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Epidemiology, treatment and outcome

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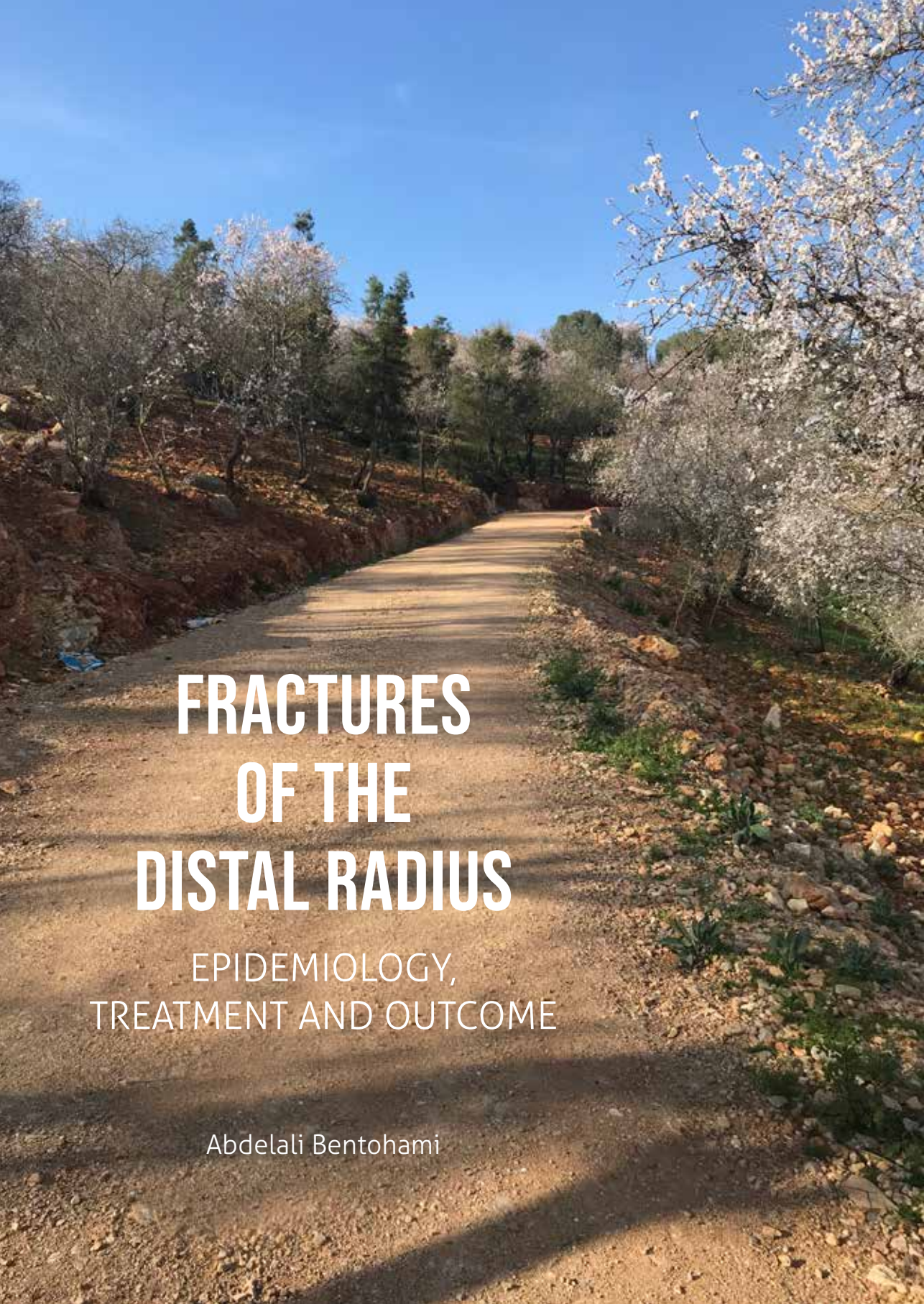

FRACTURES OF THE DISTAL RADIUS

EPIDEMIOLOGY, TREATMENT AND OUTCOME

Abdelali Bentohami

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Promotor:	Prof. dr. J.C. Goslings	AMC-UvA
Copromotor:	Dr. N.W.L. Schep	Maasstad Ziekenhuis
	Dr. T.S. Bijlsma	NoordWest Ziekenhuisgroep
Overige leden:	Dr. K.J. Ponsen	NoordWest Ziekenhuisgroep
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	Dr. C.H. van der Vlies	Maasstad Ziekenhuis
	Dr. S. van Dieren	AMC-UvA

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Dank aan mijn ouders voor het mij geven van kansen die zijzelf nooit hebben gehad

Contents

GENERAL INTRODUCTION AND OUTLINE OF THE THESIS

More than 200 years ago Abraham Colles described the treatment of a displaced distal radius fracture (DRF). Since than many studies are published about this subject. The incidence of DRFs will most likely increase further in the near future due to ageing of the population. Regardless of the high incidence of DRFs, many facets in DRF management remain questionable. This thesis focuses on demographics, treatment and outcome of distal radius fractures in the Netherlands .

PART I: Incidence and treatment variation of distal radius fractures in the Netherlands

In the literature there is a lack of recent studies assessing the incidence of DRFs in The Netherlands. Oskam et al assessed the incidence of distal radius fractures in The Netherlands in de period of 1971-1995 [1]. It is most likely that the incidence of DRFs will further increase in the near future with the increasing ageing of the population. In **chapter 1** we describe the results of a study assessing the incidence and characteristics of distal radial fractures in an urban population in the Netherlands.

Controversial aspects in distal radius fracture management may lead to practice difference among surgeons and between hospitals. The difference in practice can be justified if it is caused by patient-related factors such as alterations in patients' preference for operative treatment and the existence of specialised centres. However, variation can also be explained due to other reasons such as surgeons' preferences towards operative treatment and the degree to which surgeons involve their patients in the choice of treatment [2,3]. A prior study of Walenkamp et al. showed that although the percentage of operated DRFs was the highest in academic hospitals, the differences in percentage of surgical treated DRFs between the participating hospitals could not be explained by type of hospital, gender, age, socioeconomic status or the number of patients presenting in each hospital [4]. This discrepancy in treatment could only be explained by surgeon and patient preferences [5,6]. To determine potentially unnecessary variation, it is primarily important to report the amount in which practice difference occurs. In **chapter 2** we conducted a retrospective cohort study to compare surgical treatment of distal radius fractures between three Dutch hospitals to describe present distal radius fracture treatment in the Netherlands.

PART II: Outcome and complications of DRFs

Various criteria for radiological parameters defining "acceptable reduction" are actually used for DRFs , as there is still no unequivocal definition of "acceptable reduction" [7,8,9]. Moreover, there is no evidence of a relationship between radiological criteria and patient reported functional outcome measures (PROM) [8,9]. The variability in population and pooling of different types of distal radius fractures in literature hinders apparent comparison of studies. In **Chapter 3** we evaluate the correlation between radiological criteria for acceptable reduction and PROM in adult patients with non-operatively treated extra-articular DRFs.

Non or minimal displaced DRFs are generally considered as stable fractures and can be treated conservatively [10,11]. However, studies comparing duration of immobilization in a plaster in patients with a distal radius fracture have serious limitations. In **Chapter 4** we describe the results of a randomized controlled trial to compare the PROM of three weeks versus five weeks of plaster immobilization in adults with a non- or minimally displaced extra-articular distal radius fracture. Furthermore, we assessed the rate of operative treatment due to secondary displacement. Primarily displaced distal radius fractures are at risk of re-displacement if treated conservatively and loss of reduction following conservative treatment has been reported in up to 64% [7,12,13]. Predictors for loss of reduction are dorsal comminution and female gender ≥ 60 years [14]. Moreover, it lacks a universal definition of an unstable DRF in literature and this hinders comparison of treatment strategies.

Once the surgeon decides for operative treatment for an unstable DRF there are different treatment modalities. The last two decades an increase in operative treatment with plate fixation for displaced DRFs has been observed [5,15]. The direct costs of open reduction an plate fixation are higher than for conservative treatment [16]. Moreover, operative treatment brings the risk of complications [17,18]. In **chapter 5** we describe the results of a systematic review to asses complications following volar locking plate fixation for distal radial fractures.

A cheaper treatment modality for unstable DRF might be external fixation [13]. Therefore, in **Chapter 6** we compare PROM of volar locking plate versus external fixation in patients with unstable distal radius fractures.

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PART I

INCIDENCE AND MANAGEMENT OF DISTAL RADIUS FRACTURES IN THE NETHERLANDS

INCIDENCE AND CHARACTERISTICS OF DISTAL RADIAL FRACTURES IN THE NETHERLANDS

1

A. Bentohami, J. Bosma, G.J.M. Akkersdijk, B. van Dijkman, J.C. Goslings, N.W.L. Schep

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Abstract

The increasing incidence of distal radius fracture is thought to be due to the aging population. Surprisingly, some authors have reported a decrease in the incidence of distal radius fracture. Moreover, the type specific incidence of distal radial fracture classified according to AO classification is not well documented. The aim of this study was to assess the overall and type-specific incidences of distal radius fractures in a urban population in The Netherlands. During 2009, all persons aged ≥18 years old with an acute distal radius fracture in two hospitals in The Netherlands were prospectively registered. In 2009, the mid-year study population consisted of 245,559 inhabitants ≥18 years old. Fractures were categorized according to the AO classification. 494 patients with acute distal radius fractures were registered in the two participating hospitals during the 1-year study period. The overall incidence of distal radius fracture was 20 per 10,000 person-years. Among women, the incidence rate increased from the age of 50 and reached a peak of 124 per 10,000 person-years in women 80 years and older. Among men, the incidence rate was low until the age of 80 years and older, and reached a peak of 24 per 10,000 person-years. The incidence rate among women between 50 and 79 years was 54/10,000 person-years. Extra-articular AO type A fractures were most common among all age groups, comprising 50 % of all fractures (40 % in men and 53 % in women). The overall incidence rate of distal radius fracture was 20 per 10,000 person-years. This incidence increases with age for both women and men. A lower incidence rate among women 50–79 years of age was found than previously reported, which may indicate a declining incidence in this age group. Extra-articular AO type A fractures were the most common fracture types.

Introduction

Distal radius fractures are among the most common of all fractures, with an estimated overall incidence of 125 per 10,000 person-years in the United States [1–4]. Brogren et al. [5] showed that there was an overall incidence of 26 such fractures per 10,000 person-years in a southern region in Sweden. In that study, the incidences for both sexes were highest in the ≥80 years age group: 119 per 10,000 person-years in women and 28 per 10,000 personyears in men. Remarkably, the same authors reported that the incidence rate of distal radius fracture in women 50–79 years old was lower than previously reported, which may indicate a decrease in distal radial fractures in this group. This decrease in the incidence of distal radial fractures was also seen for the Dutch population, as the incidence decreased from 47 in 1971 to 38 per 10,000 person-years in 1995 [6].

Conversely, the incidence of distal radius fracture is estimated to double over the next 25 years according to demographics provided by the Australian Bureau of Statistics and the projected fracture rates in the United States [7]. A 17 % increase in distal radius fractures was shown in Rochester, Minnesota, USA, in the period 1945- 1954 and 1985-1994 [8]. According to Bengner et al. [9], this increase in age-specific incidence is realistic and not only the result

of an increase in diagnosed distal radius fractures. The epidemiology of distal radius fractures seems to have changed over the last years [5,6,7], it would be interesting to investigate whether there is an increase in the incidence of distal radius fractures. In addition to this, it is essential to know the distribution of different fracture types because this may influence treatment, patient functional outcome, resources, and costs. Therefore the aim of this study was to assess the overall and type-specific incidences of distal radius fracture in a representative urban population in The Netherlands.

Methods

The study was conducted in a representative urban population from two different cities in The Netherlands, each with their own local hospital. Both hospitals were teaching hospitals with 455 (Hoofddorp) and 386 beds (Almere). The two cities Almere and Hoofddorp have an estimated total population of 245,559 inhabitants (Central Bureau of Statistics of The Netherlands, 2009). The inclusion criteria for this study were: acute fracture of the distal radius and age ≥18 years old. To rule out seasonal variation, all consecutive patients visiting the emergency departments between January 2009 and January 2010 were included in the study. Sixteen patients were excluded as they were living outside the region at the time of fracture. Demographic data included gender, age, injured side, trauma mechanism, and AO fracture classification. Standard posteroanterior and lateral radiographs were obtained to diagnose the presence of a distal radius fracture. In all cases, a radiologist confirmed the distal radius fracture. Fracture classification according to the AO was performed by an experienced senior surgical resident. The AO fracture classification defines extra-articular fractures as ''A type,'' partial articular fractures as ''B type,'' and completely intra-articular fractures as ''C type.''

Statistical analysis

All analyses were performed using PASW statistics, version 18.0 (SPSS, Chicago, IL, USA). User-defined missing values were treated as missing. We calculated the incidence rates as the total of fractures divided by the midyear population. The incidence rate was expressed as the incidence per 10,000 person-years. We calculated Mid-year population as the mean value of the population on 31/12/2008 and the population on 31/12/2009. Age- and gender-specific incidence rates were calculated in general and for type of fracture. We divided patients into three age groups: 18–49, 50–79, and ≥80 years old. The numerator was defined by the number of patients, while the denominator was determined by the number of inhabitants in the catchment area (incidence = number of patients/population 9 10,000). We calculated the mean ± SD (parametric data) or medians and percentiles (nonparametric data) For continuous data and for categorical data, frequencies and percentages were calculated.

Results

Results Among the total population, 494 patients with a distal radius fracture were identified (Table 1); 315 were treated in Hoofddorp and 179 in Almere. All patients were registered via the emergency department. The median age was 63 (IQR 51–72) years. Median age in women was 64 (IQR 54–75) and the median age in men was 55 (IQR 41–67). The female to male ratio was 3:1. For patient demographics, see Table 1. In 2009, the mid-year total study population consisted of 245,559 inhabitants ≥18 years old. The overall incidence rate of distal radius fracture in 2009 was 20 per 10,000 person-years (95 % CI 18.4–21.9). The incidence was highest in the age group of 80 years and older (Table 2). Among the 494 persons with a distal radius fracture, 373 were women, yielding an incidence of 30 per 10,000 person-years (95 % CI 26.9–33). There were 121 fractures in men, yielding an incidence of 10 per 10,000 person-years (95 % CI 8.3–12.1) (Table 3). The incidence of distal radial fractures increased with age in both men and women (Table 3). Among women, the incidence increased steeply from the age of 50 years and upward and peaked at the age of 80 years to 124 per 10,000 person-years (95 % CI 95.8–160.9). Among men, the incidence rate was low until the age of 80 years and older and reached a peak of 24 per 10,000 person-years (95 % CI 9.6–49.3) (Table 3; Fig. 1). The most common trauma mechanism was a fall on the outstretched hand (84 %), a fall during ice-skating (8.7 %), or a fall from height (1.8 %). AO type A fractures were most common among all age groups, comprising 50 % of all fractures, 40 % in men and 53 % in women (Table 4). The incidence of B-type fracture was the lowest among all fracture types (24 %). The incidence of partial or complete intra-articular fracture (AO type B/C) was highest in the age group of 50–79 years in both women and men (Table 5). Extra-articular AO type A fractures were the most common fracture types, with an incidence of 4 per 10,000 person-years in men and 16 per 10,000 person-years in women (Table 5).

Discussion

This study found an overall incidence rate for distal radius fracture of 20 per 10,000 person-years. The incidence at the age of 80 years or older was 124 per 10,000 person-years in women and 24 per 10,000 person-years in men. These results differ from those obtained in earlier studies performed in Norway [10,11] and the United Kingdom [12]. In these studies the incidence rate among women increased after menopause and then reached a plateau from the age of ≥60 years. The plateau or decrease could be due to age related decreases in speed and strength of arm extension and therefore protection of the distal radius [13]. In accordance with Brogren's [5] study (Sweden) and Oskam et al. [6] (The Netherlands), our study showed a lower incidence rate among women of 50–79 years than previously reported in a series of studies [10,11,14,15] which may suggest a decreasing incidence in this age group. In our study, the incidence rate among women 50–79 years old was 54/10,000 person-years, while in previous studies the incidence in this population varied between 78 and 120/10,000 person-years [10,11,14,15] (Fig.

2). A possible explanation for the decline in the incidence rate among women 50–79 years old could be the use of bisphosphonates. Other studies found a decline of 30 % in the incidence of hip fracture in the elderly coincident with the use of bisphosphonates [16–21]. Improved muscle strength, balance, and coordination among the current generation of elderly people as compared to previous generations may also have reduced the risk of falling [21,22]. Moreover, improved prevention and treatment of chronic diseases may have influenced the decline in distal radial fracture incidence, since for example cardiovascular diseases have been associated with hip fractures, and the incidence of these diseases has declined considerably in recent decades [23]. It is predicted that the incidence of distal radius fractures will double over the next 25 years according to demographics provided by the Australian Bureau of Statistics and the projected rates of fracture in the United States [7]. However, according to Oskam et al. tendencies may be better examined longitudinally to study epidemiological changes, because it is not always reliable to do an extrapolation of observations based on historical data [6]. Oskam et al. showed that the incidence rate of distal forearm fracture increased in the period 1971–1980 but then decreased between 1981 and 1995. Bengner et al. [9] compared the incidence rate of distal radial fracture during the period 1953–1957 with that during 1981 and 1982 and found that it almost doubled between these time periods. It was predicted that it would continue to increase in the years thereafter. In contrast, a decrease in incidence rate was found in other studies [6]. Just like in previous studies, we found that patients older than 79 years had the highest risk for a distal radius fracture [6,9]. The clinical perspective of this change may be important, because biological factors like osteoporosis and comorbidity may interfere with fracture healing and with functional outcome in elderly patients [5]. Since little is known about geriatric wrist fractures, the observed changes in epidemiological trends stress the need for research into these clinically important risk groups [5]. ORCHID is the first multicenter randomized controlled trial designed to assess the difference in quality of life and functional outcome following operative treatment and conservative treatment of complex, intra-articular fractures of the distal radius in elderly patients [24]. Because of the progressively more cost-conscious management of health care, the economic and social load of distal radius fractures should be of significance [5].

This study has several limitations. The data were drawn from a relatively small community and therefore included a reduced number of patients with a distal radius fracture. However, the population was well specified and, contemplating the comprehensiveness of the patient documentation procedure, the possibility that we failed to include a considerable number of patients was found to be insignificant. We reviewed both the emergency department and the outpatient clinic data record. Therefore we were able to doublecheck and include eligible patients who had initially been missed in the emergency department. Another limitation is that the radiographic assessment was performed by a single senior surgery resident. This may have affected the reliability of the classification regarding AO fracture type and displacement. However, the AO classification is known to have good interobserver and intra-observer reliability when limited to the three main AO types, and a potential slight extent of misclassification of displacement should not have a significant influence on the outcomes [25].

Conclusion

The overall incidence rate of distal radius fracture is 20 per 10,000 person-years, and among them, extra-articular AO type A fractures are the most common. This incidence increases with age for both women and men. The lower incidence rate among women 50–79 years old may indicate a declining incidence in this age group.

