21,22]</sup> A paired  $t$  test was used to assess differences in the radiological parameters between uninjured side and 1-year follow-up. To compare the group of patients fully recovered with those not recovered after 1 year, continuous variables were analyzed using  $t$  test and categorical variables using chi-square test.  $P$  values less than 0.05 were considered statistically significant. The statistical analyses were performed in the statistical package IBM SPSS Statistics Version 26 (IBM Corp, Armonk, NY) and the statistical package R (<http://CRAN.R-project.org>).

## 3. Results

The mean patient reported PRWHE score prior to injury was  $1.4 \pm 5$ , while PRWHE score after 1 year was  $7.6 \pm 13.5$ . Radiographic results after 1 year differed significantly from the uninjured side. At the time of injury 53% ( $N=80$ ) had sustained an additional fracture of the ulna styloid. After 1 year the fracture was still radiographically present in 31% ( $N=43$ ) of the patients (Table 2).

**Table 2**  
**Radiographic outcomes 1 year**

	Injured side	Uninjured side	P value <sup>†</sup>
Radiographic measurements			
*Volar tilt (°)	5 ± 5.6	10.5 ± 3.9	<0.000
*Radial inclination (°)	24 ± 3.5	25.8 ± 2.9	<0.000
*Radial height (mm)	10.3 ± 2.6	11.6 ± 2.1	<0.000
*Ulnar variance (mm)	1.2 ± 1.8	0.7 ± 1.6	=0.001
Ulna fracture (N)	43 (30.9%)	Nil	

\* The values are given as the mean (standard deviation).

† P values derived from paired t tests given in bold.

Overall, we found no correlation between radiographic parameters and the PRWHE at 1-year follow-up within the whole group, regardless of which treatment was chosen (volar tilt  $r = -0.005$ ,  $P = 0.95$ , radial inclination  $r = -0.083$ ,  $P = 0.34$ , radial height  $r = -0.043$ ,  $P = 0.62$ , and ulnar variance  $r = 0.068$ ,  $P = 0.43$ ). No correlation between PRWHE score and the presence of an ulnar styloid fracture at 1-year follow-up (mean difference [MD] = 2.24,  $P = 0.37$ ) was found (Figs. 3–6).

We found no significant difference in radiographic findings between the 2 surgical methods considering volar tilt (MD = 0.908,  $P = 0.34$ ), radial inclination (MD = -0.97,  $P = 0.10$ ) and radial height (MD = 0.468,  $P = 0.30$ ). However, the ulnar variance was significantly smaller in the VLP group (MD = -0.819,  $P = 0.01$ ).

At 1 year, we found that 80% had regained full recovery. However, at the same time we found that 20% had PRWHE scores higher than 11.5 points compared with their preoperatively score, indicating persisting major disability (Table 3). When comparing the 2 groups we found no difference in results influenced by age, gender, injury of dominant hand, injury energy level, or manual work. Further, type of implant, time until

surgery, type of anesthesia, operation time, and duration of postoperative stay had no influence on results at 1 year in either group. However, we found that patients with high PRWHE scores at 1 year were more likely to have had an injury indoor, being unemployed or receiving disability benefits. Radiologically, we found that the patients with high PRWHE score at 1 year had significantly larger initial displacement after injury considering radial inclination ( $P = 0.004$ ) and radial height ( $P = 0.047$ ), but this was not the findings regarding volar tilt, ulnar variance, and the presence of an ulnar styloid fracture. At 1 year, no radiological difference was found affecting the functional results. Neither a dorsal displacement  $>10^\circ$  ( $P = 0.975$ ) nor an ulnar variance  $>2$  mm ( $P = 0.838$ ) compared with the uninjured side after 1 year was found to affect the functional outcome.

