From the Department of Clinical Science and Education,
Södersjukhuset, Karolinska Institutet,
Stockholm, Sweden

WRIST FRACTURES:
ASPECTS OF SURGICAL METHODS AND OUTCOME

Cecilia Mellstrand Navarro

Karolinska Institutet

Stockholm, 2014

Published by Karolinska Institutet. Printed by Åtta.45 Tryckeri AB, 170 65 Solna

ISBN 978-91-7549-543-9

To my family

Institutionen för klinisk forskning och utbildning, Södersjukhuset

Wrist fractures: Aspects of surgical methods and outcome

AKADEMISK AVHANDLING

Som för avläggande av medicine doktorsexamen vid Karolinska Institutet offentligen försvaras i Södersjukhusets aula, plan 6, Sjukhusbacken 10, Stockholm

Fredagen den 13 juni, 2014, kl 09:00

av

Cecilia Mellstrand Navarro

Leg Läkare

Huvudhandledare:
Professor Sari Ponzer
Karolinska Institutet,
Institutionen för klinisk forskning och utbildning, Södersjukhuset

Bihandledare:
Docent Leif Ahrengart
Karolinska Institutet,
Institutionen för klinisk forskning och utbildning, Södersjukhuset

Professor Hans Törnkvist
Karolinska Institutet,
Institutionen för klinisk forskning och utbildning, Södersjukhuset

Fakultetsopponent:
Professor Lars Adolfsson
Linköpings Universitet,
Institutionen för klinisk och experimentell medicin

Betygsnämnd:
Docent Marie Hasselberg
Karolinska Institutet,
Institutionen för folkhälsovetenskap

Docent Carl Ekholm
Göteborgs Universitet,
Sahlgrenska Akademin, Institutionen för kliniska vetenskaper

Professor Andre Stark
Karolinska Institutet,
Institutionen för kliniska vetenskaper,
Danderyds sjukhus

Stockholm, 2014

ABSTRACT

Wrist fractures are the most frequently occurring fractures in any emergency setting. Treatment regimens range from a plaster cast to a combination of advanced surgical methods. Many fractures heal without remaining morbidity but 15 – 30% of patients report remaining disability of the hand and wrist. The aim of this thesis was to investigate the epidemiology and outcome for patients with distal radius fractures.

In Study 1, the Patient Rated Wrist Evaluation (PRWE) questionnaire was translated from English to Swedish and validated by allowing 124 patients to be investigated twice with the Disability of the Hand Arm and Shoulder (DASH) and PRWE questionnaires. The Swedish version of the PRWE (PRWE-Swe) showed good validity, stability and responsiveness. The PRWE-Swe is a useful tool for evaluating wrist fracture patients in the scope of everyday clinical practise or future research.

In Study 2, a dataset was retrieved from the Swedish National Board of Health and Welfare containing all in- and outpatient visits of patients with wrist fractures in Sweden during the years 2005 to 2010. The analysis showed that the incidence of wrist fractures in adult patients was 26 per 10 000 person years. The proportion of surgical treatment increased from 16% to 20% between 2005 and 2010. Plating procedures increased by more than threefold and the use of external fixation diminished by 67%.

In Study 3, reoperations after wrist fracture surgery were investigated by means of a nation-wide registry study. All wrist fracture patients undergoing fracture surgery during 2001 – 2009 were extracted from a dataset from the Swedish National Board of Health and Welfare. The incidence for reoperation was highest after plating and lowest after external fixation (EF). EF patients suffered early reoperations whereas plated patients were reoperated on more than 3 years after wrist fracture surgery. New fracture surgery in the early postoperative period was the most usual reoperation in EF patients. Extraction of internal fixation material occurred most frequently in plated patients. Tendon repair and median nerve release occurred more often in plated patients than in patients with EF.

In Study 4, 140 patients 50 – 74 years of age, presenting with a dorsally displaced distal radius fracture were allocated to operation with either a volar locking plate or an external fixation in the context of a randomised controlled trial. All baseline data were equal between groups. The primary outcome measure, DASH, did not differ at 3 and 12 months. The radiographic evaluation showed better restoration of radial length in the volar locking plate group. Quality of life, as measured by EQ-5D,was better for the plate group at 2 and 6 weeks but at 3 and 12 months the results were equal in both groups. Range of motion did not differ between groups at 3 months and 1 year. Grip strength was better for the volar plate group at 3 months but the difference was no longer significant at one year.