Table 1. Characteristics of the 494 patients in the study

Characteristic		%
Median age (IQR)	63 (51-72)	
Male	121	24.6
Female	373	75.4
Injured side		
Left	249	50.4
Right	245	49.6
Hospital		
Hoofddorp	315	63.8
Almere	179	36.2

Table 2. Number of persons with distal radius fractures, the population at risk, and the incidence in the Netherlands, in 2009

Age group (years)	Population	No. of persons with fractures	Incidence /10.000 person years	95%CI
18-49	146115	113	8	6.1 – 9.2
50-79	91611	313	34	31.2 – 38.3
80+	7797	68	87	69.4 – 111.3
Total	245523	494	20	18.4 – 21.9

Table 3. Number of persons with distal radius fractures, the population at risk, and the incidence in the Netherlands, in 2009

Sex	Age group (years)	Population	No. of persons with fractures	Incidence /10.000 person years	95%CI
Male	18-49	71.495	49	7	5.1 - 9.1
	50-79	45.999	65	14.	10.9 - 18.0
	80+	2.928	7	24	9.6 - 49.3
	Total	120.422	121	10	8.3-12.1
Female	18-49	74.620	64	9	6.6 - 10.9
	50-79	45.612	248	54	47.8 - 61.6
	80+	4.869	61	124	95.8 - 160.9
	Total	125.101	373	30	26.9-33.0
Total		245.523	494	20	18.4 - 21.9

Table 4. AO-classification 23.A2-C3 of 494 distal radius fractures, cross tabulated for different hospitals

AO-classification	No. (%)	Men (%)	Women (%)
A: Extra-articular fractures	247 (50)	49 (40)	198 (53)
B: Partially-articular fractures	121 (24)	44 (36)	67 (18)
C: Complete-articular fractures	126 (25)	28 (23)	98 (26)
Total	494 (100)	121 (24)	373 (75)

Table 5 Incidence of distal radius fractures per 10,000 persons in a western region of the Netherlands, during 2009, grouped according to AO type and age group

		19-49y		**50-79y**		**80+y**		**Total**	
Sex	AO-type	n	Incidence (95% CI)	n	Incidence (95% CI)	n	Incidence (95% CI)	N	Incidence (95% CI)
Male	Type A	23	1.9 (1.2-2.9)	22	1.8 (1.1 - 2.8)	4	0.3 (0.1 - 0.9)	49	4 (3-5)
	Type B	19	1.6 (0.9 - 2.5)	23	1.9 (1.2 - 2.9)	2	0.2(0.0-0.6)	44	4 (3-5)
	Type C	7	0.6 (0.2-1.2)	20	1.7 (1.0 - 2.6)	1	0.1 (0.0 - 0.5)	28	2 (2-3)
Female	Type A	28	2.2 (1.5 - 3.2)	132	10.6 (8.8- 13)	38	3.0 (2.2 - 4.2)	198	16 (14-18)
	Type B	18	1.4 (0.9 - 2.3)	45	3.6 (2.6 - 4.8)	14	1.1 (0.6 - 1.9)	77	6 (5-8)
	Type C	18	1.4 (0.9 - 2.2)	71	5.7 (4.4 - 7.2)	9	0.7 (0.3 - 1.4)	98	8 (6-10)

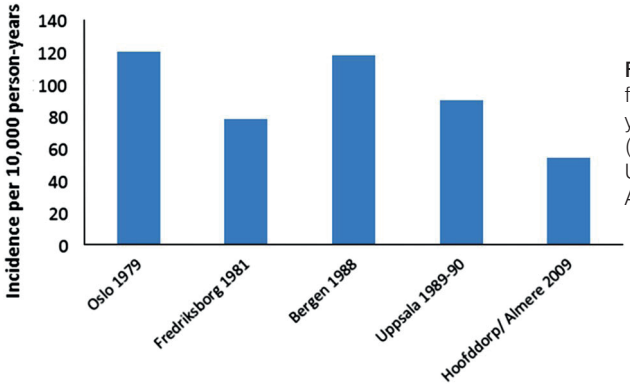

Fig. 2 Incidence rates for distal radial fracture among women 50–79 years old in Oslo (Norway), Bergen (Norway), Fredriksborg (Denmark), Uppsala (Sweden), and Hoofddorp/ Almere (The Netherlands)

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DEMOGRAPHICS, FRACTURE PATTERNS AND TREATMENT STRATEGIES FOLLOWING WRIST TRAUMA

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Marjolein A.M. Mulders, Abdelali Bentohami, M. Suzan H. Beerekamp, Jasper Vallinga, J. Carel Goslings, Niels W.L. Schep

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Abstract

The objective of this study was to determine the percentage of radiographs which showed a fracture of the wrist. Secondary, the fracture characteristics and the received treatment were determined. Additionally, the percentage of operatively treated patients with a distal radius fracture was compared between the hospitals. A retrospective cohort study was performed in three Dutch hospitals in all consecutive adult patients with wrist trauma who presented at the ED. A fracture of the wrist was defined as a fracture of the distal one-third part of the radius, the distal one-third part of the ulna or any carpal bone. Fracture classification according to the AO/OTA classification, the amount of displaced fractures, and the received treatment were recorded. Out of 1740 patients with wrist trauma, 49% sustained one or more fractures of the wrist. The distal radius was most frequently fractured (61%). Almost half of the distal radius fractures was extra-articular (AO/OTA type A2-3) and 61% of fractures was displaced. Of all patients who sustained a distal radius fracture, 14% was treated operatively. Significantly more patients were treated operatively in the academic hospital in comparison to the teaching and non-teaching hospital.

Introduction

A traumatic injury of the wrist is one of the most common reasons for patients to visit the emergency department (ED). Although, the incidence of wrist injury is unknown, it is recognized that distal radius fractures are the most common fractures with an overall incidence rate, ranging between of 20 to 37 per 10,000 person years in Europe to 125 per 10,000 person years in the United States [2, 4, 5, 8]. Moreover, the age-specific incidence has increased over the past 50 years [3, 9].

Up till now, it is unknown how many patients who present at the ED with a trauma of the wrist, actually sustained a fracture of the wrist. Moreover, the incidence of distal radius fractures is increasing, consequently it is also important to know the fracture characteristics and patterns since this influences the choice of treatment. Both the a-priori chance of a fracture and the treatment may influence functional outcomes, resource allocation, and healthcare costs.

Therefore, the primary aim of this study was to determine which percentage of radiographs, requested due to suspicion of a wrist fracture, indeed showed a fracture of the wrist. Secondary, the fracture characteristics and patterns and the received treatment were determined. Additionally, the percentage of operatively treated patients with a distal radius fracture was compared between the hospitals.

Materials and methods

A retrospective cohort study was conducted in three Dutch hospitals: one academic hospital, one teaching hospital and one non-teaching hospital. All consecutive patients who underwent a radiograph of the wrist following wrist trauma were included. To rule out the seasonal variation on the incidence of fractures among patients with acute trauma of the wrist, all consecutive patients visiting the ED during one year were included.

Patients younger than 18 years of age, patients who sustained a trauma of the wrist more than three days (>72 hours) before presentation at the ED and patients who were referred with radiographs from another hospital or had returned for reassessment of the same injury were excluded. The medical charts of all the included patients were evaluated.

Wrist trauma was defined as a high or low energetic trauma involving the wrist, for example a fall on the outstretched hand, or a motor vehicle accident. A fracture of the wrist was defined as a fracture of the distal one-third part of the radius, the distal one-third part of the ulna and all carpal bones. It was assessed whether the radiologist reported a fracture of the distal radius and/or carpus. Demographic data included gender, age, injured side and trauma mechanism. Fracture characteristics included fracture classification according to the AO/OTA classification, presence of a concomitant fracture of the ulnar styloid process and the amount of displaced fractures that underwent open or closed reduction. Additionally, the received treatment (operative or conservative) was noted.

Statistical analysis

User-defined missing values were treated as missing. Normality of continuous data was tested by inspecting the normality plots. Normally distributed data were presented as mean and standard deviation (SD) and non-normally distributed data were presented as median and interquartile range (IQR). Categorical data was presented as numbers with corresponding percentages. Univariate analysis was performed to test the difference in the primary and secondary outcome measures between patients with a distal radius fracture and patients without. Continuous data were tested using a Mann Whitney U-test (non-parametric data). Chi-square analysis was used for statistical testing of categorical data. Multivariable logistic regression was used to determine if the difference in operative treatment of distal radius fractures between the three hospitals was significant, controlled for the confounders age and AO/OTA classification. In all tests, a p-value of less than 0.05 was considered to indicate statistical significance. All analyses were performed using SPSS version 23 (Chicago, Illinois, USA).

Results

A total of 1740 patients were included. The median age was 51 years (IQR 34 to 65 years) with a range of 18 to 97 years. Acute wrist trauma occurred more often in women than in men. Most patients sustained a fall on the outstretched hand (Table 1).
Of all patients, 847 (49%) patients had one or more fractures of the wrist. The median age of patients who had a wrist fracture significantly differed from patients who did not have a fracture; it was higher in patients who sustained a fracture of the wrist (58 years versus 43 years). Additionally, female patients had significantly more fractures of the wrist compared to male patients. There was no significant difference in the incidence of fractures between the three hospitals (Table 2).
There was a major increase of patients presenting with a trauma of the wrist during December and January and a slight increase from June till September. The ratio between wrist fractures and wrist trauma remained stable over the year (Figure 1).

In total, 1152 fractures were found in 847 patients. The distal radius was most frequently fractured after wrist trauma, in 707 patients (61.4%). From all distal radius fractures, 47% of those fractures was an extra-articular fracture (AO/OTA type A2-3). Fourteen patients sustained an isolated fracture of the distal ulna or ulnar styloid process (AO/OTA type A1). In 227 patients (32%) a distal radius fracture was accompanied by a fracture of the ulnar styloid process. An antebrachial fracture was found in 45 patients (Table 3). Moreover, 61% of patients had a displaced fractures which required open or closed reduction.

A total of 152 patients (18%) sustained a fracture of the carpal bones. The triquetrum and scaphoid were the most frequent fractured carpal bones. In 26 patients (17%) a carpal bone fracture was combined with a fracture of the distal radius or other carpal bones. Nine patients sustained multiple fractures of the carpal bones (Table 3).
Most distal radius fractures were seen in the teaching hospital, followed by the academic hospital and the non-teaching hospital. The distribution of the fracture classifications was significantly different among the three hospitals ($p=0.006$) (Figure 2).

Of all patients who sustained a distal radius fracture, a total of 102 patients (14.4%) were treated operatively. Significantly more patients were treated operatively in the academic hospital in comparison to the teaching hospital and non-teaching hospital (academic hospital: 25.6%; teaching hospital: 7.3%; non-teaching hospital: 13.4%; $p<0.001$). This difference was statistically significant in multivariable logistic regression, corrected for the confounders age and AO/OTA classification. Additionally, younger patients and AO/OTA type C fractures were significantly more often treated operatively (type A: 5.4%; type B: 7.5%; type C: 35.7%; $p<0.001$) (Table 4, Figure 2).

Discussion

This study demonstrates that half of the wrist radiographs in patients with a trauma of the wrist trauma does not show a fracture. Of all fractures in the wrist, the majority are fractures of the distal radius (61%), more specifically AO/OTA type A2-3 fractures. Moreover, patients who were treated in the academic hospital and who sustained an AO/OTA type C were more likely to be treated operatively.

The a priori change of having a fracture of the wrist (49%) is much higher compared with the a priori change of having a significant malleolar fracture following ankle trauma, another frequent extremity trauma, which is 9.3% in the study of Stiell et al. [11]. Taking these figures into account one may argue that with an a priori change of almost 50% of having a wrist fracture a standard radiograph of the wrist following trauma is mandatory. However nowadays, governments aim to limit their healthcare expenses, and therefore every effort should be undertaken to make healthcare more efficient and to reduce costs. With a growing population of elderly, an increase in wrist trauma patients over the last 50 year has been seen [3, 9]. Therefore, even a small reduction in negative radiographs may be cost-effective.

The results of this study are consistent with previous studies showing a marked excess of fractures in females in the occurrence of acute wrist fractures. This may be explained by the fact that women live longer compared to men and that osteoporosis is more frequent in women [5]. As expected a fall on outstretched hand was the most common trauma mechanism in acute wrist injuries [1]. Moreover, the distribution of the fracture characteristics was consistent with the literature [4, 6].

Furthermore, this study shows a noticeable difference between the three hospitals in the percentage of patients treated operatively for a distal radius fractures. This difference is statistically significant, even after correction for fracture severity and age, indicating that there is no broad consensus on operation indication. This phenomenon was also seen in a study of Walenkamp et al., who determined the variation in surgical treatment of distal radius fractures in the Netherlands [12]. This study showed that although the operative rate was the highest in the academic hospital, the differences in operative rates between the hospitals could not be explained by hospital type, percentage of females, age of the patient, the socioeconomic status or the number of patients presenting in each hospital. However, the variation in treatment strategies could be explained by surgeon and patient preferences [7, 8, 10]. Although an operatively treated distal radius fracture is more expensive than a non-operatively treated distal radius fracture, there does not seem to be a financial motivation since patients who were treated in the academic hospital were more likely to be treated operatively.

In addition, Walenkamp et al. stated that the variation could possibly be explained by the difference in fracture patterns between the hospitals, suggesting that academic hospitals have a larger number of severely injured patients resulting in more comminuted fractures. However, in our study we corrected for fracture severity and still found a higher operative rate in the academic hospital compared to the teaching and non-teaching hospital.

An important limitation of this study is the lack of follow-up. First, for patients who did

not undergo radiographic examination. Therefore the exact percentage of wrist fractures of the total population of patients following wrist trauma presenting at the ED is not known. In other words the a priori change of a wrist fracture in this patient category is not exact. However, in all hospitals included in this study there was a very low threshold to perform a radiograph in a patient with wrist trauma. Therefore, we assume that the a priori change of a wrist fracture is approximately 49%. Second, for patients who did not receive treatment or initially conservative treatment, there may be a possibility that some of these patients eventually received operative treatment due to a redisplacement of the fracture, malunion or non-union.

Conclusion

Of all patients, 49% who present at the ED with a trauma of the wrist actually sustained a fracture of the wrist. The distal radius is most often fractured. Significantly more patients with a distal radius fracture are treated operatively in an academic hospital in comparison to a teaching and non-teaching hospital. This indicates a lack of consensus on the treatment of distal radius fractures and we should aim to minimise the variation in treatment strategies.

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Table 1. Characteristics of the 1740 included patients

	N (%)
Age (years); median (IQR), range	51 (34-65), 18-97
Female patients	1107 (63.6)
Injured side (right)	885 (50.9)
Hospital	
Academic hospital	497 (28.6)
Teaching hospital	801 (46)
Non-teaching hospital	442 (25.4)
Trauma mechanism	
Fall on outstretched hand (FOOSH)	1246 (71.6)
Fall (during ice skating)	110 (6.3)
Fall from height	29 (1.7)
High energetic trauma	29 (1.7)
Pain and swelling without trauma	29 (1.7)
Punch	28 (1.5)
Ball versus hand	8 (0.5)
Miscellaneous	217 (12.5)
Missing	44 (2.5)

Table 2. Patient's age, sex and hospital type, specified for wrist fracture: yes or no

Wrist fracture	Yes (N=847)	No (N=893)	P-value
Age (years); median (IQR), range	58 (44 – 69), 18 – 97	43 (28 – 59), 18-96	< 0.001*
Number of female patients (%)	578 (68)	531 (59)	< 0.001*
Hospital			
Academic hospital	257 (30)	240 (27)	
Teaching hospital	380 (45)	421 (47)	0.28
Non-teaching hospital	210 (25)	232 (26)	

* Significant

Table 3. Fracture characteristics of 1152 fractures in 847 patients

	N (%)
Distal radius fractures, AO/OTA-classification	
A2-3: extra-articular	332 (28.8)
B1-3: partially articular	176 (15.3)
C1-3: complete articular	199 (17.3)
Distal ulna fractures	
A1: Isolated distal ulna fracture	14 (1.2)
Antebrachial fracture	45 (3.9)
Associated fracture of the ulnar styloid process	227 (19.7)
Carpal bone fractures	
Scaphoid (navicular bone)	73 (6.3)
Triquetrum	72 (6.3)
Other carpal bones	14 (1.2)
Total count of fractures	**1152**

Table 4. Difference in operative treatment between hospitals,corrected for confounders age and AO/OTA classification

	OR	95% CI		P-Value
		Lower	Upper	
Academic hospital vs. teaching hospital	0.288	0.163	0.509	<0.001*
Academic hospital vs. non-teaching hospital	0.423	0.237	0.756	0.004*
Teaching hospital vs. non-teaching hospital	0.680	0.357	1.297	0.242
AO-class A vs. B	1.158	0.545	2.461	0.703
AO-class A vs. C	8.826	4.981	15.639	<0.001*
AO-class B vs. C	0.131	0.068	0.253	<0.001*
Age	0.980	0.966	0.995	0.010*

Nagelkerke R square = 0.286
* Significant

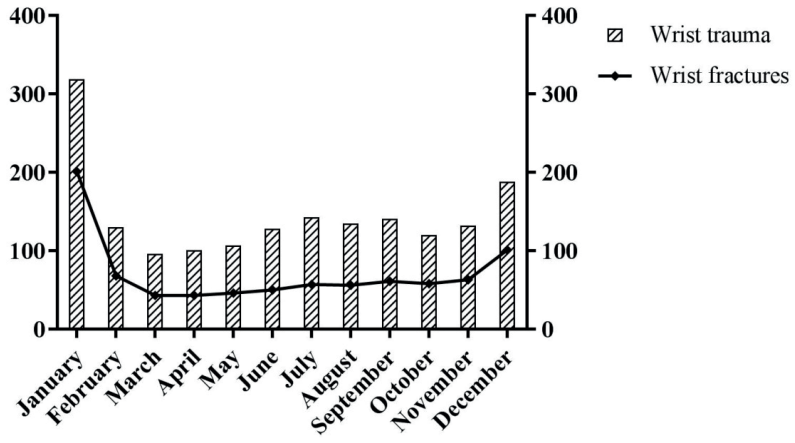

Figure 1. Incidence of wrist trauma and fractures presented per month.

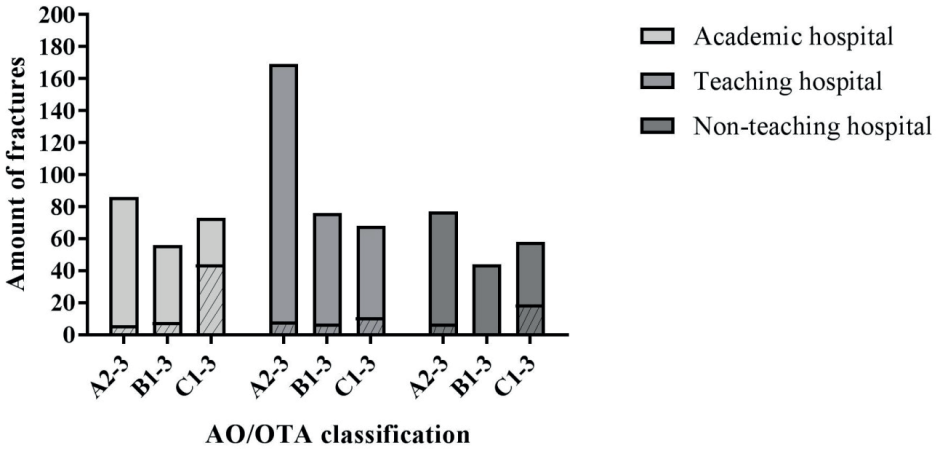

Figure 2. Distribution of 707 distal radius fractures for each hospital. Shaded area shows the amount of fractures which are treated operatively.