#### 4. Discussion

In our study, we found no correlation between radiographic measurements and wrist function at 1-year follow-up in patients with extra-articular (A0 type A3) distal radius fractures operated with a VLP or EF. Furthermore, with the exception of significantly smaller ulnar variance in the VLP group no difference in radiographic findings was found between the 2 surgical methods. Still, there were 20% reporting persisting disability after 1 year, but no correlation to radiological outcomes were found.

The possible correlation between radiological findings and the PRWHE score has been studied previously. Synn et al,<sup>[11]</sup> in a study of 53 patients, demonstrated no associations between radiographic findings and the PRWHE score at 6 months postinjury in older patients above the age of 53. Among patients included in that study, 51% ( $n = 27$ ) received surgical treatment that included pin fixation or volar plating. Karnezis et al<sup>[23]</sup> demonstrated a moderate correlation ( $r = -0.53$ ) with PRWHE and the degree of radial height 12 months postinjury. Their study

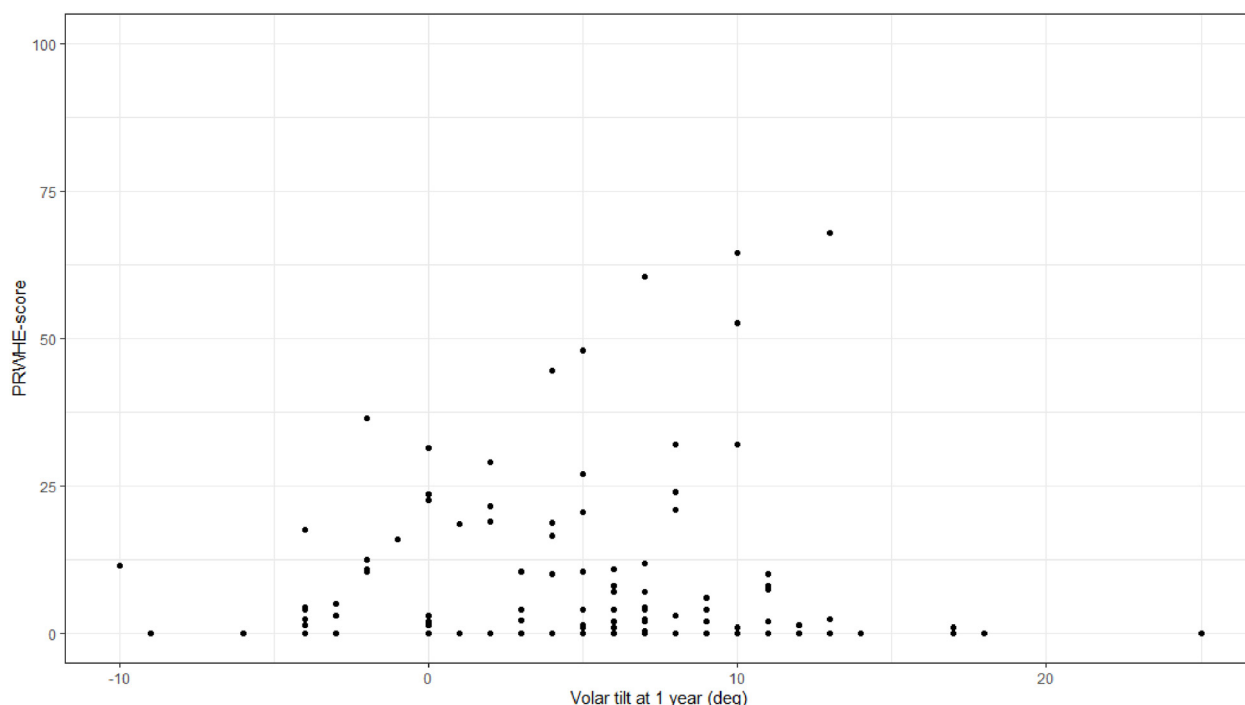


Figure 3. Result volar/dorsal tilt at 1 year.