In conclusion, the PRWE is a useful patient-reported outcome measure for wrist fracture evaluation. Volar plate fixation of a wrist fracture yields faster recovery of grip strength and quality of life than external fixation but entails a higher risk of reoperations in the long term. The clinical end-result after volar plating and external fixation is equal after wrist fracture surgery in patients 50 – 74 years of age.

LIST OF PUBLICATIONS

I. **Mellstrand Navarro C**, Ponzer S, Törnkvist H, Ahrengart L, Bergström G. Measuring outcome after wrist injury: translation and validation of the Swedish version of the patient-rated wrist evaluation (PRWE-Swe).
BMC Musculoskelet Disord. 2011 Jul 22;12:171. doi: 10.1186/1471-2474-12-171.

II. **Mellstrand Navarro C**, Pettersson HJ, Törnkvist H, Ponzer S. Operative treatment of distal radial fractures is increasing: results from a Swedish nation-wide study. *Bone Joint J 2014;96-B:in press.*

III. **Mellstrand Navarro C**, Pettersson HJ, Enocson A. Complications after distal radius fracture surgery – Results from a Swedish nation-wide registry study. *Submitted.*

IV. **Mellstrand Navarro C,** Ahrengart L, Törnkvist H, Ponzer S. External fixation or volar locking plate for dorsally displaced distal radius fractures in osteoporotic patients – a randomised controlled study. *Manuscript.*

CONTENTS

LIST OF ABBREVIATIONS

ADL	Activities of Daily Living
AO	Arbeitsgemeinschaft für Osteosynthesefragen
AP	Anterioposterior
CI	Confidence Interval
EF	External Fixation
EQ-5D	EuroQuol 5 Dimensions
DASH	Disability of the Arm, Shoulder and Hand
EPL	Extensor Pollicis Longus
FPL	Flexor Pollicis Longus
HRQoL	Health Related Quality of Life
MFA	Muscular Functional Assessment
NOMESCO	Nordic Medico-Statistical Committee
PROM	Patient-Reported Outcome Measures
PRWE	Patient Rated Wrist Evaluation
RCT	Randomised Controlled Trial
ROM	Range Of Motion
SCB	Statistiska Centralbyrån
SF-36	36 items Short Form Survey
SMFA	Short Muscular Functional Assessment
VLP	Volar Locking Plate

BACKGROUND

INTRODUCTION

It is now 200 years since the wrist fracture was first described by Abraham Colles in 1814.[1] In his article "On the Fracture of the Carpal Extremity of the Radius" he described the swelling, pain and deformity typically present after a displaced distal radius fracture. For a modern surgeon, it is difficult to understand the sharpness in Colles' description of the fracture, but one must remember that the writing of his article preceded the invention of radiography by more than 80 years.

Wrist fractures are the most frequently treated fractures in any emergency setting.[2] The fracture is most frequently due to a fall onto a hyperextended wrist, with a combination of axial load and bending forces that produce the fracture of the distal metaphyseal part of the radius. Three fracture patterns are most common: Some fractures only involve a part of the articular surface, and a volar or dorsal part of the radius is still intact. This subgroup of intraarticular distal radius fractures was described by John Rhea Barton in 1838[3] and still carries his name in many publications. There is also the complete fracture of the distal radius, with a volar displacement of the distal fragment. This fracture type is named after Robert William Smith, who described the fracture pattern in 1847.[4] The most common type of wrist fractures, however, is the dorsally displaced distal radius fracture, with or without avulsion of the ulnar styloid. It is often referred to as Colles' fracture, and it constitutes some 90% of distal radius fractures. This is the fracture type that is focused on in the rest of this thesis.

Classification of wrist fractures is controversial, and no particular classification system has ever gained unanimous acknowledgement.[5] The problem with the distal radius fracture is that the available classification systems do not provide straight-forward treatment options or prognoses, and a great deal of clinical judgement and experience is necessary to define the best treatment options for wrist fractures.[5,6] Moreover, all of the classifications used for wrist fractures have been reported to entail problems concerning low intra- and interobserver reliability.[5,7,8] One classic frequently used fracture classification systems is Frykmans's classification[9], which divides wrist fractures into eight groups defined by the presence of intraarticular engagement and involvement of the ulnar styloid. Widely used is also the classification of the Swiss 'Arbeitsgemeinschaft für Osteosynthesefragen' (AO)[10] with its fundamental division into intra- and extra articular fractures with a grading dependent on the presence of comminution of the fracture. The Fernandez classification[11] is based on the injuring forces applied to the wrist at fracture, and bending, shearing, compression and avulsion mechanisms are explanations behind the groupings in this classification system. There are numerous other classification systems, such as Older's, Melone's, Mayo's, Lidstrom's, and Gartland and Werley's, and yet others, but they will not be described in more detail here.