PART II

OUTCOME AND COMPLICATIONS OF DRFS

RADIOLOGICAL CRITERIA FOR ACCEPTABLE REDUCTION OF EXTRA-ARTICULAR DISTAL RADIAL FRACTURES ARE NOT PREDICTIVE FOR PATIENT-REPORTED FUNCTIONAL OUTCOME

3

A. Bentohami, T.S. Bijlsma, J.C. Goslings, P. de Reuver, L. Kaufmann, N.W.L. Schep

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Abstract

The purpose of this study was to assess the association between arm-specific disability measured with the *Quick*DASH *questionaire* and radiological criteria in patients with extra-articular distal radial fractures. A consecutive series of 385 patients were initially treated non-operatively for an extra-articular distal radial fracture and 257 (69 %) patients were included in the study. In 203 of these patients (78%) the quality of radiographic reduction was judged to be adequate by radiological parameters which included dorsal tilt, radial inclination, and radial shortening In 54 patients (22%) the quality of radiographic alignment was judged to be inadequate. We observed no effect of radiographic parameters on the functional outcome. Female sex and longer duration of follow-up (>35 months) were the only independent prognostic factors significantly associated with a worse QuickDASH score.

Introduction

The incidence of distal radial fractures is 400/100.000 in the Netherlands [1]. Therefore, these fractures represent a large amount of the daily workload for practising orthopaedic and trauma surgeons [2]. Most patients with distal radial fractures can be treated non-operatively in a cast, with excellent functional results [3,4]. Numerous authors have suggested radiological parameters to define an acceptable reduction. They include dorsal tilt, radial inclination, intra-articular displacement, and radial shortening. However, several studies have shown minimal or no improvement of functional outcome with improved radiographic alignment [5–13]. Over the last decade open reduction and internal fixation of distal radius fractures has become more popular [14]. Some authors claim that patients treated by operation show improved functional outcome [14-22]. Despite this tendency towards surgery, in a recent review it was argued that in the absence of a large, long-term, prospective, randomized, controlled trial, there is no definitive clinical evidence for the superiority of any particular treatment over another [23]. The clinical problem is whether an operation is indicated when accepted radiographic parameters of an adequate alignment are not met. Decision making regarding extra-articular fractures can be especially challenging. Most of these studies included patients with AO type A, B, as well as type C fractures, possibly resulting in heterogeneity [14-18, 24]. Therefore, the aim of this study was to assess the association between disability and accepted radiological criteria defining acceptable alignment in patients with extra-articular ,AO type A, distal radial fractures.

Patients and Methods

We conducted a retrospective study of all non-operatively treated, extra-articular distal radial fractures, of type A2 and A3, in a consecutive group of patients treated over a 2- year period. Type A2 and A3 fractures are defined as extra-articular fractures of the distal radius (A2:radius, simple and impacted . A3: radius, multifragmentary)
Patients over 18 years of age with a minimum follow up of at least 24 months and who filled out and returned the quick version of the Disabilities of the Arm, Shoulder and Hand (*Quick*DASH) questionnaire were included in the study.
Non-operative treatment was defined as closed reduction of the fracture, if necessary, and subsequent immobilization in a cast.
The patients' medical charts and digital radiographs were reviewed. An adequate alignment was defined as: dorsal angulation $<15°$, palmar tilt $<20°$, radial inclination $>15°$ and an ulnar positive variance <5mm [25]. Dorsal angulation and palmar tilt were measured on lateral images, from an angle created between the articular surface of distal radius and a line perpendicular to the long axis of the radius ($>0°$is dorsal angulation, $<0°$ is palmar tilt). When one of these radiographic conditions was not met, alignment was considered inadequate. The radiographic parameters were measured by three authors (AB) (TB) and (LK)on posterior anterior (PA) and lateral radiographs 6 weeks after the fracture using a digital picture archiving and communication system (PACS; AGFA Medical, Mortsel, Belgium). Radiographic parameters of the first 50 patients were measured by the first author (AB) under the supervision of LK and TB, a trained radiologist and trauma surgeon respectively. Subsequent measurements were obtained by AB only.

All patients were contacted by letter and were asked to fill out the *Quick*DASH questionnaire [26]. The *Quick*DASH questionnaires were sent by mail and a reminder was sent after 1 month to patients who did not respond. Four weeks later patients were contacted by phone, if they had not responded. These patients were asked to fill out and return the questionnaires. The *Quick*DASH questionnaire is a shortened version of the DASH Outcome Measure. Instead of 30 items, the *Quick*DASH questionnaire has 11 items (scored 1-5) to measure physical function and symptoms in people with musculoskeletal disorders of the upper limb. At least 10 of the 11 items must be completed for a score to be calculated. The scores are transformed to a 0-100 scale for easy comparison. A higher score indicates greater disability.

Data analysis

Descriptive analysis was used to record baseline characteristics and compare them between patients with excellent or inadequate alignments. For continuous datathe mean (SD) (parametric data) and medians and the 25-75% interquartile ranges (IQR) (non-parametric data) were calculated. A multivariate linear regression analysis was carried out to asses any relationship between sex, follow up, quality of reduction, dorsal tilt, radial inclination, ulnar variance and *Quick*DASH score. Differences in *Quick*DASH scores were assessed using Student's t-test (parametric data) or the Mann-Whitney U-test (non-parametric data). Differences were considered statistically significant

with *p*-values <0.05. Categorical data were compared using the Chi-squared test. A *p*-value <0.05 was taken as the threshold of statistical significance.

Results

During the study period 385 patients were initially treated non-operatively for an extra-articular distal radial fracture in. A total of 257 patients (68.2%) with an extra-articular distal radius fracture filled out and returned the *Quick*DASH questionnaires and these patients were included in the analysis. One hundred and twenty-eight patients were excluded for various reasons. Eight patients were treated surgically after initial conservative therapy because of an intra-articular fracture, 64 patients had died, 25 patients were lost to follow up, 19 patients returned to their country of originand 12 patients were unable to respond due to dementia. The median age of our study population was 65 years (IQR 48 to 76) and included 198 women. There were 153 AO type A2 (60%) and 104 type A3 (40%) fractures. In 161 patients the fracture was reduced by a closed manoeuvre after administering local anaesthesia in the fracture haematoma. In 96 patients the fractures were only minimally displaced on presentation and did not require reduction. The patient demographics are listed in Table 1.

In 203 patients (78%) the quality of radiographic alignment was judged to be adequate and in 54 patients (22%) the quality of radiographic alignment was judged to be inadequate (Table 2). In 44 patients this alignment was inadequate according to one parameter, in eight patients the alignment was inadequate according to two parameters and in two patients it was inadequate according to three parameters.

The median *Quick*DASH score in patients with an adequate alignment was 2.3 points (IQR 0 to 14) points and in patients with an inadequate alignment 3.4 (IQR 0 to 28) after a mean follow up of 36 (SD 7) months. These scores did not differ ($p = 0.49$). The median *Quick*DASH scores of patients with an inadequate alignment according to one parameters, two parameters and three parameters were respectively 5.7 (IQR 0 to 29), 1.1 (IQR 0 to 32.4), and 5.7. The median *Quick*DASH score in AO type A2 fractures was 2.3 (IQR 0 to 14) and in AO type A3 fractures it was 4.5 (IQR 0 to 19) However, patients with an AO type-A3 fracture had a significant poorer quality of alignment compared with patients with an AO type- A2 type fracture (Chi-squared test, $p < 0{,}01$). We observed no effect of these individual radiographic parameters on the functional outcome (Figure 1). A multivariate linear regression analysis indicated that female sex and a longer duration of follow-up were significantly associated with a worse *Quick*DASH score corrected for AO fracture type and quality of reduction (Table 3).

Discussion

In this study no relationship was found between functional outcome and quality of reduction in patients with extra-articular distal radial fractures (A2/A3). Most of the patients (78%) had an adequate alignment and a good functional outcome. Fifty-four patients had an inadequate alignment, but their functional outcome did not differ from the patients with an adequate alignment. However, other studies have suggested that adequate quality of radiographic alignment is associated with a better functional outcome [14-22]. Their authors state that treatment should strive to regain adequate alignment to optimize functional outcome. It is difficult to compare these studies because of different inclusion criteria. As noted earlier, most of these studies included patients with AO type A, B, as well as type C fractures, possibly resulting in heterogeneity. Moreover, studies that analyze functional outcome after operative treatment often tend to include younger patients [17,20,24]. Previous research has shown that many objective clinical variables such as range of motion of the wrist, do not reflect functional outcomes of importance to the patients [27]. Self-reported and previously validated and reliable measures such as the QuickDASH allow clinicians to assess outcomes from their patients' perspectives in a valid and reliable way. A strength of this study is that only patients with extra-articular AO type A2 and A3 types of fractures were analyzed, in patients with a median age of 65 years. Therefore, the results of this study can be generized to most patients with extra-articular distal radial fractures. In 22% of the patients the quality of the alignment was graded inadequate. Young et al. have already shown a lack of association between the radiographic and functional outcomes in the elderly [13]. They stated that in the older patients with low wrist demands adequate results were found, despite sub-optimal radiographic results and degenerative changes, "because of the low functional demands and not because they are older". In younger patients, it has been suggested that the degree of pain reported after post-traumatic wrist deformity may be directly proportional to the functional demands [28]. Unsatisfactory radiographic outcomes in older patients do not necessarily translate into unsatisfactory functional outcomes, and non-operative treatment may be the preferred method of treatment in this age group [29]. We are confident that an X-ray at 6 weeks shows the final position of the fracture in which it will consolidate. Most radial fractures are liable to displace within the first 2 weeks [30], only 7% to 8% displace after this time [30,31] and none after 6 weeks [32]. We recognize that this study has its limitations. First, it is a retrospective analysis and also, we did not include a control group of surgically treated patients. Nevertheless, it was found that adequate radiographic alignment appears not to be associated with better patient-reported functional outcomes in patients with non-operatively treated extra-articular distal radial fractures. This suggests that a conservative approach in patients with an extra-articular distal radial fracture may be reasonable. In our opinion, the outcomes of our study justify a prospective randomized trial comparing conservative and operative treatment of patients with extra-articular distal radial fractures to determine the optimal criteria for the appropriate treatment. A post hoc power analysis using the data in our study (0.8 , 0.05, SD 10) indicates that 2200 patients would have to be randomized into groups of operative and conservative treatment.

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Table 1. Characteristics of 257 patients treated conservatively for an extra-articular distal radial fracture

		%
Age (years); median (IQR)	65 (48-76)	
Female (n)	198	77
A2 AO type (n)	153	60
A3 AO type (n)	104	40
Fractures reduced (n)	161	62
Adequate radiographic alignment (n)	203	78
Follow-up (months);	36 (7) mean (SD)	
IQR: interquartile ranges		

Table 2. Median and quartiles of the radiographic parameters in the adequately and inadequately aligned fractures.

		Dorsal tilt (degrees)	Radial inclination (degrees)	Ulnar variance (mm)
Inadequate alignment (n = 54)				
Median		-6	15	2
Percentiles	25	-22	12	0
	75	1	22	4
Adequate alignment (n = 203)				
Median				
Percentiles	25	-3	25	0
	75	-11	22	0
		3	28	2

Table 3. Multivariable linear regression analysis for dependent variables and the QuickDASH score.

	p-value	95% confidence interval
		Range
Sex	**0.003**	−13.3 to −2.8
Follow- up	**0.025**	−0.7 to −0.1
Reduction	0.10	12.1 to 1.1
Dorsal tilt	0.93	−0.2 to 0.2
Radial inclination	0.49	−0.3 to 0.6
Ulnar variance	0.54	−2.0 to 1.1
AO fracture type	0.21	−1.7 to 7.6

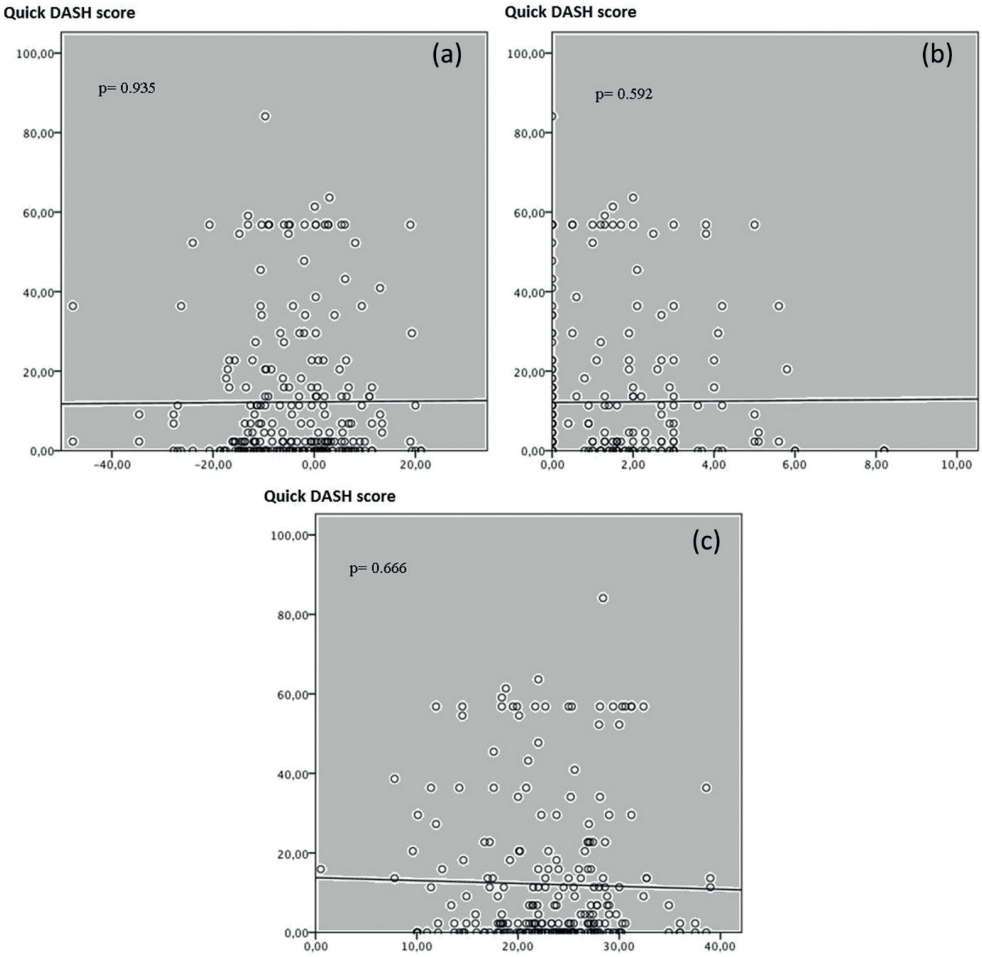

Figure 1. Dorsal tilt (a), ulnar variance (b), and radial inclination (c) were not significantly associated with the QuickDASH score.

NONDISPLACED DISTAL RADIAL FRACTURES IN ADULT PATIENTS: THREE WEEKS VERSUS FIVE WEEKS OF CAST IMMOBILIZATION; A RANDOMIZED CONTROLLED TRIAL. (DR PIP I, DISTAL RADIUS PLASTER IMMOBILIZATION PERIOD I)

4

Abdelali Bentohami, Eva van Delft, Nico Sosef, Jefrey Vermeulen,
Carel Goslings, Niels Schep

Abstract

Patients with non- or minimally displaced distal radial fractures, that do not need repositioning, are mostly treated by a short-arm cast for a period of 4 to 6 weeks. A shorter period of immobilization may lead to a better functional outcome. Purpose We conducted a randomized controlled trial to evaluate whether the duration of cast immobilization for patients with non- or minimally displaced distal radial fractures can be safely shortened toward 3 weeks. Patients and Methods The primary outcomes were patient-reported outcomes measured by the Patient-Related Wrist Evaluation (PRWE) and Quick Disability of Arm, Shoulder and Hand (QuickDASH) score after 1-year follow-up. Secondary outcome measures were: PRWE and QuickDASH earlier in follow-up, pain (Visual Analog Scale), and complications like secondary displacement. Results Seventy-two patients (male/female, 23/49; median age, 55 years) were included and randomized. Sixty-five patients completed the 1-year follow-up. After 1-year follow up, patients in the 3 weeks immobilization group had significantly better PRWE (5.0 vs. 8.8 points, p ¼ 0.045) and QuickDASH scores (0.0 vs. 12.5, p ¼ 0.026). Secondary displacement occurred once in each group. Pain did not differ between groups (p ¼ 0.46). Conclusion Shortening the period of immobilization in adult patients with a non or minimally displaced distal radial fractures seems to lead to equal patient-reported outcomes for both the cast immobilization groups. Also, there are no negative side effects of a shorter period of cast immobilization. Therefore, we recommend a period of 3 weeks of immobilization in patients with distal radial fractures that do not need repositioning.

Introduction

Distal radial fractures (DRF) account for up to 20% of all extremity fractures [1]. Optimal treatment is important, as the injury-related loss of function in the wrist can lead to occupational disability, decreased school attendance, lost work hours, loss of independence, and lasting disability as well as significant medical costs [2,3]. Most patients with non- or minimally displaced DRF can be treated nonoperatively with short-arm cast immobilization alone, with excellent functional results [4,5]. Current practice is a short-arm cast for 4 to 6 weeks [2,6]. Previous results might suggest that a shorter period of immobilization could be safe, and may accelerate and enhance functional recovery [7–10]. Some authors believe that 3 weeks of cast immobilization could be sufficient [7,8]. It is even stated that nondisplaced DRF do not need stabilization by cast immobilization at all, perhaps only for pain relief [9,11]. Most DRF are at risk to displace within the first 2 weeks; only 7 to 8% displace after this time period [11–13]. To assess the clinical controversy of the duration of the immobilization period, we conducted a randomized controlled trial. Three weeks of short-arm cast immobilization was compared with the mean regular period of immobilization of 5 weeks in adult patients with non- or minimally displaced DRF. We hypothesize that 3 weeks of cast immobilization lead to better patient-reported outcomes after 1 year compared with 5 weeks of cast immobilization and that this treatment does not lead to more complications.

Materials and Methods

Three weeks of short-arm cast immobilization was compared with 5 weeks of short-arm cast immobilization in adult patients with non- or minimally displaced DRF. Only stable fractures were included in this study. Potential unstable fractures like Smith fractures and displaced fractures were excluded. In the DRF included in the study, no reduction, manipulation of the fracture, or molding of the cast was performed. Criteria for minimal displacement were based on the Lindstrom's criteria: dorsal angulation < 15°, volar tilt < 20°, radial inclination < 15°, ulnar variance < 5 mm, and an articular step-off < 2 mm [14].

Inclusion Criteria

- Age > 18 years.
- Non- or minimal displaced DRF.

Exclusion Criteria

- Fracture of the contralateral arm.
- Pre-existent abnormalities of the fractured distal radius.
- Open fractures.
- Fractures with associated instability (e.g., displaced and reduced fractures and Smith fractures).