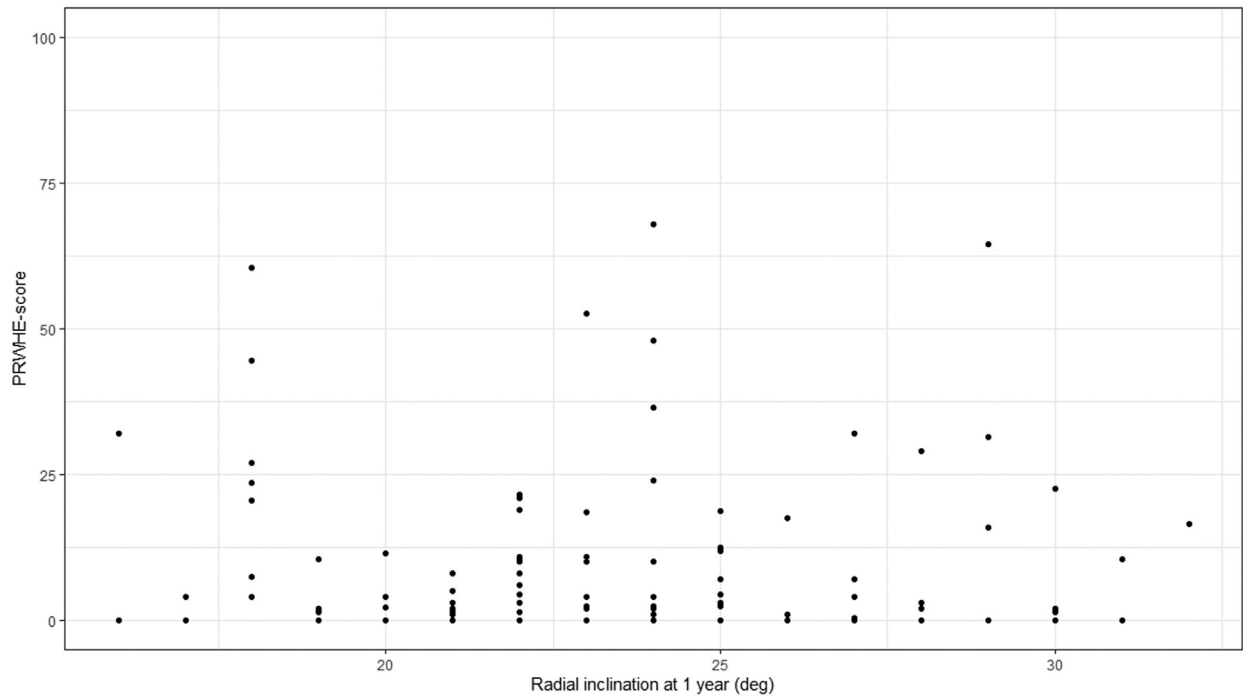


Figure 4. Result radial inclination at 1 year.

was smaller (n=30) and the mean age was lower than of our study with mean age 46 versus 56 in our study. Furthermore, all included patients received surgical treatment with closed reduction and pin fixation, and the radial shortening was found to be 2.0mm compared with our findings with radial shortening

1.6 mm. Plant et al<sup>[24]</sup> (n=45) only presented radiological results according to volar tilt and ulnar variance, and the patients, which resembled ours in terms of mean age (56), all received surgical fixation with percutaneous pinning or volar plate. A weak correlation between volar tilt (r=0.20), but no correlation