Randomization, Blinding, and Follow-Up

Patients were informed about this study at the emergency department, after checking the above-mentioned inclusion and exclusion criteria. After obtaining informed consent, patients were randomized into the intervention group (3 weeks short-arm cast immobilization) or in the control group (5 weeks short-arm cast immobilization). Permuted block randomization using a computer-generated randomization schedule was used. To prevent bias, stratification by age (< 60 or 60 years of age) and gender was performed. As there is no evidence that the type of cast or removal of the cast has any impact on redisplacement, we chose to treat all patients in a short-arm cast in neutral position [15,16]. After 3 or 5 weeks, according to the randomization, the cast was removed. After the cast immobilization period, all patients were treated according to the after-treatment protocol: Patients were motivated to start mobilization directly after removal of the cast. Physiotherapy was not generally advised. None of the patients received a resting splint after cast removal. Follow-up was performed at the outpatient clinic at 1 week, 3 or 5 weeks, 6 weeks, 3 months, 6 months, and 1 year after the initial trauma. At these points, an X-ray was performed to determine secondary displacement. The ethical committee approved the protocol.

Outcome Measures

The primary outcome of this study was patient-reported outcome, measured by the Patient-Related Wrist Evaluation (PRWE) and Quick Disability of Arm, Shoulder and Hand (QuickDASH)

score after 1-year follow-up. The PRWE is a questionnaire to evaluate the patient-reported outcome in patients with disorders of the wrist. The minimal clinically important difference (MCID) of the PRWE is 11.5 points. Pain and function are scored on a 0 to 10 scale, summed to a score between 0 and 100, with 0 being the best possible outcome and 100 the worst [17,18]. The QuickDASH score is another questionnaire to evaluate patients with disorders involving the joints of the upper limb, with a MCID of 14 points between groups. Patients can score pain and functional outcome on a 1 to 5 scale, where 1 is the best possible outcome and 5 the worst. The total sum will be counted and converted by a formula resulting in a 0 to 100 score, where 0 is the best possible outcome and 100 the worst [19,20]. Secondary outcome measures were: PRWE and QuickDASH at 6 and 12 weeks and 6 months, pain (Visual Analog Scale [VAS]) measured by a pain diary, and complications such as complex regional pain syndrome (CRPS), mal- or non-union, and secondary displacement.

Power Analysis

The primary outcomes were PRWE and QuickDASH score after 1 year. The MCID of the QuickDASH score is 14 points [19]. Based on a difference of 14 points, a sample size of 30 patients per treatment group was calculated with a power (1–□) of 80% and a type I error (□) of 5%, allowing a 10% drop-out. In total, 72 patients should be included in the study, 36 in each group.

Statistical Methods

Descriptive analysis was performed to compare baseline characteristics. For continuous data, the mean and standard deviation for parametric data or medians and interquartile ranges (IQRs) for nonparametric data were calculated. To determine whether differences between the two groups were significant, we log transformed the outcomes if the data were not normally distributed and we used linear regression analyses. Adjustments were made for age and gender. A p-value of < 0.05 was taken as the threshold of statistical significance.

Results

A total of 72 patients were included in this study, 36 in each group. Baseline characteristics of these patients are displayed in Table 1. Seven patients were lost to follow-up and another 19 patients had incomplete QuickDASH or PRWE scores after 1 year. This is shown in Fig. 1

Primary Outcome

After completing the follow-up at 1 year, the intervention group (3 weeks cast immobilization) had statistically better functional outcome, as shown in Table 2. The median PRWE after 1 year was better in the 3-week group, 5.0 (IQR: 0□12.5) versus 8.8 (IQR: 1.7□23.5) in the 5-week group (p ¼ 0.045). The median QuickDASH score after 1 year was 0 (IQR: 0□6.8) in the 3-week group compared with 12.5 (IQR: 2.8□27.0) in the 5-week group (p ¼ 0.026). Nevertheless, both the PRWE and the QuickDASH did not reach the MCIDs of 11.5 and 14 points.

Secondary Outcome

In Table 2, the results of functional outcome after 6 and 12 weeks and 6 months for both groups are listed. Although patients who were treated with 3 weeks of cast immobilization showed better results (except for PRWE score at 6 months), the difference between the groups was not statistically significant. After cast removal, patients in the 3-week cast immobilization group did not mention to suffer more pain compared with the control group. Median VAS in the 3-week cast group was 3.1 (IQR: 1.0–4.8) and 2.6 in the 5-week group (IQR: 0.5–4.2), respectively (p ¼ 0.46). During the study period, there were no complications in fracture healing. In both groups, no cases of non-union or CRPS were noted. In both groups, one patient showed minimal secondary displacement of the DRF according to the Lindstrom's criteria [14]. However, both patients did not need surgical treatment or reduction of the fracture because of good patient-reported outcome.

Discussion

In this randomized controlled trial, we evaluated whether the duration of immobilization period in patient with non- or minimally displaced DRFs could be safely reduced to 3 weeks. This study showed that shortening the period of cast immobilization is safe in these patients. A higher rate of possible complications that might occur after earlier cast removal, such as an increased number of secondary displacements of the fractures or increased pain sensation, was not found in this study. Although a statistically significant difference in patient reported outcome after 1 year in favour of the 3-week immobilization group was found, the MCID for both PRWE and QuickDASH was not reached. There was no significant difference during the follow-up at 6 and 12 weeks and 6 months. We do not have a clear explanation for the statistical differences between the patient-reported outcomes after 1 year, but this study has some limitations. Sixty-five patients completed 1 year of clinical follow-up, and only 7 patients were lost to follow-up. However, only 46 patients (64%) completed all the PRWE and QuickDASH scores (Fig. 1). Some patients were lost to follow-up and others were not motivated to participate anymore. As shown in Fig. 1, more patients were lost to follow-up in the 5-week immobilization group. Furthermore, in this group less patients completed the questionnaires after 1 year. However, it is not totally clear why this was the case. One might assume that the patients in the 5-week immobilization group were less motivated to participate in this study and complete the questionnaires, because they received the regular period of immobilization. It is also possible that patients did not return to follow-up after 1 year, because they were free of complaints and recovered uneventful. Though, it is to be expected that patients who were not fully recovered would visit the clinic on their scheduled appointments. Therefore, one can assume that the functional outcome of the patients lost to follow-up was at least equal to the patients who were not lost to follow-up. Although only a drop-out of 10% was anticipated in the power analyses, 33% of initially randomized patients did not complete the PRWE and QuickDASH score after 1 year. The data of patients who did not complete the study of 1-year follow-up were considered as random missing data and therefore

only the available data were analyzed and the number of available questionnaires is shown in Table 3. The difference in functional outcome was measured using PRWE and QuickDASH; both are scores specific for functional outcome of the upper extremities. PRWE is the most responsive instrument for evaluating patient-reported outcome of DRF [17]. The QuickDASH is considered to be the most appropriate instrument for evaluating patients with disorders involving the joints of the upper limb.[19] In this study, the PRWE and QuickDASH score were used to analyze a homogenous group of patients, with nondisplaced DRF. At present, the majority of DRF are treated nonoperatively. Also, there has been a dramatic rise in open reduction and internal fixation (ORIF) [16,21]. Nevertheless, whether long-term outcomes after ORIF are superior to nonoperative treatment is still a matter of debate [3,15]. The complication rate of nonoperative treatment of DRF is 0 to 13.5% [22–24]. The overall complication rate after ORIF is 16.5%, with 7.7% major complications being hardware failure, tendon rupture, or carpal tunnel syndrome [25]. According to the literature, the complication rate of Kirschner wiring is even higher: 26 to 28% [26,27]. As surgical treatment is associated with considerable risks, it should only be recommended to those patients for whom there is a risk that nonoperative treatment could lead to unsatisfactory functional result, for example, in case of secondary displacement [28].

In this study, we examined only patients with non- or minimally displaced (stable) DRF. As these patients do not suffer significant displacement, there is no need for ORIF. Besides, it is thought that ORIF in these patients will not speed up the recovering process compared with an immobilization period of 3 weeks. Instable fractures as displaced and reduced DRF and Smith fractures were excluded from this study. The results of this study are in accordance with the existing literature on this topic. The big difference is that in this study a homogenous group of patients with stable non- or minimally displaced DRF were included. A prospective study for conservative treatment of DRF with non- or minimal displacement concluded that 3- and 5-week cast immobilization leads to equally good results. The functional outcome was measured by the Gartland and Werley functional score [7]. A study in patients who underwent reduction of their displaced DRF followed by cast immobilization showed comparable range of motion 1 year after initial 3 or 5 weeks' cast immobilization. Patients who received 3 weeks immobilization after reduction experienced less pain and had improved grip strength compared with the 5 weeks immobilization group [10]. In this study, the Gartland and Werley functional score was used to assess functional outcome. This score provides an assessment of the functional outcome, amount of pain, strength, and time to union. We did not use the Gartland and Werley functional test as its use has not been validated. Others assessed outcome following cast immobilization of both nondisplaced as well as severely displaced DRF [29,30]. Functional outcome seems to be good in both studies. Although patients were not randomized, different periods of cast immobilization for nondisplaced and displaced DRF were used, as well as different types of casts. Therefore, we were not able to extrapolate these results to the results of our study. The most important conclusion to be drawn from our study is that earlier cast removal will not lead to more complications like secondary displacement or more pain. Besides, patient reported outcomes seem to be at least equal in both the 3 and 5 weeks cast immobilization groups. Therefore, we recommend that castimmobilization for non- or minimally displaced DRF can be safely discontinued after 3 weeks.

Table 1. Group characteristics

N	3 weeks immobilization	5 weeks immobilization	Total	p-Value
Male	10	13	23	0.61
Female	26	23	49	
< 60 y	21	18	39	0.64
> 60 y	15	18	33	
Intra- articular	19	19	38	0.61
Extra-articular	16	11	27	
Total	36	36	72	
Median	IQR 27.7-68.8	IQR 48.4-66.5	IQR 40.4-67.4	

Abbreviations: IQR, interquartile range; y, years of age.
Note: Baseline characteristics of the 72 randomized patients.

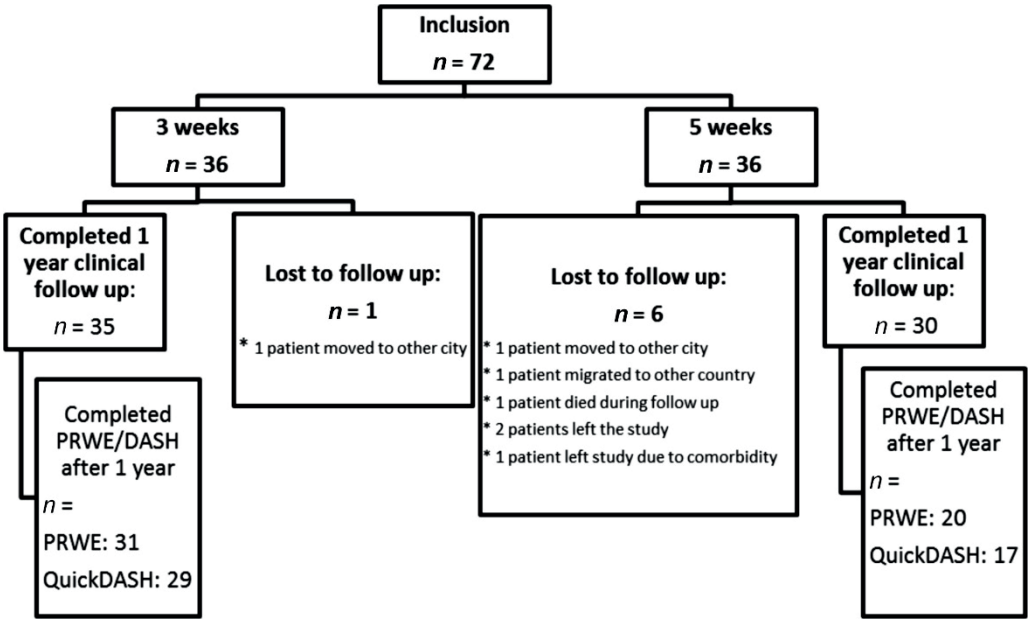

Fig. 1 Number of inclusion, follow-up.

Table 2. Results, primary, and secondary outcomes

Variables	Value	3 weeks	IQR	5 weeks	IQR	Difference	p-Value
Primary outcome							
Function 1 year							
PRWE, n = 51	0-100	5.0, n = 31	0-12.5	8.8, n = 20	1.7-23.5	3.8	0.045
QuickDASH, n = 46	0-100	0.0, n = 29	0-6.8	12.5, n = 17	2.8-27.0	12.5	0.026
Secondary outcome							
Function, 6 weeks							
PRWE, n = 54	0-100	20.0, n = 32	8.4-50.3	30.7, n = 22	17.4-57.6	10.7	0.32
QuickDASH, n = 48	0-100	13.6, n = 27	0-45.4	22.4, n = 21	0-39.5	8.8	0.74
Function, 12 weeks							
PRWE, n = 42	0-100	10.0, n = 22	0.7-42.9	24.3, n = 20	12.9-34.5	14.3	0.054
QuickDASH, n = 39	0-100	14.7, n = 20	0.6-27.4	20.5, n = 19	6.8-29.5	5.8	0.34
Function, 6 months							
PRWE, n = 26	0-100	9.5, n = 14	1.5-24.7	8.3, n = 12	0.9-22.9	-1.2	0.33
QuickDASH, n = 23	0-100	4.5, n = 14	0-24.3	4.5, n = 9	1.1-23.9	0	0.95
Median VAS	0-10	3.1, n = 25	1-4.8	2.6, n = 21	0.5-4.2	-0.5	0.46

Abbreviations: IQR, interquartile range; PRWE, Patient-Related Wrist Evaluation; QuickDASH, Quick Disability of Arm, Shoulder and Hand; VAS, Visual Analog Scale.

Note: Primary outcome: QuickDASH and PRWE score after 1 year. Secondary outcome: QuickDASH and PRWE score after 6 and 12 weeks and 6 months and median VAS after removal of the cast.

Table 3. Follow-up: Number of patients

	Total		3 weeks cast immobilization		5 weeks cast immobilization	
	N	%	N	% start	N	% start
Randomization	72	100	36	100	36	100
Lost to follow-up	6	8	1	3	5	14
Completed 1 year clinical follow-up	65	90	35	97	30	83
Completed 1 year follow-up;						
PRWE	51	71	31	86	20	56
QuickDASH	46	64	29	81	17	47
Completed follow-up with PRWE/QuickDASH scores						
6 weeks						
PRWE	54	75	32	89	22	61
QuickDASH	48	67	27	75	21	58
12 weeks						
PRWE	42	58	22	61	20	56
QuickDASH	39	54	20	56	19	53
6 months						
PRWE	26	36	14	39	12	33
QuickDASH	23	32	14	39	9	25
1 year						
PRWE	51	71	31	86	20	56
QuickDASH	46	64	29	81	17	47

Abbreviations: PRWE, Patient-Related Wrist Evaluation; QuickDASH, Quick Disability of Arm, Shoulder and Hand.

Note: Total patients included in study = 72. Lost to follow-up = 6, completed PRWE/QuickDASH after 1 year = 51/46.

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COMPLICATIONS FOLLOWING VOLAR LOCKING PLATE FIXATION FOR DISTAL RADIAL FRACTURES; A SYSTEMATIC REVIEW

5

A. Bentohami, K. de Burlet, N. de Korte, M.P.J. van den Bekerom,
J.C. Goslings, N.W.L. Schep

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Summary

The purpose of this systematic review is to assess the prevalence of complications following volar locking plate fixation of distal radial fractures. A computer-based search was carried out using EMBASE and PUBMED/MEDLINE. Only prospective comparative and prospective cohort studies that presented data concerning complications after treatment of distal radial fractures with a volar locking plate in human adults with a minimal follow-up of six months were included. Two quality assessment tools were used to assess the methodological quality of the studies (level of evidence rating according to the Oxford Centre of Evidence Based Medicine and the modified version of the Cochrane Bone, Joint and Muscle Trauma Group's former quality assessment tool). Thirty three studies were eligible for final assessment. Most complications were problems with nerve and tendon function as well as complex regional pain syndrome. With an overall complication rate of 16.5 % most of which were "minor" complications and low rates of nonunion and malunion, volar locking plate fixation can be considered a reasonably safe treatment option for patients with distal radial fractures.

Introduction

Fractures of the distal radius are among the most common injuries in orthopedics, accounting for up to 15% of all extremity fractures [1]. Over the last decade, following the introduction of locking plates, open reduction and internal fixation has become more popular. Volar locking plates are designed to improve and maintain anatomic alignment even in patients with poor metaphyseal bone quality [2]. Reported complication rates of distal radius fracture treatment vary widely, from 9% to 60% [1,3]. Initial reports of this technique by Orbay et al. reported very few complications (3–4%) [2,4], but subsequent studies have indicated higher complication rates: Rozental et al. [5] reported a 22% incidence of complications following fixation use of a 2.4-mm locking compression plate (LCP) volar distal radius plate (Synthes, Inc, West Chester, PA) or distal volar radius plate (DVR™; Hand Innovations LLC, Miami, FL); [6] reported an overall complication rate of 27% after fixation with the LCP volar distal radius plate. We have performed a systematic review to assess the incidence of complications after surgical volar locking plate fixation of distal radial fractures.

Methods

The methods and results of this study are reported according to the PRISMA guidelines [7].

Information sources:
A comprehensive literature search was performed with the assistance of a clinical librarian, using the following Mesh search terms: "complications", "volar plating", "plate fixation", "plate osteosynthesis", "plate", "radius fractures", "radius fracture", "fracture fixation". The search

was limited to the following databases: PubMed/Medline, Cochrane Clinical Trial Register, and Embase. Studies were searched in the period from 2000 to January 2013, as the first volar locking plate for DRF was described in 2002 by Orbay [2]. Due to linguistic reasons the search was restricted to articles written in the English, German, and Dutch language.

Inclusion and Exclusion Criteria

All titles and abstracts of relevant studies were reviewed by two reviewers (AB and KB), with a set of predefined inclusion and exclusion criteria. Inclusion criteria: All articles that collected data prospectively and reported complications after treatment of distal radial fractures with a volar locking plate in adults with a minimal follow-up of six months and a minimum number of six cases. All types of distal radial fractures were included. Exclusion criteria: Biomechanical and cadaveric studies; review articles and expert opinions; retrospective studies, because the reporting of complications is unreliable; abstracts from scientific meetings that were not published as full text articles; articles reporting on five patients or fewer; and articles presenting data that were thought to have been published elsewhere.

Study selection:

The included publications were checked manually for additional references potentially meeting the inclusion criteria and not found by the electronic search.

Two reviewers (AB and KB) independently reviewed the titles and abstracts of potentially relevant publications. A hand-search of the references of all these studies retrieved was undertaken for any further potential studies. From the full texts the reviewers independently selected articles for inclusion in this review. Disagreement was resolved by group discussion; with arbitration by a third author (NK) where differences remained. Studies were not blinded for author, affiliation or source.

Data collection

After the initial assessment for inclusion, two authors (AB and KB) independently extracted data including: numbers of patients, gender, ages, types of treatment, follow-up times, revision rates and complications.

Data items

Major complications were defined as complications that required surgical intervention and minor complications as complications that require no surgical intervention. Major complications included: hardware failure; malunion; deep infection (requiring surgical drainage); tendon rupture; carpal tunnel syndrome; and removal of symptomatic plates or screws. Minor complications included: superficial infection; loss of reduction; neuritis; and complex regional pain syndrome (CRPS). We extracted all information regarding the level of evidence, the mean time of follow-up, the numbers of patients initially included in the studies and the numbers of patients available for follow-up, patient demographics, surgical approach, type of implant and postoperative regimen.