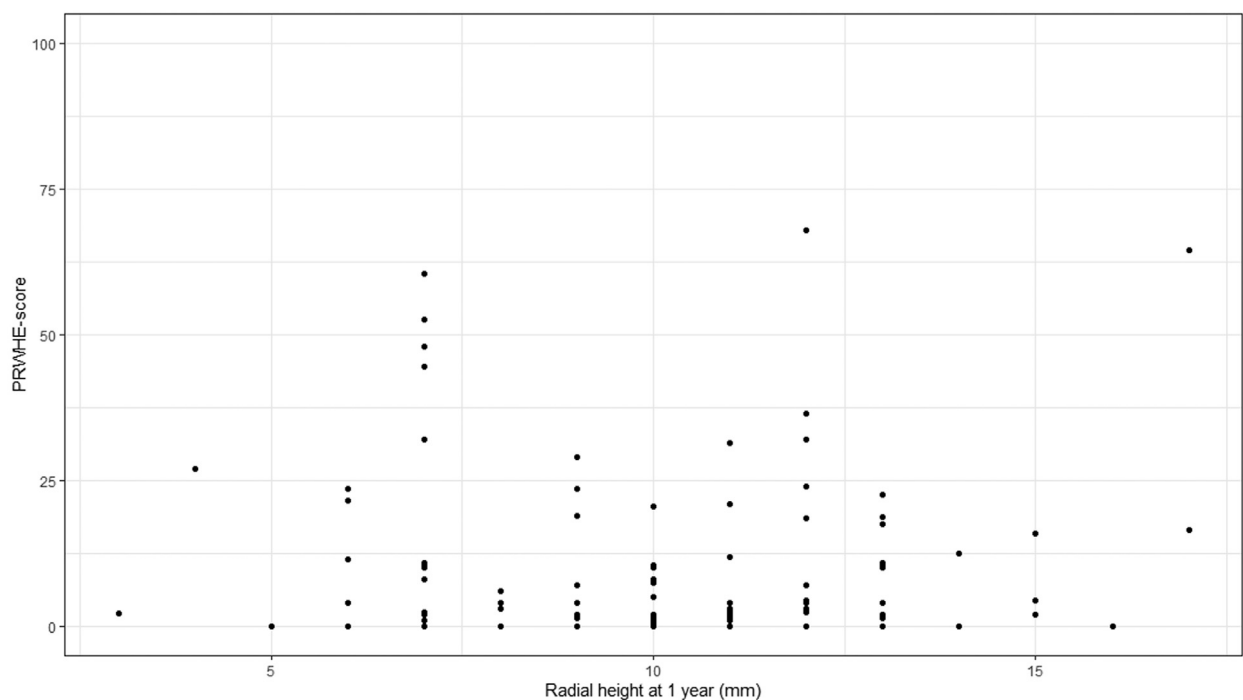


Figure 5. Result radial height at 1 year.

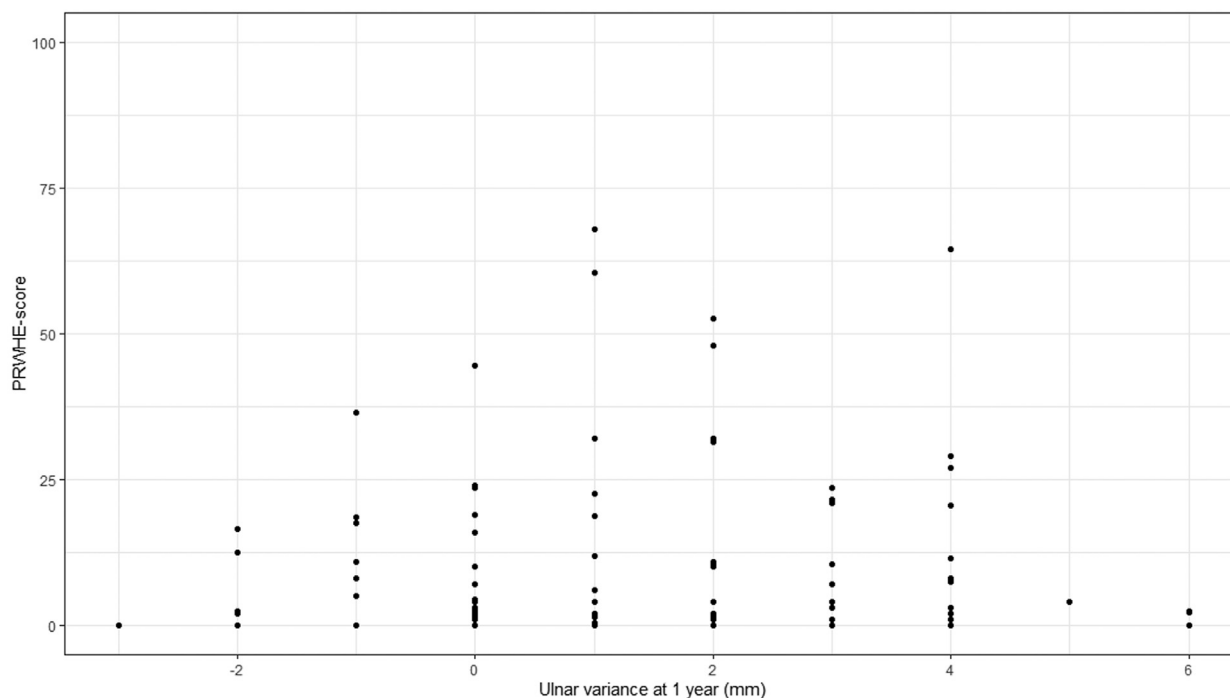


Figure 6. Ulnar variance at 1 year.

between ulnar variance ( $r=0.03$ ) and the PRWHE score at 12 months, was reported in their study. Volar tilt was found to be  $3.5^\circ$  and ulnar variance 1.4 mm, which differed somewhat to our findings of  $5^\circ$  and 1.2 mm, respectively.

At 1 year, most patients had good scores and there was no statistically significant difference at a group level. When comparing the patients with poor results to those who had gained full recovery, they were more likely to be unemployed or disabled. This may indicate that patients with poorer functional results have other health issues. Roh et al<sup>[25]</sup> found that preoperative anxiety and catastrophic pain ideation were associated with delayed recovery after DRF and Yeoh et al<sup>[26]</sup> found depression to be the strongest predictor of worse functional score after 1 year. Our patients with poor outcome were also more likely to have sustained a low-energy indoor trauma and they had more loss of radial inclination and radial height, indicating osteoporosis. Fitzpatrick et al<sup>[27]</sup> found that postmenopausal osteoporotic women had worse functional outcomes than women without osteoporosis sustaining similar injuries at 1 year. No significant difference in ROM or radiographic data between the groups were found. Roh et al<sup>[28]</sup> also identified osteoporosis to be a risk factor delaying long-term functional recovery after DRF. This indicates that factors that can predict long-term results after surgical treatment of DRF are influenced by other issues than radiologic findings alone.

Our study included more patients than previous studies, which makes it less probable that our failure to detect a correlation between radiographic findings and functional outcomes is due to an underpowered study.

Previous studies have indicated that radiographic and functional outcomes are more closely correlated in younger patients.<sup>[29,30]</sup> This was not supported by our study, where all patients were under the age of 70.

With the exception of the failure of EF to maintain ulnar variance to the same extent as VLP, we found no significant difference in radiographic parameters between the 2 surgical treatments. Similar results have been found in other studies<sup>[31–36]</sup>

Some studies have reported that more than 40% of distal radius fractures have an associated ulnar styloid fracture.<sup>[37–39]</sup> This is consistent with our study (53% ulnar styloid fracture).

The frequency of ulnar styloid nonunion has previously been found to be between 26%<sup>[40]</sup> and 63%,<sup>[37]</sup> and functional outcome scores for such patients were not worse than for patients with healed fractures.<sup>[37,41–43]</sup> In our study, there were 31% nonunions and we found no correlation to the PRWHE score after 1 year.

The major strengths of our study were a large sample size ( $n=142$ ), a uniform type of fractures and a high follow-up rate (91%). We used validated radiographic measurements, and the use of the PRWHE, the most sensitive outcome measure for patients sustaining wrist injuries, also strengthens our results.<sup>[16]</sup> The patients were recruited from the trauma unit in 2 hospitals, and a large number of surgeons were involved in the primary treatment. This renders external validity of the results although one could also argue that this also raise a concern regarding the level of experience the surgeons had with management of this type of injury.