Methodological quality and level of evidence

The methodological quality of the studies was assessed by assigning levels of evidence as previously defined by the Centre for Evidence Based Medicine (http://www.cebm.net). Levels of evidence (LoE) were assigned by two authors (AB and KB). Disagreement was resolved by group discussion; with arbitration by a third author (NK) where differences remained. Adequate duration of follow-up was considered a minimum of six months. Moreover the modified version of the Cochrane Bone, Joint and Muscle Trauma Group's former quality assessment tool was used to assess the methodological quality of the included studies. This included random sequence generation, allocation concealment, blinding of participants and personnel, assessor blinding, defined in- and exclusion criteria and adequate duration of follow-up; the higher the value, the better methodological quality and least chance of bias, with a maximum score of 24.

Results

A total of 264 articles were identified, of which 37 were potentially relevant after screening the title and abstract and excluding repeat publication of data (Figure 1). Three articles were excluded because the number of complications was not mentioned or because no or not only volar locking plates were used. [8,9,10]. One randomized controlled trial comparing external and percutaneous pin fixation with plate fixation for intra-articular distal radial fractures was excluded as in the plating group volar, dorsal or combined plate fixation was used and it was not clear if these complications were caused solely following volar locking plating [11]. Two studies of non-locking volar plates were excluded. [12,13]. Full text screening resulted in 31 studies eligible for analysis. After a search update two other studies were included [14,15]. The 33 final articles included a total of 1817 patients (Table 1). The surgical procedure of volar locking plating consisted of exposing the distal part of the radius was through a palmar approach along the flexor carpi radialis tendon. After the release of the pronator quadratus muscle, the fracture site was exposed, reduced and fixed using a volar locking plate. The overall complication rate was 16.5%. There were 8.8% minor complications and 7.7% major complications. The commonest complications were nerve and tendon related complications as well as complex regional pain syndrome (CRPS) (Table 2).

Quality assessment

The majority of studies had well-defined inclusion and exclusion criteria, interventions and outcome measures. An adequate duration of follow-up was considered a minimum of six months which applied to all studies. The studies by Jakubietz et al., Wei et al. and Grewal et al. were graded the strongest of selected studies and of highest scientific quality [14,15,16]. (Table 3).

Level of Evidence

Sixteen of the studies provided the highest level of evidence (Table 4) . Eleven of these studies included a sample size calculation (Table 1). Complication rates in these studies varied widely (2

– 38.9%). Most complications were nerve and tendon related (2-25%). In addition Matschke et al. reported a high rate of loss of reduction 12% [17]. Screw or plate related complications requiring plate removal or revision were low (2-6%) [17-21]. Only one study reported any deep infections (3%) [19]. Three studies were graded LoE 2, being designed as prospective, randomized studies of low-level [22] or well-designed controlled trials without randomization [23,24] (Table 5). In these most complications were nerve or tendon related varying from 2-7%. Fourteen studies were graded LoE 4, all of them being prospective non-randomized, non-comparative studies (Table 6).

Discussion

The overall complication rate following volar locking plates in patients with a distal radial fracture showed to be 16.5% (Minor 8.8% and major 7.7%). The most common complications following application of a volar locking plate were nerve and tendon related complications as well as complex regional pain syndrome.

Initial reports by Orbay documented a lower complication rate after volar locking plate fixation of distal radial fractures. [2,4]. However, the complication rate in this systematic review is comparable with previous studies in which the complication rates range between 17 and 27% . [6,25,26]. These were also mostly nerve and tendon related complications.

According to literature the complication rate after K-wiring of distal radial fractures ranges between 26 and 28% [27,28] The complication rate after conservative treatment in a cast ranges between 0 and 13.5% [29,30]. As Ward et al stated in their study the complication rate is associated with the surgeon's experience [31]. In their study complication rates decreased with increasing surgeon experience, suggesting that many of these complications can be avoided. Specifically, avoiding prolonged or aggressive traction on the median nerve may decrease postoperative nerve dysfunction. Attention to these early complications allowed them to adjust their practice to avoid similar problems in later cases [31]. There was a trend towards increased complications in cases where more than ten days elapsed between injury and surgery or where supplementary K-wiring was used. We found that no less than 16 of the 33 eligible studies provided the highest LoE. Complication rates in these studies varied strongly (0 – 38.9%). Four studies with the highest LoE had complication rates of less than 5% [27,28,30,32]. A possible explanation could be the increased experience with volar locking plates over the years because these studies are probably conducted in centres with a high level of experience. In this review only four studies defined malunion and their opinions vary considerably concerning the degree of clinically acceptable malunion. [29,33,34]. The following range was defined as malunion: Dorsal tilt >5-10°, volar tilt >20°, radial inclination <15°, radial shortening >2-5 mm, articular incongruity >1-2 mm. There are some limitations to this review. Proceedings from annual meetings (conferences) were not included in this review. Only PUBMED, EMBASE and the Cochrane databases were used for search. Therefore, some valuable information might be lost. PUBMED

and EMBASE are the largest medical databases and widely used to search for medical information. Because of the different study designs and characteristics, data could not be pooled and the data were summarized separately per study. Therefore, a former meta-analysis was not applicable. Moreover, the definitions of complications in this study to define major and minor complications may be arbitrary Most authors used miscellaneous definitions for major and minor complications.. In particular CRPS can lead to severe dysfunction although mostly resolves with minimal longer term problems. In addition late complications have been reported such as late tendon ruptures and these will have been missed at reviews at 6 months so the overall complication rates are likely to be a little higher especially for major complications. Based on the overall numbers of reported minor and major complications, we conclude that volar locking plate fixation is a reasonably safe treatment option for patients with distal radial fractures. However, an overall complication rate of 16.5% is considerable and appears to be related to experience.

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Table 1. Overview of included studies

	Author	Level of Evidence	Number of patients with volar locking plates	Sample size calculation	Type of volar locking plate	Follow-up (months)	Complications (%)
1	Arora et al.2011	1	36	Yes	VLP (Synthes, Hand Innovations))	12	36.1
2	Arora et al. 2007	4	112	No	VLP (Synthes/ Stryker/ Aptus/ITS)	15	30.4
3	Chappuis et al.2011	2	15	No	VLP (Synthes, Hand Innovations)	6	13.3
4	Chirpaz et al. 2011	4	25	No	VLP (Matrix/Synthes)	14	44.0
5	Chung et al. 2008	2	55	Yes	VLP (Hand Innovations)	12	20.0
6	Chung et al. 2007	1	66	No	VLP (Stryker)	12	16.7
7	Drobetz et al. 2002	4	50	No	VLP (Mathys)	26	32.0
8	Egol et al. 2008	1	39	No	VLP (Stryker)	12	20.5
9	Gong et al. 2011	1	26	No	VLP*	6	3.8
10	Grewal et al. 2011	1	18	Yes	VLP (Synthes)	12	38.9
11	Hollevoet et al. 2011	1	20	Yes	VLP (Synthes)	19	70.0
12	Jakubietz et al. 2008	1	15	No	VLP (Aptus Radius)	6	13.3
13	Jakubietz et al 2012	1	22	Yes	VLP (Aptus Radius)	12	40.9
14	Jupiter et al. 2010	4	125	No	VLP (Synthes)	24	22.4
15	Knight et al. 2010	4	40	No	VLP (Synthes)	14	40.0
16	Kwan et al. 2011	4	75	No	VLP (Synthes)	24	12.0
17	Lattmann et al. 2011	4	228	No	VLP (Synthes)	12	14.9
18	Marcheix et al. 2010	1	50	Yes	VLP*	6	2.0
19	Matschke et al. 2010	1	266	No	VLP (synthes)	24	15.9
20	McFadyen et al. 2011	1	27	Yes	VLP (Synthes, Hand Innovations)	6	0
21	Oshige et al. 2007	2	31	Yes	VLP (Mizuho)	11	3.2
22	Othman et al. 2009	4	17	No	VLP (synthes)	8.4	11.8

	Author	Level of Evidence	Number of patients with volar locking plates	Sample size calculation	Type of volar locking plate	Follow-up (months)	Complications (%)
23	Rozental et al. 2009	1	23	Yes	VLP (Hand Innovations/ Wright Medical)	12	4.3
24	Sakhaii et al. 2003	4	100	No	VLP (synthes)	10	10.0
25	Shetty et al. 2011	4	23	No	VLP (synthes)	20	4.3
26	Souer et al. 2009	1	57	Yes	VLP*	6	8.8
27	Sugun et al. 2012	4	46	NO	VLP *	19	30.4
28	Wei et al. 2009	1	12	Yes	VLP (EBI optilock)	12	16.7
29	Wilcke et al. 2011	1	33	Yes	VLP ((Swemac))	12	15.2
30	Wong et al. 2005	4	30	No	VLP (synthes)	>12	20.0
31	Wong et al. 2009	4	35	No	VLP (Stryker)	10	5.7
32	Yasuda et al. 2009	4	40	No	VLP (Nakashima)	12	20.0
33	Zettl et al. 2009	1	60	No	VLP (Clinical-House)	12	33.3

*No brand mentioned

Table 2. Type and number of complications

Minor complications			**Major complications**		
Complication	n	%	Complication	n	%
Superficial infection	9	0.5	Hardware failure	20	1.1
Loss of reduction	18	1.0	Deep infection	4	0.2
CRPS	29	1.6	Tendon rupture	30	1.7
Tendon irritation	69	3.8	CTS	51	2.8
Neuritis	34	1.9	Removal of hardware	20	1.1
			Malunion	15	0.8
Total	**159**	**8.8%**	**Total**	**140**	**7.7%**

CRPS= Complex Regional Pain Syndrome, CTS= Carpal Tunnel Syndrome

Table 3. Quality assessment outcome of all analyzed studies according to the modified version of the Cochrane Bone, Joint and Muscle Trauma Group's former quality assessment tool (QAT, http://www.cochrane-handbook.com)

Study	Allocation concealment	Intention-to-treat analysis	Assessor blinding	Comparable baseline characteristics	Participant blinding	Treatment provider blinding	Care program comparability	Defined in - and exclusion criteria	Well-defined interventions	Well-defined outcome measures	Clinically useful diagnostic tests	Adequate duration of follow-up	QAT Score
Arora et al. 2011	2	0	1	2	0	0	2	2	2	2	2	2	***15***
Arora et al. 2007	0	0	0	2	0	0	2	2	2	2	2	2	***12***
Chappuis et al. 2011	2	0	0	2	0	0	2	1	2	2	2	1	***14***
Chirpaz et al. 2011	0	0	0	2	0	0	2	2	2	2	2	2	***14***
Chung et al. 2008	0	0	1	2	2	2	2	2	2	2	2	2	***19***
Chung et al. 2007	0	2	2	0	0	0	2	2	2	2	2	2	***16***
Drobetz et al. 2002	0	0	0	0	0	0	2	0	2	2	2	2	***10***
Egol et al. 2008	0	0	2	0	0	2	2	2	2	2	2	2	***16***
Gong et al. 2011	0	0	0	2	0	2	2	2	2	2	2	0	***14***
Grewal et al. 2011	2	2	2	2	0	0	2	2	2	2	2	2	***20***
Hollevoet et al. 2011	0	0	2	2	0	0	2	2	2	2	2	2	***16***
Jakubietz et al. 2008	2	0	0	2	0	2	2	2	2	2	2	1	***16***
Jakubietz et al. 2012	2	0	2	2	0	2	2	2	2	2	2	2	***20***
Jupiter et al. 2010	0	0	0	2	0	0	2	0	2	2	2	2	***12***
Knight et al. 2010	0	0	0	2	0	0	2	1	2	2	2	2	***13***

Study	Allocation concealment	Intention-to-treat analysis	Assessor blinding	Comparable baseline characteristics	Participant blinding	Treatment provider blinding	Care program comparability	Defined in - and exclusion criteria	Well-defined interventions	Well-de-fined outcome measures	Clinically useful diagnostic tests	Adequate duration of follow-up	QAT Score
Kwan et al. 2010	0	0	0	2	0	0	2	2	2	2	2	2	***12***
Lattmann et al. 2011	0	0	0	2	0	0	2	2	2	2	2	2	***14***
Marcheix et al. 2010	2	2	0	2	0	0	2	2	2	2	2	1	***17***
Matschke et al. 2010	0	0	0	2	0	0	2	2	2	2	2	2	***14***
McFadyen et al. 2011	2	0	2	2	0	0	2	2	2	2	2	1	***17***
Oshige et al. 2007	0	0	0	2	0	0	2	2	2	2	2	1	***13***
Othman et al. 2007	0	0	0	2	0	0	2	2	2	2	2	1	***13***
Rozental et al. 2009	2	2	0	2	0	0	2	2	2	2	2	2	***18***
Sakhaii et al. 2003	0	0	0	2	0	0	2	2	2	2	2	1	***13***
Shetty et al. 2011	0	0	2	2	0	0	2	2	2	2	1	1	***14***
Souer et al. 2009	2	2	0	2	0	0	2	2	2	2	2	1	***17***
Sugun et al. 2012	0	0	0	2	0	0	2	2	2	2	2	2	***14***
Wei et al. 2009	2	2	2	2	0	0	2	2	2	2	2	2	***20***
Wilcke et al. 2011	2	0	0	2	0	0	2	2	2	2	2	2	***16***
Wong et al. 2005	2	0	0	0	0	0	2	2	2	2	2	2	***12***
Wong et al. 2009	2	0	0	0	0	0	2	2	2	2	0	0	***10***
Yasuda et al. 2009	0	0	0	2	0	0	2	2	2	2	2	2	***14***
Zettl et al. 2009	0	0	0	2	0	0	2	2	2	2	2	2	***14***

Bold values indicate that the higher the value, the better methodological quality and least chance of bias, with a maximum score of 24 QAT quality assessment tool

Table 4. Studies graded level of evidence I according to the Oxford Centre of Evidence Based Medicine (http://www.cebm.net)

Author	No of pts with VLP	Hardware failure	Hematoma evacuation	Malunion	Hardware removal	Deep infection	CTS	Tendon rupture	Superficial infection	Loss of reduction	Neuritis	CRPS	Tendinitis	Scar related	Total
Arora et al. 2011	36						1 (2.7)	1 (2.7)				2 (5.6)	9 (25.0)		13
Chung et al. 2007	66	1 (1.5)	1 (1.5)				1 (1.5)		2 (3.0)				1 (1.5)	3 (4.5)	
Egol et al. 2008	39			1 (2.6)	1 (2.6)	1 (2.6)		2 (5.2)			2 (5.2)	1 (2.6)	1 (2.6)		8
Gong et al. 2011	26						1 (3.8)								1
Grewal et al. 2011	18							3 (16.6)				1 (5.6)	3 (16.6)		7
Hollevoet et al. 2011	20								2 (10.0)		12 (60.0)				14
Jakubietz et al. 2008	15											1 (6.6)		1 (6.6)	2
Jacubietz et al. 2012	22				1 (4.5)		5 (22.7)					2 (9.1)	1 (4.5)		
Marcheix et al. 2010	50											1 (2.0)			1
Matschke et al. 2010	266	4 (1.5)		1 (0.4)	6 (2.4)		5 (1.9)	4 (1.5)	1 (0.4)	5 (1.9)	8 (3.0)		8 (3.0)		42
McFadyen et al. 2011	27														0
Rozental et al. 2009	23												1 (4.3)		1
Souer et al. 2009	57				3 (5.3)		2 (3.5)	1 (1.8)							6
Wei et al. 2009	12						2 (16.6)								2
Wilcke et al. 2011	33				2 (6.1)		1 (3.0)	1 (3.0)							7
Zettl et al. 2009	60						6 (10.0)	1 (1.7)			7 (11.6)	2 (3.3)			16

Percentage is mentioned between brackets, CTS = Carpal Tunnel Syndrome, CRPS = Complex Regional Pain Syndrome

Table 5. Studies graded level of evidence II according to the Oxford Centre of Evidence Based Medicine (http://www.cebm.net)

Author	No of pts	Hardware failure	Hematoma evacuation	Malunion	Deep infection	CTS	Tendon rupture	Superficial infection	Loss of reduction	neuritis	CRPS	Tendonitis	Scar related	total
Chappuis et al. 2011	15					1 (6.6)					1 (6.6)			2
Chung et al. 2008	55	1 (1.8)	1 (1.8)			1 (1.8)		2 (3.6)	1 (1.8)		2 (3.6)	1 (1.8)	1 (1.8)	9
Oshige et al. 2007	31						1(0.1)							1

Percentage is mentioned between brackets, CTS = Carpal Tunnel Syndrome, CRPS = Complex Regional Pain Syndrome

Table 6. Studies graded level of evidence IV according to the Oxford Centre of Evidence Based Medicine (http://www.cebm.net)

Author	No of pts with VLP	Hardware failure	Hematoma evacuation	Malunion	Hardware removal	Deep infection	CTS	Tendon rupture	Superficial infection	Loss of reduction	Neuritis	CRPS	Tendonitis	Scar related	Total
Arora R et al. 2007	112	5 (4.5)					3 (2.7)	4 (3.6)		3 (2.7)	5 (4.5)		14 (12.5)		34
Chirpaz et al. 2011	25	2 (8.0)		3 (12.0)			4 (16.0)						2 (8.0)		10
Drobetz et al. 2002	50	1 (2.0)				2 (4.0)	1 (2.0)	7 (14.0)		1 (2.0)		3 (6.0)	1 (2.0)		16
Jupiter et al. 2010	125	2 (1.6)						2 (1.6)		2 (1.6)			9 7.2)		28
Knight et al. 2010	40	1 (2.5)		10 (25.0)				5 (12.5)							16
Kwan et al. 2011	75	1 (1.3)					3 (3.9)			3 (3.9)			2 (2.6)		9
Lattmann et al. 2011	228						5 (2.0)	4 (1.8)	1 (0.4)	2 (0.9)		9 (3.9)	5 (2.0)		32
Othman et al. 2009	17	1 (2.8)							1 (5.9)						2
Sakhaii et al. 2003	100					1 (1.0)	2 (2.0)								3
Shetty et al. 2011	23											1 (4.3)			1
Sugun et al. 2012	46						1 (2.2)	1 (2.2)					12 (26.0)		
Wong et al. 2005	30						2 (7.0)							4 (13.3)	6
Wong et al. 2009	35									1 (3)		1 (2.9)			2
Yasuda et al. 2009	40				5 (12.5)		1 (2.5)	1 (2.5)				4 (10.0)		2 (5.0)	13

Percentage is mentioned between brackets, CTS = Carpal Tunnel Syndrome, CRPS = Complex Regional Pain Syndrome

FUNCTIONAL OUTCOME IN PATIENTS WITH UNSTABLE DISTAL RADIUS FRACTURES, VOLAR LOCKING PLATE VERSUS EXTERNAL FIXATION: A META-ANALYSIS

6

M. J. Walenkamp, A. Bentohami, M.S.H. Beerekamp, R.W. Peters,
R.van der Heiden, J.C. Goslings, N.W. L. Schep

Abstract

The aim of this study was to compare bridging external fixation with volar locked plating in patients with unstable distal radial fractures regarding functional outcome. A systematic search was performed in the Cochrane Central Register of Controlled Trials, Medline and EMBASE. All randomized controlled trials that compared bridging external fixation directly with volar locked plating in patients with distal radial fractures were considered. Three reviewers extracted data independently from eligible studies using a data collection form. Studies in which the primary endpoint was measured on the disabilities of the arm shoulder and hand (DASH) score at 3, 6 and 12 months were included in the analysis. To this end, mean scores and standard deviations were extracted. The software package Revman 5 provided by the Cochrane Collaboration was used for data analysis. Three studies involving 174 patients were analyzed. Ninety patients were treated with an (augmented) bridging external fixator and 84 with a volar locking plate. Data were analyzed with the random effects model. The robustness of the results was explored using a sensitivity analysis. Patients treated with a volar locking plate showed significantly lower DASH scores at all times. A difference of 16 ($p = 0.006$), six ($p = 0.008$) and eight points ($p = 0.06$) was found at 3, 6 and 12 months follow-up, respectively. Patients treated with a volar locking plate showed significantly better functional outcome throughout the entire follow-up. However, this difference was only clinically relevant during the early postoperative period (3 months).