However, the study was limited to patients having surgical fixation of their fractures. For this reason, the results cannot be extrapolated to patients treated conservatively, but should be interpreted in the context of the studied age group, type of fracture and the applied treatment methods. Further, our results do not translate into intra-articular deformity or severe degrees of extra-articular deformity, since no patients in this study had either of those 2 findings. Follow-up was limited to 1 year, thereby it is not possible to identify patients who will develop long-term symptoms and disability consequent to the injury.

**Table 3**  
**Patients fully recovered and patients not recovered after 1 year**

	Fully recovered (N=113) PRWHE $\leq$ 11.5	Not recovered (N=29) $\Delta$ PRWHE $>$ 11.5	P value
Gender			
Male	12	2	
Female	101	27	<i>P</i> =0.549 <sup>†</sup>
Age (years)	56.2 (11.6)	56.1 (7.7)	<i>P</i> =0.986 <sup>*</sup>
Dominant hand injured	47	17	<i>P</i> =0.100 <sup>†</sup>
Mechanism of injury			
Traffic	2	0	
Indoor	15	13	
Outdoor	67	13	
Work	7	2	
Sport	20	0	
Other	2	1	<b><i>P</i>=0.005<sup>†</sup></b>
Energy of trauma			
Low-energy trauma	87	26	
High-energy trauma	26	3	<i>P</i> =0.131 <sup>†</sup>
Work status			
Working, student, retired	104	20	
Disability, unemployed	9	9	<b><i>P</i>=0.001<sup>†</sup></b>
Manual labor	43	13	<i>P</i> =0.293 <sup>†</sup>
Radiology preop			
Volar tilt	-20.3 (10.6)	-24.1 (12.0)	<i>P</i> =0.109 <sup>*</sup>
Radial inclination	18.9 (5.7)	15.3 (6.4)	<b><i>P</i>=0.004<sup>*</sup></b>
Radial height	7.0 (4.3)	5.1 (4.0)	<b><i>P</i>=0.047<sup>*</sup></b>
Ulnar variance	2.6 (2.6)	2.4 (1.8)	<i>P</i> =0.698 <sup>*</sup>
Ulnar styloid fracture	57	16	<i>P</i> =0.783 <sup>†</sup>
$\Delta$ dorsal tilt $>$ 10° at 1 year	26	6	<i>P</i> =0.975 <sup>†</sup>
$\Delta$ ulna $>$ 2mm at 1 year	27	6	<i>P</i> =0.838 <sup>†</sup>
Implant			
Volar plate	56	13	
External fixator	57	16	<i>P</i> =0.649 <sup>†</sup>
Anesthesia			
General anesthesia	23	4	
Brachial plexus block	90	25	<i>P</i> =0.422 <sup>†</sup>
Time until surgery (days)	5.42 (4.1)	4.4 (3.7)	<i>P</i> =0.219 <sup>*</sup>
Duration of surgery (min)	52.5 (19.9)	57.2 (20.9)	<i>P</i> =0.267 <sup>*</sup>
Postoperative stay (days)	1.4 (0.9)	1.3 (0.8)	<i>P</i> =0.787 <sup>*</sup>

Low-energy trauma: fall from standing.

High-energy trauma: fall from greater than standing height, sporting, or traffic injury.

\* Continuous variables are analyzed using Student *t* test and the values are given as the mean and standard deviation (SD) in parentheses.

<sup>†</sup> Categorical variables were analyzed using chi-square test.

Significant values (*P*<0.05) are listed in bold.

In conclusion, for extra-articular fractures, healing within a close range to normal values, there is little effect of radiographic alignment on functional outcome.

Future studies should focus on the limits of radiographic deviations, which might influence the patients' outcome.

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