Introduction

Fractures of the distal radius are common and account for an estimated 17 % of all fractures diagnosed [1, 2]. Twothirds of these fractures are displaced and require reduction [3]. Several treatment modalities have been advocated, and decision-making is mainly based on fracture type [4, 5]. One possible surgical treatment method is bridging external fixation. This technique relies on ligamentotaxis to obtain and maintain fracture alignment [6]. However, since the introduction of locking plates, open reduction and internal fixation (ORIF) has become increasingly popular in surgical reduction [7]. This technique provides immediate stable fixation that allows early mobilization [5, 8] and may result in a more rapid recovery and improved regain of function [9]. Conversely, bridging external fixation augmented (with or without additional Kirschner wires) is a less demanding, less invasive and faster procedure. Excellent results have been described for both techniques [10–15]. However, no conclusive evidence has been published favoring ORIF with a volar locking plate over bridging external fixation or vice versa [16]. Margaliot et al. [11] conducted a meta-analysis of studies published between 1980 and 2004 on external and internal fixation of distal radial fractures. They concluded there was not sufficient evidence to support the use of ORIF over external fixation. However, outcome data from a large variety of different techniques of internal fixation were pooled. Studies on both locking and nonlocking implants were included resulting in considerable heterogeneity across studies [11]. More recently, Wei et al. [17] performed a similar meta-analysis comparing functional outcome at 1 year in

patients with unstable distal radius fractures. The authors pooled data from 12 randomized and nonrandomized trials on seven different techniques of internal fixation. A secondary subgroup analysis of four studies for volar locking plates revealed a significant difference on the disabilities of the arm shoulder and hand (DASH) score in favor of this technique. Unfortunately, exact DASH scores could not be reported, and therefore, clinical relevance of these differences is difficult to evaluate [18]. Moreover, this analysis included one retrospective study [19] and one trial that compared volar locking plates with closed reduction and percutaneous pinning [20]. The authors emphasized that their results were tempered by a substantial heterogeneity present across studies [17]. However, their significant findings justify further examination regarding the benefits of volar locking plates. Recent studies on ORIF with volar locking plate have described most benefit in the early postoperative period [21, 22]. In addition to improved functional results at 1 year, a more rapid recovery is of clinical interest as well. Therefore, the primary aim of this meta-analysis was to compare bridging external fixation with volar locked plating in patients with unstable distal radius fractures, regarding functional outcome as measured on the DASH score, at 3, 6 and 12 months follow-up. The secondary aim was to compare grip strength, flexion and extension and radiological parameters at 1 year follow-up.

Materials and methods

The present study was reported according to the PRISMA guidelines (Preferred Reporting Items for Systematic reviews and Meta-Analyses) [23].

Eligibility criteria

All randomized clinical trials that compared (augmented) bridging external fixation with volar locking plates in adult patients with unstable distal radial fractures were considered. Publication language was restricted to English and Dutch. Studies that did not clearly define the patient population (unstable distal radius fracture) and thus did not the fine the indication for surgery were not included. Trials that compared different fixation techniques or other implants were not included either. Studies that reported functional outcome on the disability of arm, shoulder and hand score at 3, 6 and 12 months follow-up were included.

Types of outcome measures

The primary outcome measure of this meta-analysis was a functional outcome defined by the DASH score at 3, 6 and 12 months follow-up. The DASH score is a validated 30-item, self-report questionnaire designed to measure physical function and symptoms in patients with musculoskeletal disorders of the upper limb. Lower scores indicate a better functional outcome. The total scale score ranges from 0 (no disability) to 100 (most severe disability) [24]. The secondary outcome measures of this review were as follows: grip strength measured as a percentage of the uninjured side, flexion and extension in degrees, and radiological parameters including radial inclination, volar tilt, ulnar variance and radial length at a minimal of 1 year follow-up.

Data sources

We conducted a search for three electronic databases: Cochrane Central Register of Controlled Trials, Medline and EMBASE in March 2013. In order not to miss recently published literature, the use of MESH terms was avoided. The complete search strategy is depicted in Table 1. Additionally, a cross-reference check for the articles of interest was performed.

Study selection

All titles that resulted from the search strategy described above were screened independently by three reviewers. Publications reporting on completely different subjects were identified and excluded. If titles did not provide sufficient information, abstracts were examined. Cohort studies, case studies, comments and current (management) views were excluded. Eligibility with regard to the in- and exclusion criteria of the remaining articles was subsequently assessed based on full text. Disagreement was resolved by means of discussion which included a second trauma surgeon with a master in clinical epidemiology (NS).

Data extraction

Three reviewers extracted data independently from eligible studies using a data collection form. Items include study type, number of subjects, patient characteristics, fracture types, treatment method, length of follow-up and outcome measures. Means and standard deviations were extracted for continuous outcomes or calculated from confidence intervals. Studies in which these values were not reported were excluded [15]. If multiple treatment types were studied, only data regarding patients treated with bridging external fixation or ORIF were extracted. Risk of bias was assessed using the GRADE guidelines [25].

Data synthesis

The software package Revman 5 provided by the Cochrane Collaboration was used for data analysis [26]. The mean differences in DASH scores between treatment groups at 3, 6 and 12 months were calculated with 95 percent confidence intervals. The random effects model was used to pool data [27]. Heterogeneity was explored using the chisquare test, with significance set at p\0.1. For quantification, I 2 was used with values less than 30 % indicating low heterogeneity [28, 29].

Sensitivity analysis

The stability of the results regarding the DASH scores at 3, 6 and 12 months was tested using a sensitivity analysis under different assumptions. Sensitivity analyses were performed based on methodological quality of the included studies and the meta-analytic model. In addition, the robustness of results was explored by consecutively excluding one study.

Results

Literature search

The search yielded 197 results, three of which met our inclusion criteria (Fig. 1) [30–32]. In total, 174 patients were included, of which 90 were treated with an (augmented) bridging external fixator and 84 patients with a volar locking plate.

Description of included studies

The study characteristics are summarized in Table 2. Egol et al. [31] randomized 88 patients with an unstable distal radial fracture to undergo either bridging external fixation (EBI, Parsippany, New Jersey or Stryker, Mahwah, New Jersey) and a K-wire construct or ORIF with a volar locking plate (Hand Innovations, Miami, Florida or Stryker). Inclusion criteria were as follows: loss of reduction following closed reduction and cast immobilization, open fractures or anticipated fracture instability. Criteria for an adequate reduction measured on conventional X-rays included residual dorsal angulation of \10 and loss of radial height of \2 mm. Randomization was performed with a random number generator. The result was handed in a sealed envelope to the treating physician. Seventy-seven patients were included in the analysis, 38 received external fixation with supplementary K-wires and 39 a volar locking plate. DASH scores were reported at a follow-up of 3, 6 and 12 months. Wei et al. [33] randomized 46 patients with an unstable distal radius fracture to be treated with augmented external fixation (n = 22), a volar locking plate (n = 12) or a radial locking column plate (n = 12). Fractures were considered unstable if fracture fragments were redisplaced following closed reduction and cast immobilization, or if three of the following criteria were met: dorsal angulation of [20, dorsal comminution, an intra-articular fracture, an associated ulnar styloid fracture or age[60 years. Patients were randomized into three study arms in two phases. First, patients were assigned to be treated with augmented external or internal fixation. During a second randomization, the patients who had been assigned to receive internal fixation were further randomized to be treated with either a volar locking (EBI OptiLock, Parsippany, New Jersey) or a radial locking column plate. Randomization was done by computer-generated allocation using sealed, opaque envelopes. Only data on patients treated with an external fixator or with a volar locking plate were included in this meta-analysis. Treatment with external fixation (Hoffmann II Compact, Stryker) was augmented with K-wires in all patients, additional small buttress plates (n = 2) or filling of the metaphyseal void with cancellous bone allograft (n = 4) as deemed appropriate by the surgeon. Two patients who had originally been assigned to be treated with a volar locking plate received additional fixation with a dorsal plate, and four patients received supplemental bone grafting following fixation with a volar locking plate. These patients were included in the analysis in the group they were originally assigned to. DASH scores were reported at a follow-up of 3, 6 and 12 months. Wilcke et al. [32] randomized 63 patients under the age of 70 into volar locking plating (n = 33) or bridging external fixation (n = 30). Only dorsally displaced AO type A and C1 fractures with an axial shortening of C4 mm or a dorsal angulation of C20 were included. Randomization was performed by a sealed envelope procedure. Randomization was conducted in blocks of 20 with age stratification set

on 50 years. Patients were treated with a volar locking plate (Ko¨nigsee; Swemac, Sweden) or an external fixator (Hoffmann II Compact, Stryker). In one patient, additional augmentation with a K-wire was performed. DASH scores were reported at a follow-up of 3, 6 and 12 months. Methodological quality The methodological quality of the included randomized controlled trials was moderate according to the guidelines of the GRADE working group [25]. All studies described the process of allocation concealment. Wei et al. randomized their patients into three study arms in two phases resulting in three treatment groups with unequal numbers of subjects. Patients were not blinded since the treatment involved a surgical procedure. Completion of follow-up at 1 year was 78 % in Wei's study and 100 % in the two other included studies. In the study by Wei et al., all patients were analyzed based on the intention to treat principle. Egol et al. did not clearly describe crossover to other treatment arms and the type of analysis applied. In the study by Wilcke, one patient in the external fixator group was reoperated and received a supplementary volar plate. This patient was analyzed in the external fixator treatment arm. Power calculations were done for all three trials. Functional and radiological outcome At 3 months follow-up, there was a significant difference of 16 points in DASH score favoring the locking plate (95 % CI -24.52, -6.64). At 6 and 12 months, we found a significant difference of 6 (95 % CI -9.83, -2.58) and eight points (95 % CI -15.55, -0.44), respectively (Fig. 2a–c). A significant difference in volar tilt was observed in favor of treatment with a volar locking plate (Fig. 3). No significant differences were demonstrated in the other secondary outcomes (Table 3). Sensitivity analysis Based on methodological quality, the study by Egol et al. was first excluded since they used a per protocol analysis. Subsequently, the trial by Wei et al. was excluded because of their considerable lost to follow-up. These analyses did not alter the findings or conclusions; all differences remained significant. This was similar when the metaanalytic model was changed. Considerable heterogeneity was found in the analysis of DASH score at 3 and 12 months. Data were homogenous for the DASH score at 6 months (I 2 = 0 %). When the study by Egol et al. was excluded, data were homogenous (I^2 = 0 %) for the analysis of DASH score at 3 months as well. The same was witnessed for the DASH score at 12 months when the trial by Wei et al. was excluded.

Complications

A complication rate of 26 % in the external fixator group and 20 % in the volar locking plate group was found (Table 4). These differences were not significant (Fig. 4).

Discussion

This meta-analysis revealed a better functional outcome in patients with unstable distal radius fractures treated with a volar locking plate compared with (augmented) external fixation at 3, 6 and 12 months follow-up. Patients treated with a volar locking plate showed faster rehabilitation reflected in a 16-point difference in DASH score at 3 months. This difference subsided at 6 and 12 months to six and eight points, respectively. However, in order to fully appreciate these finding, the clinical relevance of the differences in DASH scores should be taken into consideration. The minimal clinically important difference is the smallest difference in an outcome score that a patient perceives as beneficial. In patients with wrist pathology, the minimal clinically important difference in DASH score ranges between 10 points and 15 points [34, 35]. Therefore, functional outcome at 3 months can be considered to be both significantly better and clinically relevant for patients treated with a volar locking plate. Although considerable heterogeneity was found in the analysis of DASH scores at 3 and 12 months, the differences remained significant under the sensitivity analyses. No clinical or methodological issues could be identified explaining this heterogeneity. Another significant difference between treatment methods was a slightly improved anatomical restoration of the volar tilt in the ORIF group. The mean difference between external fixation and volar locking plate was six degrees, which indicates a more accurate anatomical reconstruction. Nevertheless, we should keep in mind that radiographic parameters are surrogate endpoints and their clinical relevance remains disputed [36, 37]. There are several strengths to this meta-analysis which include the comprehensive search of the literature and the inclusion of similar trials. Studies in which implants other than volar locking plates, e.g., the fragment-specific wrist fixation system, nonlocking plates or a combination of volar and dorsal plating were used, were not included [14, 20, 38–41]. Similarly, studies using a different form of external fixation and studies with an unclear definition of unstable fractures were excluded as well [20]. Therefore, the results of this meta-analysis will most likely reveal the true magnitude and direction of the differences between the treatments under study. However, the results of this study should be interpreted with caution because of the following limitations. The power of this meta-analysis was limited since the sample size of the included studies was relatively small. Moreover, the three trials included various AO fracture types and used different definitions of fracture instability and therefore indication for surgery. Finally, unfortunately, only three trials could be included in this analysis. Nevertheless, the quality of a meta-analysis is often considered to be more susceptible to heterogeneity present across studies than the number of included trials [42, 43]. After all, pooled results can be obtained from as few as two studies. A traditional argument in favor of ORIF with a volar locking plate is early mobilization, which theoretically results in less muscle weakness and therefore improved regain of wrist function. Additionally, the locking principle provides a more rigid construction in the subchondral area of the distal radius, especially in patients with osteoporosis. This theory is in accordance with the results of the current meta-analysis that revealed a significant and clinically relevant improved patient-reported functional outcome for volar locking plate at 3 months. This difference remained significant under a sensitivity analysis and can therefore be considered to be robust. A more rapid recovery might benefit high demanding patients or athletes, and therefore, treatment with volar locking plate for these types of patients with an unstable distal radius fracture is recommended.

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Table 1. Search strategy

Medline

((((distal[Title/Abstract]) AND fracture*[Title/Abstract]) AND ((radius[Title/Abstract]) OR radial[Title/Abstract])) OR (((((colles'
fracture*[Title/Abstract]) OR colles fracture*[Title/Abstract]) OR smith fracture*[Title/Abstract]) OR barton fracture*[Title/Abstract]) OR wrist fracture*[Title/Abstract])) AND (((volar[Title/Abstract]) OR palmar[Title/Abstract]) OR palmer[Title/Abstract]) AND ((((external fix*[Title/Abstract]) OR fixation ext*[Title/Abstract]) OR fixateur ext*[Title/Abstract]) OR fixator ext*[Title/Abstract])

EMBASE

((((distal.ti,ab) AND fracture*.ti,ab) AND ((radius.ti,ab) OR radial.ti,ab)) OR (((((colles' fracture*.ti,ab) OR colles fracture*.ti,ab) OR smith fracture*.ti,ab) OR barton fracture*.ti,ab) OR wrist fracture*.ti,ab)) AND (((volar.ti,ab) OR palmar.ti,ab) OR palmer.ti,ab) AND ((((external fix*.ti,ab) OR fixation ext*.ti,ab) OR fixateur ext*.ti,ab) OR fixator ext*.ti,ab)

Cochrane Central Register of Controlled Trials

(distal:ti,ab,kw and fracture*:ti,ab,kw) AND (radius:ti,ab,kw or radial:ti,ab,kw or ''Colles' fracture*'':ti,ab,kw or ''Colles fracture*'':ti,ab,kw
or ''Barton's fracture'':ti,ab,kw or smith fracture*:ti,ab,kw or ''Smith's fracture*'':ti,ab,kw or wrist fracture*:ti,ab,kw) AND
(''volar'':ti,ab,kw or ''palmar'':ti,ab,kw or ''Palmer'':ti,ab,kw) AND (extern*:ti,ab,kw or ''fixation'':ti,ab,kw or ''fixator'':ti,ab,kw or
fixat*:ti,ab,kw)

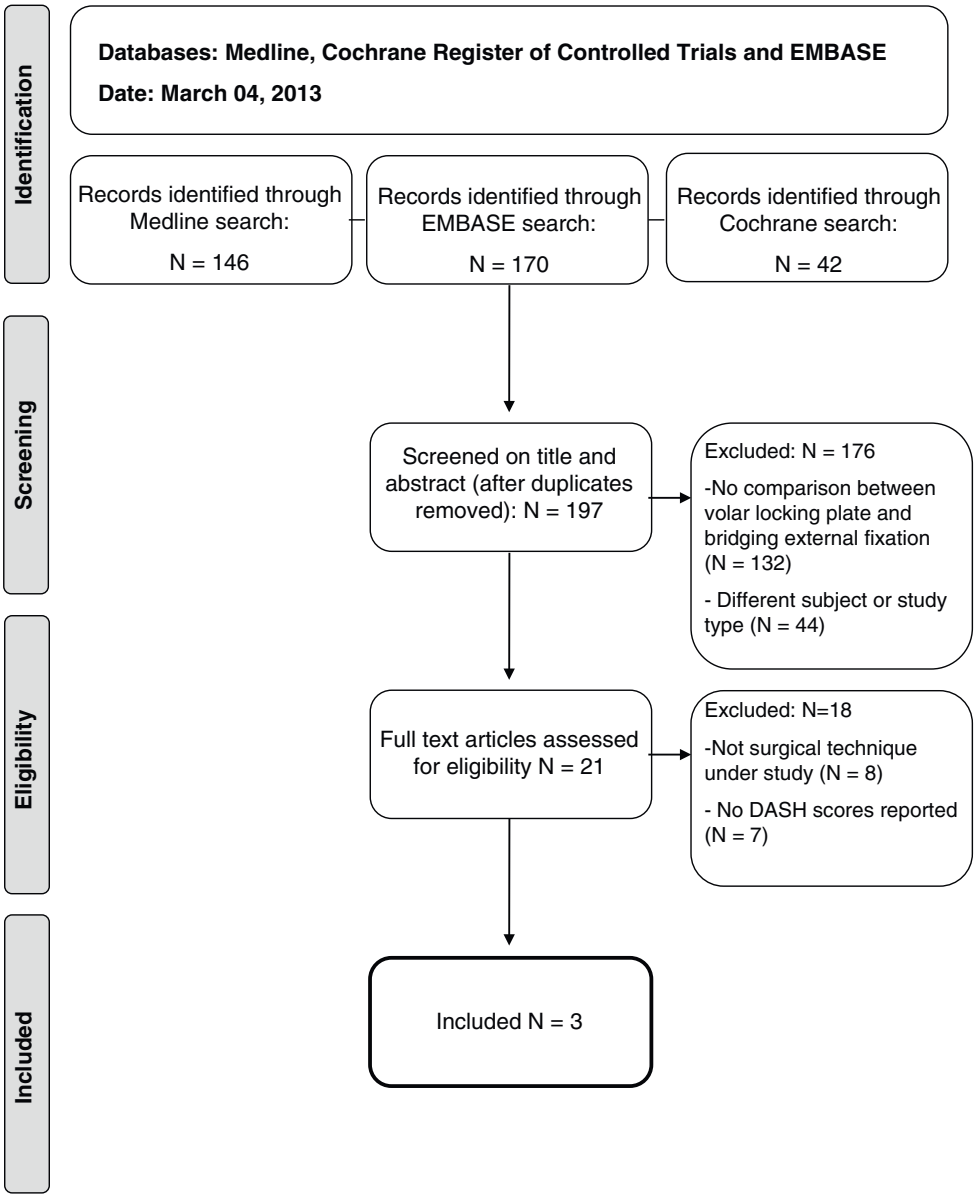

Fig. 1 Flow diagram of in- and excluded studies

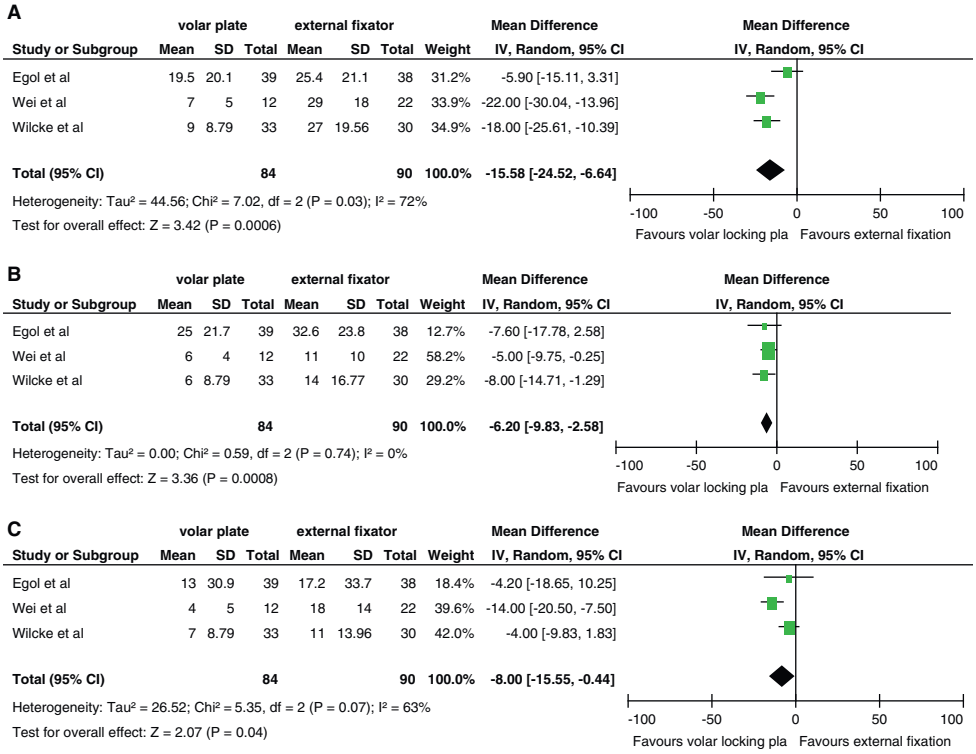

Fig. 2 DASH scores at 3, 6 and 12 months. a Table and forest plot illustrating functional outcome based on DASH scores comparing external fixation with a volar locking plate at 3 months with a random effects model. b Table and forest plot illustrating functional outcome based on DASH scores comparing external fixation with a volar locking plate at 6 months with a random effects model. c Table and forest plot illustrating functional outcome based on DASH scores comparing external fixation with a volar locking plate at 12 months with a random effects model. *SD* standard deviation, *CI* confidence interval, *df* degrees of freedom, *IV* inverse variance

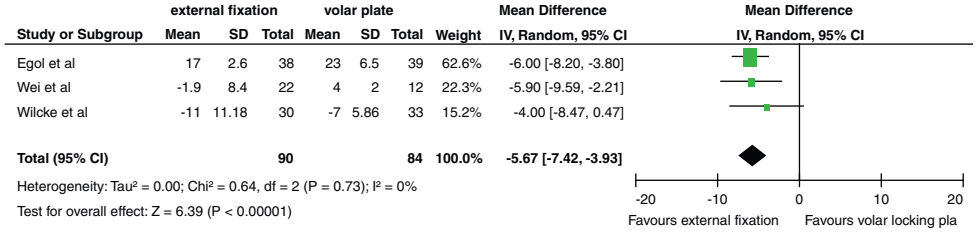

Fig. 3 Volar tilt. Table and forest plot illustrating radiographic outcome based on volar tilt comparing external fixation with a volar locking plate at 12 months with a random effects model. The found difference of six degrees indicates a more accurate anatomical reconstruction of the volar tilt after treatment with a volar locking plate. *SD* standard deviation, *CI* confidence interval, *df* degrees of freedom, *IV* inverse variance

Table 3. For the secondary outcomes such as grip strength, flexion, extension, radial inclination, ulnar variance and radial length, no significant differences were demonstrated

Outcome	Number of studies	Mean difference
Grip strength as percentage of uninjured side	3	-1.73 (-12.27, 15.73)
Flexion (degrees)	2	0.44 (-4.66, 5.53)
Extension (degrees)	2	4.46 (-5.21, 14.14)
Radial inclination (degrees)	2	-2.06 (-4.6, 0.49)
Ulnar variance (mm)	3	-0.086 (1.82, 0.10)
Radial length (mm)	3	-0.96 (-1.96, 0.04)

Table 4. Complications

Complication	ORIF with volar locking plate (N)	Bridging external fixator (N)
Pin tract infection		9
Deep infection	1	
Ruptured extensor/flexor	3	1
pollicis longus tendon CRPS Ia		3
Nonunion	1	1
Painful retained hardware	4	
CTSb	2	
Tenolysis for postoperative stiffness		1
Malunion		4
Tendinitis	1	1
Total	17/84 (20 %)	23/90 (26 %)

[a] Complex regional pain syndrome type 1

[b] Carpal tunnel syndrome

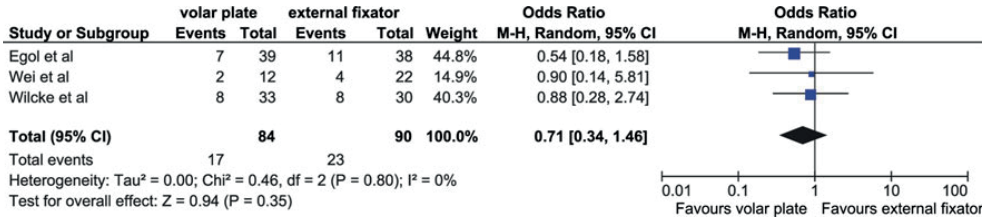

Fig. 4 Complications. Table and forest plot illustrating the complication rate comparing treatment with external fixation with a volar locking plate with a random effects model. *CI* confidence interval, *df* degrees of freedom, *M–H* Mantel–Haenszel

APPENDICES

SUMMARY

PART I Incidence and management of distal radius fractures in the Netherlands

In **Chapter 1** we performed a population-based study to estimate the overall and type-specific incidences of distal radius fractures in an urban population in the Netherlands. During 2009, all persons aged ≥18 years with an acute distal radius fracture were prospectively registered in two hospitals in the Netherlands In 2009, the mid-year study population consisted of 245,559 inhabitants ≥18 years old. Fractures were categorized according to the AO classification. 494 patients with acute distal radius fractures were registered in the two participating hospitals during the 1-year study period. The overall incidence of distal radius fracture was 20 per 10,000 person-years. Among women, the incidence rate increased from the age of 50 and reached a peak of 124 per 10,000 person-years in women 80 years and older. The incidence rate among women between 50 and 79 years was 54/10,000 person-years. Among men, the incidence rate was low until the age of 80 years and older, and reached a peak of 24 per 10,000 person-years. Extra-articular AO type A fractures were most common among all age groups, comprising 50 % of all fractures (40% in men and 53% in women). The incidence of distal radius fractures increases with age for both women and men. However, a lower incidence rate among women 50-79 years of age was found than previously reported in several other studies, which may indicate a declining incidence in this particular age group.

In **Chapter 2** we conducted a retrospective cohort study to compare the practice variation of surgical treatment of distal radius fractures between three Dutch hospitals, including one academic hospital. Almost half of the distal radius fractures was extra-articular (AO/OTA type A2-3) and 61% of fractures were displaced. Of all patients who sustained a distal radius fracture, 14% were treated operatively. Significantly more patients were treated operatively in the academic hospital in comparison to the teaching and non-teaching hospital. The difference could probably be explained by the variation in fracture patterns and associated injuries, indicating that academic hospitals have a larger number of severely injured patients. However, in our study we corrected for fracture severity and still found a higher operative rate in the academic hospital compared to the teaching and non-teaching hospital. This remains an unexplained practise variation.

Part II Outcome and complications of distal radius fractures

To determine patient related outcome measures (PROMs) following a distal radius fracture, it is important to use validated tools such as the Quick Disability of Arm, Shoulder and Hand (QuickDASH) and Patient-Related Wrist Evaluation (PRWE) scores.

In **chapter 3** we conducted a retrospective study to assess the association between PROMs, measured with the QuickDASH questionnaire, and radiological criteria in patients with extra-articular distal radial fractures. A consecutive series of 385 patients were initially treated non-operatively for an extra-articular distal radial fracture and 257 (69 %) patients were included in the study. In 203 of these patients (78%) the quality of radiographic reduction was judged

to be adequate by radiological parameters, which included dorsal tilt, radial inclination, and radial shortening. In 54 patients (22%) the quality of radiographic alignment was judged to be inadequate. We observed no effect of radiographic parameters on the PROMs. Female sex and longer duration of follow-up (>35 months) were the only independent prognostic factors significantly associated with a worse QuickDASH score.

In **chapter 4** We conducted a randomized controlled trial to evaluate whether the duration of cast immobilization for patients with non- or minimally displaced distal radial fractures can be safely shortened toward 3 weeks. The primary outcomes were patient-reported outcomes measured by the PRWE and QuickDASH score after 1-year follow-up. Secondary outcome measures were: PRWE and QuickDASH earlier in follow-up, pain (Visual Analog Scale), and complications like secondary displacement. Seventy-two patients (male/female, 23/49; median age, 55 years) were included and randomized. Sixty-five patients completed the 1-year follow-up. After 1-year follow up, patients in the 3 weeks immobilization group had significantly better PRWE (5.0 vs. 8.8 points, $p = 0.045$) and QuickDASH scores (0.0 vs. 12.5, $p = 0.026$). Secondary displacement occurred once in each group. Pain did not differ between groups ($p = 0.46$). Shortening the period of immobilization in adult patients with a non- or minimally displaced distal radial fractures seems to lead to equal patient-reported outcomes for both the cast immobilization groups. Correspondingly, there are no negative side effects of a shorter period of cast immobilization. Therefore, we recommend a period of 3 weeks of immobilization in patients with non- or minimal displaced distal radial fractures.

In **chapter 5** we performed a systematic review to assess the prevalence of complications following volar locking plate fixation of distal radial fractures. A computer-based search was carried out using EMBASE and PUBMED/MEDLINE. Only comparative and prospective cohort studies that presented data concerning complications following treatment of distal radial fractures with a volar locking plate in adults with a minimal follow-up of 6 months were included. Two quality assessment tools were used to assess the methodological quality of the studies (level of evidence rating according to the Oxford Centre of Evidence Based Medicine and the modified version of the Cochrane Bone, Joint and Muscle Trauma Group's former quality assessment tool). An adequate duration of follow-up was considered a minimum of six months which applied to all studies. Three studies were graded the strongest of selected studies and of highest scientific quality. Thirty three studies were eligible for final assessment. The majority of studies had well-defined inclusion and exclusion criteria, interventions and outcome measures Most complications were nerve and tendon associated as well as complex regional pain syndrome. Based on the overall numbers of reported minor and major complications, we conclude that volar locking plate fixation is a reasonably safe treatment option for patients with distal radial fractures. However, an overall complication rate of 16.5% is considerable and should be taken into account.

In **chapter 6** we performed a literature study to compare bridging external fixation with volar

locked plating in patients with unstable distal radial fractures regarding functional outcome. A systematic search was performed in the Cochrane Central Register of Controlled Trials, Medline and EMBASE. All randomized controlled trials comparing bridging external fixation directly with volar locked plating in patients with distal radial fractures were considered. Three reviewers extracted data independently from eligible studies using a data collection form. Studies in which the primary endpoint was measured on DASH score at 3, 6 and 12 months were included in the analysis. Three studies involving 174 patients were analyzed. Ninety patients were treated with an (augmented) bridging external fixator and 84 with a volar locking plate. Data were analyzed with the random effects model. The robustness of the results was explored using a sensitivity analysis. Patients treated with a volar locking plate showed significantly lower DASH scores at all times. A difference of 16 ($p = 0.006$), six ($p = 0.008$) and eight points ($p = 0.06$) was found at 3, 6 and 12 months follow-up, respectively. Patients treated with a volar locking plate showed significantly better functional outcome throughout the entire follow-up. However, this difference was only clinically relevant during the early postoperative period (3 months).

GENERAL DISCUSSION

IMPLICATIONS AND FUTURE PERSPECTIVES

Implications

The implications of this thesis will be demonstrated in the following case. Two 60 year old female patients sustained a distal radius fracture (DRF), which happens regularly due to an incidence rate of 54/10,000 person-years **(Chapter 1)**. At the Emergency Department of two different hospitals a wrist radiograph was made, which showed a displaced extra-articular distal radius fracture in both patients. Both fractures were reduced using traction and manipulation in a closed manner. The quality of radiographic reduction was judged to be adequate according to the Dutch guidelines in both patients. One patient was treated operatively with a volar locking plate, while the other patient was treated non-operatively with a plaster for 6 weeks **(Chapter 1, 2).** The operating surgeon told the resident that a volar plate leads to better initial results than an external fixator **(Chapter 6).** However, in case of an non or minimal displaced extra -articular fracture the patient could be safely treated with a plaster for three weeks. **(Chapter 4)** . The resident also understood from the surgeon that the VIPER study showed that operatively-treated patients with an acceptably reduced extra-articular distal radius fracture have better patient-reported outcomes compared to nonoperatively-treated patients after three months with a PRWE score of 11 vs 33 respectively, and after one year of 4 versus 10 points. Furthermore, that loss of reduction following conservative treatment has been reported in up to 64%. The non-operating surgeon, however, stated that there is no relation between radiographic parameters and patient related outcome **(Chapter 3)**. Moreover the surgeon pointed out that operative treatment with a locking plate has a chance of 17 percent on a complication **(Chapter 5)**. After one year of follow up both patients were satisfied with their treatment and had good patient related outcome.

First, also in case of DRF more roads lead to Rome. Second, there still is no unambiguous policy in the treatment of DRF due to several reasons. We will elaborate on this topic in the "Future perspectives" section. As a result of this absence of unequivocal strategy there is a great difference in treatment variety between Dutch hospitals.

Future perspectives

There is a considerable difference in treatment of patients with a distal radius fracture in the Netherlands [1]. To minimize this variation in treatment, scientific evidence should be provided and integrated in national guidelines. Future studies should aim on the cost effectiveness of each treatment modality corrected for age, gender, occupation and patients demands. Also patient preference should be considered as highly important to support shared decision making between doctors and patients. Especially because there is no strict correlation between radiographic parameters and PROM, particularly in the elderly [2,3]. Furthermore, in the absence of a well-defined and validated definition of what is an acceptable reduction, international guidelines use different radiological thresholds. Future research should therefore aim on finding

specific thresholds for radiological parameters which correlate with patient-reported functional outcome. These parameters should not only include the regular parameters such as radial inclination, dorsal and volar tilt and radial shortening, but also carpal alignment and coronal plane translation as stated in a recent study [4] .

According to demographics provided by the Australian Bureau of Statistics and the projected incidence of distal radius fractures in the United States, it is expected that the incidence of distal radius fracture will double over the next 25 years [5]. Consequently, the financial and public burden of distal radius fractures is significant. Therefore, this topic merits further research to develop better models to predict the risks of redisplacement and to support shared decision making between doctors and patients. However, one should take into consideration that there is no strict correlation between radiographic parameters and PROM, especially in the elderly [2,3].

In the first chapter of this thesis we found that patients older than 79 years had the highest risk for a distal radius fracture. With the ageing of the population the clinical context of this matter may be of great relevance. In the elderly other biological factors like osteoporosis and comorbidity may interfere with functional outcome. Since little is known about geriatric wrist fractures, the observed changes in epidemiological trends stress the need for research into these clinically important risk groups.

Unsatisfactory radiographic outcomes in older patients with DRF do not automatically result into unsatisfactory functional outcomes and conservative treatment may be the preferred method of treatment in the elderly [2,3]. However, when the injury affects daily activities and hinders independency an operation in this age group may be significant. Not only patient age but especially patient demands should be taken into account to realize a tailor made treatment of adult patients with DRF. Also this topic merits further research.

There is a French saying: *'La meilleure technique est la technique que tu connais le mieux'*. (The best technique is the one you know best). In case of DRF the surgeons preference plays an important role in the choice of treatment of DRF. Both conservative and surgical treatment of DRF lead to good functional results. Although loss of reduction following conservative treatment has been reported in up to 64% [6,7,8], there is no strict correlation between radiographic parameters and PROM, especially in the elderly [2,3]. Moreover, as stated in this thesis, operative treatment of DRF has a considerable chance on a complication. We are still not able to predict which DRF are at risk of redisplacement, thus we still lack evidence for best treatment option.

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SAMENVATTING, IMPLICATIES EN TOEKOMSTPERSPECTIEVEN

DEEL I Incidentie en behandeling van distale radiusfracturen in Nederland

In **hoofdstuk 1** hebben we een populatie-gebaseerde studie uitgevoerd om de algemene en specifieke incidentie van distale radiusfracturen in een stedelijke omgeving in Nederland te schatten. In 2009 werden alle personen van 18 jaar en ouder met een acute distale radiusfractuur prospectief geregistreerd in twee ziekenhuizen in Nederland. In 2009 bestond de halfjaarlijkse studiepopulatie uit 245.559 inwoners van 18 jaar en ouder. Fracturen werden gecategoriseerd volgens de AO-classificatie. Tijdens de onderzoeksperiode van één jaar werden 494 patiënten met acute distale radiusfracturen geregistreerd in de twee deelnemende ziekenhuizen. De totale incidentie van distale radiusfracturen was 20 per 10.000 persoonsjaren. Bij vrouwen nam de incidentie toe vanaf de leeftijd van 50 jaar en bereikte een piek van 124 per 10.000 persoonsjaren bij vrouwen van 80 jaar en ouder. De incidentie bij vrouwen tussen 50 en 79 jaar was 54 / 10.000 persoonsjaren. Bij mannen was de incidentie laag tot de leeftijd van 80 jaar en ouder, en bereikte een piek van 24 per 10.000 persoonsjaren. Extra-articulaire AO type A-fracturen kwamen het meest voor bij alle leeftijdsgroepen, en omvatten 50% van alle fracturen (40% bij mannen en 53% bij vrouwen). De incidentie van distale radiusfracturen neemt toe met de leeftijd voor zowel vrouwen als mannen. Er werd echter een lagere incidentie gevonden bij vrouwen van 50-79 jaar dan eerder werd gerapporteerd in verschillende andere onderzoeken, wat kan wijzen op een afnemende incidentie in deze specifieke leeftijdsgroep.

In **hoofdstuk 2** hebben we een retrospectieve cohortstudie uitgevoerd om de praktijkvariatie van chirurgische behandeling van distale radiusfracturen tussen drie Nederlandse ziekenhuizen, waaronder één academisch ziekenhuis, te vergelijken. Bijna de helft van de distale radiusfracturen was extra-articulair (AO / OTA type A2-3) en 61% van de fracturen was gedislokeerd. Van alle patiënten die een distale radiusfractuur opliepen, werd 14% operatief behandeld. In het academisch ziekenhuis werden beduidend meer patiënten operatief behandeld dan in het opleidings- en niet-opleidingsziekenhuis. Het verschil zou waarschijnlijk verklaard kunnen worden door de variatie in ernst van de fracturen en bijbehorende verwondingen, wat zou kunnen liggen in het feit dat academische ziekenhuizen een groter aantal ernstig gewonde patiënten opvangen. In onze studie hebben we echter gecorrigeerd voor de ernst van de fractuur en vonden we nog steeds een hoger aantal operaties in het academisch ziekenhuis in vergelijking met de andere twee ziekenhuizen. Dit blijft een onverklaarde praktijkvariatie.

Deel II Uitkomsten en complicaties van de behandeling van distale radiusfracturen

Om patiënt gerapporteerde uitkomstmaten te bepalen na een distale radiusfractuur, is het belangrijk om gevalideerde tools te gebruiken zoals Quick Disability of Arm, Shoulder and Hand (QuickDASH) en Patient Related Wrist Evaluation (PRWE) scores.

In **hoofdstuk 3** hebben we een retrospectieve studie uitgevoerd om de associatie tussen patiënt gerapporteerde uitkomstmaten, gemeten met de QuickDASH-vragenlijst, en radiologische criteria bij patiënten met extra-articulaire distale radiale fracturen te beoordelen. Een opeenvolgende reeks van 385 patiënten werd aanvankelijk niet-operatief behandeld voor een extra-articulaire distale radiale fractuur en 257 (69%) patiënten werden in het onderzoek geïncludeerd. Bij 203 van deze patiënten (78%) werd de kwaliteit van de repositie op basis van radiologische criteria als voldoende beoordeeld. Bij 54 patiënten (22%) werd de kwaliteit van de repositie op basis van radiologische criteria als onvoldoende beoordeeld. We zagen geen correlatie tussen radiografische parameters en de patiënt gerapporteerde uitkomstmaten. Vrouwelijk geslacht en een langere follow-up (> 35 maanden) waren de enige onafhankelijke prognostische factoren die significant geassocieerd waren met een slechtere QuickDASH-score.

In **hoofdstuk 4** hebben we een gerandomiseerde gecontroleerde studie uitgevoerd om te evalueren of de duur van gips-immobilisatie voor patiënten met niet- of minimaal gedisloceerde distale radiale fracturen veilig kan worden verkort tot drie weken. De primaire uitkomsten waren door de patiënt gerapporteerde uitkomsten, gemeten aan de hand van de PRWE- en QuickDASH-score na 1 jaar follow-up. Secundaire uitkomstmaten waren: PRWE en QuickDASH eerder in de follow-up, pijn (Visual Analog Scale) en complicaties zoals secundaire dislocatie. Tweeënzeventig patiënten (man / vrouw, 23/49; mediane leeftijd, 55 jaar) werden geïncludeerd en gerandomiseerd. Vijfenzestig patiënten voltooiden de follow-up van 1 jaar. Na 1 jaar follow-up hadden patiënten in de immobilisatie-groep van 3 weken significant betere PRWE (5,0 vs. 8,8 punten, $p = 0,045$) en QuickDASH-scores (0,0 vs. 12,5, $p = 0,026$). Secundaire dislocatie trad eenmaal op in elke groep. Pijnsensatie verschilde niet tussen de groepen ($p = 0,46$). Het verkorten van de immobilisatieperiode bij volwassen patiënten met een niet of minimaal gedisloceerde distale radiale fractuur lijkt te leiden tot gelijke door de patiënt gerapporteerde uitkomsten voor beide groepen. Dienovereenkomstig zijn er geen negatieve effecten van een kortere periode van immobilisatie. Daarom raden we een periode van drie weken immobilisatie aan bij patiënten met niet of minimaal gedisloceerde distale radiale fracturen.

In **hoofdstuk 5** hebben we een systematische review uitgevoerd om de prevalentie van complicaties na volaire plaatfixatie van distale radiale fracturen te beoordelen. Er is een zoekopdracht uitgevoerd met EMBASE en PUBMED / MEDLINE. Alleen vergelijkende en prospectieve cohortstudies die gegevens presenteerden over complicaties na behandeling van distale radiale fracturen met een volaire plaat bij volwassenen met een minimale follow-up van zes maanden, werden geïncludeerd. Er werden twee instrumenten gebruikt om de

methodologische kwaliteit van de onderzoeken te beoordelen (bewijskrachtbeoordeling volgens het Oxford Centre of Evidence Based Medicine en de aangepaste versie van de voormalige kwaliteitsbeoordelingstool van de Cochrane Bone, Joint and Muscle Trauma Group). Een adequate follow-upduur van minimaal zes maanden werd als adequaat beschouwd. Drieëndertig onderzoeken kwamen in aanmerking voor de eindbeoordeling. De meeste complicaties waren zenuw- en peesgerelateerd, evenals complex regionaal pijnsyndroom. Op basis van het totale aantal gemelde kleine en grote complicaties, concluderen we dat volaire plaatfixatie een redelijk veilige behandelingsoptie is voor patiënten met distale radiale fracturen. Een totaal complicatiepercentage van 16,5% is echter aanzienlijk en hiermee moet rekening worden gehouden. De meeste onderzoeken hadden duidelijk gedefinieerde in- en uitsluitingscriteria, interventies en uitkomstmaten. Drie studies werden beoordeeld als de beste van geselecteerde studies met de hoogste wetenschappelijke kwaliteit.

In **hoofdstuk 6** hebben we een studie uitgevoerd om overbruggende externe fixatie te vergelijken met volaire platen bij patiënten met onstabiele distale radiale fracturen wat betreft functionele uitkomst. Er werd systematisch gezocht in het Cochrane Central Register of Controlled Trials, Medline en EMBASE. Alle gerandomiseerde gecontroleerde onderzoeken waarbij overbrugging met externe fixatie werd vergeleken met behandeling met volaire platen bij patiënten met distale radiale fracturen werden beschouwd. Drie beoordelaars hebben onafhankelijk van elkaar van in aanmerking komende onderzoeken gegevens opgehaald met behulp van een gegevensverzamelingsformulier. Studies waarin het primaire eindpunt werd gemeten op de DASH-score na 3, 6 en 12 maanden, werden in de analyse opgenomen. Er werden drie onderzoeken met 174 patiënten geanalyseerd. Negentig patiënten werden bejegend met een overbruggende fixateur externe en 84 met een volaire plaat. De gegevens werden geanalyseerd met het random effects-model. De robuustheid van de resultaten is onderzocht met behulp van een gevoeligheidsanalyse. Patiënten die met een volaire plaat werden behandeld, vertoonden te allen tijde significant lagere DASH-scores. Een verschil van 16 ($p = 0,006$), zes ($p = 0,008$) en acht punten ($p = 0,06$) werd gevonden na respectievelijk 3, 6 en 12 maanden follow-up. Patiënten die werden behandeld met een volaire plaat lieten een significant beter functioneel resultaat zien gedurende de gehele follow-up. Dit verschil was echter alleen klinisch relevant tijdens de vroege postoperatieve periode (3 maanden).

Implicaties

Twee 60-jarige vrouwelijke patiënten liepen een distale radiusfractuur op. Een fractuur die regelmatig voorkomt met een incidentie van 54/10.000 persoonsjaren **(Hoofdstuk 1)**. Op de afdeling spoedeisende hulp van twee verschillende ziekenhuizen werd een polsfoto gemaakt, die bij beide patiënten een gedisloceerde extra-articulaire distale radiusfractuur liet zien. Beide fracturen werden gereponeerd door middel van tractie en manipulatie. De kwaliteit van de repositie werd bij beide patiënten adequaat beoordeeld conform de Nederlandse richtlijnen. De ene patiënt werd operatief behandeld met een volaire plaat, terwijl de andere patiënt conservatief werd behandeld met gips gedurende zes weken **(Hoofdstuk 1, 2)**. De opererende chirurg

vertelde de opleiding-assistent dat een volaire plaat tot betere resultaten leidt dan een fixateur externe **(hoofdstuk 6)**. In het geval van een niet of minimaal gedisloceerde extra-articulaire fractuur kan de patiënt veilig gedurende drie weken in gips worden behandeld **(Hoofdstuk 4)**. De chirurg voegde eraan toe dat de VIPER-studie heeft aangetoond dat operatief behandelde patiënten met een succesvol gereponeerde extra-articulaire distale radiusfractuur betere functionele uitkomsten hebben in vergelijking met conservatief behandelde patiënten met na drie maanden een PRWE-score van 11 versus 33 respectievelijk, en na één jaar van 4 versus 10 punten. Bovendien is redislocatie na conservatieve behandeling gemeld bij maximaal 64% van de gevallen. De niet-opererende chirurg verklaarde echter dat er geen verband bestaat tussen radiografische parameters en door de gerapporteerde functionele uitkomsten **(hoofdstuk 3)**. Bovendien wees deze chirurg erop dat operatieve behandeling met een volaire plaat 17 procent kans heeft op een complicatie **(hoofdstuk 5)**. Na een jaar follow-up waren beide patiënten tevreden met hun behandeling en hadden beiden een goed functioneel resultaat.
Ook bij de behandeling van DRF leiden er meerdere wegen naar Rome. Voorts is er tot op heden, om meerdere redenen, geen eenduidig beleid ten aanzien van de behandeling van DRF. In het hoofdstuk "Toekomstperspectieven" zullen wij hier dieper op ingaan. Als gevolg van het gebrek aan een eenduidig beleid is een grote variëteit in behandelingsstrategieën van DRF in Nederlandse ziekenhuizen.

Toekomstperspectieven

Er is een aanzienlijk verschil in de behandeling van patiënten met DRF in Nederland [1]. Om deze variatie in behandeling tot een minimum te beperken, moet wetenschappelijk bewijs worden geleverd en geïntegreerd in nationale richtlijnen. Toekomstige studies moeten gericht zijn op de kosteneffectiviteit van elke behandelingsmodaliteit, gecorrigeerd voor leeftijd, geslacht, beroep en de behoeften van de patiënt. Ook moet de voorkeur van de patiënt als zeer belangrijk worden beschouwd om de gedeelde besluitvorming tussen artsen en patiënten te ondersteunen. Vooral omdat er geen strikte correlatie is tussen radiografische parameters en PROM, in het bijzonder bij oudere patiënten [2,3]. Bovendien gebruiken, bij gebrek aan een goed gedefinieerde en gevalideerde definitie van wat een aanvaardbare repositie is, internationale richtlijnen verschillende radiologische criteria. Toekomstig onderzoek moet daarom gericht zijn op het vinden van specifieke drempelwaarden voor radiologische parameters die correleren met de functionele uitkomst. Deze parameters zouden niet alleen de reguliere parameters moeten omvatten zoals radiale inclinatie, dorsale en volaire kanteling en radiale verkorting, maar ook carpale uitlijning en coronale vlak translatie zoals vermeld in een recente studie [4].

Volgens de demografische gegevens van het Australische Bureau voor de Statistiek en de verwachte incidentie van distale radiusfracturen in de Verenigde Staten, wordt geschat dat de incidentie van distale radiusfracturen de komende 25 jaar zal verdubbelen [5]. Bijgevolg is de aanzienlijke financiële en publieke last van distale radiusfracturen. Daarom verdient dit

onderwerp verder onderzoek om betere modellen te ontwikkelen om de risico's van redislocatie te voorspellen en om gedeelde besluitvorming tussen artsen en patiënten te ondersteunen. Men moet er echter rekening mee houden dat er geen strikte correlatie bestaat tussen radiografische parameters en patiënt gerapporteerde functionele uitkomsten, vooral niet bij ouderen [2,3].

In het eerste hoofdstuk van dit proefschrift beschreven we dat patiënten ouder dan 79 jaar het hoogste risico hebben op een distale radiusfractuur. Met de vergrijzing van de bevolking kan de klinische context van deze kwestie van groot belang zijn. Bij ouderen kunnen andere biologische factoren, zoals osteoporose en comorbiditeit, de functionele uitkomsten verstoren. Aangezien er weinig bekend is over geriatrische polsfracturen, onderstrepen de waargenomen veranderingen in epidemiologische trends de noodzaak van onderzoek naar deze klinisch belangrijke risicogroepen. Onbevredigende radiografische resultaten bij oudere patiënten met DRF leiden niet automatisch tot onbevredigende functionele resultaten en conservatieve behandeling kan de voorkeursbehandeling zijn bij ouderen [2,3]. Wanneer het letsel echter de dagelijkse activiteiten beïnvloedt en de onafhankelijkheid belemmert, kan een operatie in deze leeftijdsgroep van belang zijn. Er moet niet alleen rekening worden gehouden met de leeftijd van de patiënt, maar vooral met de behoeften van de patiënt om een op maat gemaakte behandeling van volwassen patiënten met DRF te realiseren. Ook dit onderwerp verdient nader onderzoek.

Er is een Frans gezegde: 'La meilleure technique est la technique que tu connais le mieux'. (De beste techniek is degene die u het beste beheerst). Bij DRF speelt de voorkeur van de chirurg een belangrijke rol bij de keuze van de behandeling van de DRF. Zowel conservatieve als chirurgische behandeling van DRF leiden tot goede functionele resultaten. Hoewel redislocatie na conservatieve behandeling is gemeld bij maximaal 64% van de gevallen [6,7,8], is er geen strikte correlatie tussen radiografische parameters en patiënt gerapporteerde functionele uitkomsten en in het bijzonder bij oudere patiënten [2,3]. Bovendien, zoals vermeld in dit proefschrift, heeft operatieve behandeling van DRF een aanzienlijke kans op complicaties. We kunnen nog steeds niet voorspellen welke DRFen het risico lopen op redislocatie, dus het ontbreekt ons nog steeds aan overtuigend bewijs voor de beste behandelingsoptie.

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PhD PORTFOLIO

Name PhD student: Abdelali Bentohami
PhD supervisor: Prof. dr. J.C. Goslings

	Year	Workload (ECTS)
PhD training		
General courses		
Good Clinical Practice	2008	0.25
Kritisch lezen	2009	0.25
SPSS	2012	1.0
Specific courses		
Dissectie en toegangschirurgie van de bovenste extremiteit. Wenckebach Instituut, Groningen	2009	1.0
Specialty Course Hoofd Hals Chirurgie (AMC)	2010	1.0
Stryker advanced course (More than basic)	2011	1.0
“Introductie en Hands-on arthroscopie” (Nederlandse Vereniging voor Arthroscopie)	2012	1.0
AO-Trauma – Foot and Ankle Advanced Symposium	2012	1.0
Stry		
Seminars, workshops and masterclasses		
Monthly research meetings Trauma Unit	2009-2011	1.0
Surgery in Low Resource Settings	2013	0.5
Dutch Chapter of the International College of Surgeons	2016	0.25
Oral presentations		
NVvH, Succesvolle controle van een Clostridium difficile type 027 uitbraak door cohort isolatie van geïnfecteerde patiënten	2007	0.5
ESTES, Antalya, Radiological criteria for acceptable reduction of extra-articular distal radial fractures are not predictive for patient-reported functional outcome.	2008	0.5
Rabat, Hopital Cheikh Zayd, Radiological criteria for acceptable reduction of extra-articular distal radial fractures are not predictive for patient-reported functional outcome.	2009	0.5
Traumadagen, Radiological criteria for acceptable reduction of extra-articular distal radial fractures are not predictive for patient-reported functional outcome.	2009	0.5
NVvh, Amsterdam Wrist Rules, a clinical decision aid	2011	0.5

Tanger, Fractures of distal radius fracture: an overview	2013	0.5
Casablanca, Surgical treatment of intra-articular distal radius fractures	2016	0.5
Poster Presentations		
ECCMID Munich, Successful control of a Clostridium difficile type 027 outbreak by cohort isolation of infected patients	2007	0.5
(Inter)national conferences		
Voorjaarsvergadering NVvH	2007-2019	6.5
Najaarsvergadering NVvH	2007-2019	3.25
Traumadagen	2007-2019	6.5
The 17th European Congress of Clinical Microbiology and Infectious Diseases together with the 25th International Congress of Chemotherapy, Munich, Germany	2007	0.5
Voorjaarsvergadering Nederlandse Vereniging voor Medische Microbiologie, Papendal, Arnhem	2007	0.25
ESTES[1] Antalya/ Turkey	2009	0.75
ESTES Brussels/ Belgium	2010	0.75
ESTES Milan/ Italy	2011	0.75
ESTES Basel/ Switzerland	2012	0.75
ESTES Lyon/ France	2013	0.75
ESTES Frankfurt/ Germany	2014	0.75
ESTES Amsterdam/ The Netherlands	2015	0.75
ESTES Valencia/ Spain	2018	0.75
World Federation of Associations of Pediatric Surgeons (WOFAPS), Qatar	2019	1.0
Teaching		
AO classification of fractures, Casablanca	2014	0.5
Management of hip fractures, Marrakech	2015	0.5
Management of distal radial fractures, Casablanca	2015	0.5
Management of distal radial fractures, Tanger	2016	0.5
Laparoscopic cholecystectomy, Agadir	2017	0.5
Management of upper extremity fractures, Casablanca	2017	0.5
Achilles tendon rupture, the Amsterdam way, Casablanca	2018	0.5
Awards		
Best oral presentation, Traumadagen	2009	

[1] European society for trauma and emergency surgery

DANKWOORD

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Curriculum Vitae

Abdelali Bentohami werd geboren op 26 oktober 1978 te Amsterdam. Na het eindexamen Atheneum in 1996 aan het Pieter Nieuwland College in Amsterdam, begon hij in 1998 aan zijn studie Geneeskunde aan de Vrije Universiteit in Amsterdam. In 2005 haalde hij zijn artsexamen, waarna hij als arts-assistent werkzaam was op de afdeling Heelkunde van het Spaarne Ziekenhuis te Hoofddorp. In 2007 begon hij aan de opleiding tot chirurg in het Spaarne Ziekenhuis (opleider: dr. G.J.M Akkersdijk) en in het AMC (Opleider: Prof. Dr. O. Busch). In 2013 rondde hij zijn opleiding tot chirurg af en in dat zelfde jaar richtte hij de zelfstandig behandelcentra van Bento Clinics op. In 2010 richtte hij stichting Santé Pour Tous op. Santé Pour Tous is een medische hulporganisatie die chirurgische interventies doet bij arme patiënten in Marokko en ook de kwaliteit van de medische zorg in Marokko probeert te verbeteren. Onder de vlag van Santé Pour Tous en Bento Clinics voert Abdelali jaarlijks vele chirurgische procedures uit in Nederland en Marokko.