Important features of the wrist fracture include, besides the radiological presentation, the amount of energy transmitted to the bone at the moment of fracture. High-energy injuries are more likely to produce concomitant ligamentous injuries and complex

fracture patterns, which are not always readily assessable on the primary x-ray.[12] Moreover, the quality of the bone is also of the utmost importance. In osteoporotic bone, even a moderate trauma can cause fractures that are difficult to treat, with a high risk of malunion and a poor end result. The age of the patient, the level of function in daily life and demands on the wrist are also important corner-stones in the care of a distal radius fracture patient.

EPIDEMIOLOGY

Wrist fractures occur at all ages, with peak incidences in childhood and at high ages.[2] The fracture is often due to a moderate energy injury in paediatric patients, with sports being a large contributor as the fracture mechanism.[13-16] The epiphysis constitutes a *locus minoris* in the growing population and explains the high incidence of fractures in children.[16] The incidence of distal radius fractures in children and adolescents has been reported to be approximately 40 - 90/10 000 person-years[14,16,17] with boys around 14 years of age having the highest incidence.[14-17] In young adults representing a healthy population with good bone stock, the incidence is lower,[18,19] and the fractures are often attributable to a moderate- to high-energy trauma.[19,20] After the menopause, osteoporosis is a major cause of a majority of fractures in the distal radius in women[18,21-23] with a steeply rising incidence after the age of 50.[2,24-27] The fracture incidence for women after the menopause has been reported to be as high as 60 - 120/10 000 person-years.[18,24,26,28-32]

TREATMENT OPTIONS

A wrist fracture can be treated in a variety of ways depending on the fracture properties. Treatment regimens range from an elastic bandage to a combination of advanced surgical modalities. The treatment must be carefully chosen, taking into account the fracture pattern, the patient's age and needs, the risk of future loss of function and personal preferences of the patient and surgeon.

Treatment with a cast is the most frequent choice for a wrist fracture.[33] A dorsal splint below the elbow is created and moulded around the wrist. The plaster cast provides relative stability of the fracture and, to be successful in maintaining the fracture in an anatomical position, it demands a considerable amount of inherent stability of the fracture itself.[34] The plaster cast provides effective pain release and, when properly applied, it allows a free range of motion of the elbow and fingers. It is usually kept on until the fracture has healed enough to allow range-of-motion exercises, which last approximately 4 weeks. Cast treatment is a good choice for stable fractures;[35,36] it has a low cost and complications are limited to pressure ulcers from the cast.

When presenting with a displaced fracture, patients are anaesthetised, either locally or generally, and the fracture is manipulated to return to its correct anatomical position. In stable fracture patterns, often in combination with a good bone stock, plaster treatment is sufficient to maintain the alignment of the fracture until the fracture has healed.[34] In

approximately 20% of cases, plaster treatment is not considered stable enough and a surgical intervention is initiated to avoid future malunion.[37]

A classic and minimally invasive surgical method for fracture fixation is percutaneous fixation by means of pins, or Kirschner wires. It was first described for use in wrist fractures by De Palma in the 1950's.[38] The fracture is manipulated without opening the skin over the fracture site, and thin metal rods are placed across the fracture area for stabilisation.[39-41] After the procedure, the wrist is usually put in a cast until the fracture has healed.[40] Some of the advantages with this method are that it is minimally invasive, operating times are generally short and the cost of the surgical hardware is low.[42] Drawbacks are that the hardware is not stable and there is a risk of loosening of the pins with secondary displacement of the fracture as a result.[39] The Kirschner wires can be left buried under the skin or percutaneously at the discretion of the surgeon. With protruding Kirschner wires, there is always an increased risk of superficial infection.[43] When the pins are left under the skin, they are sometimes difficult to find and extraction must be performed under local or general anaesthesia with a risk of tendon and nerve injury.[44,45] At times, pins migrate inwards and may be buried in bone and therefore become difficult or impossible to extract. Other risks connected with this method are that nerves or tendons may be injured during the procedure itself owing to the percutaneous technique: stab incisions are made and nerves and tendons are neither visualized nor retracted.[46] With a good surgical technique and careful handling of the soft tissues and metalware, this is an option for final fixation in juvenile fractures.[44,45] It is also useful as a temporary or permanent aid for reducing fractures when performing an external or internal fixation.

External fixation involves a scaffold of metal which is kept, as the name suggests, on the outside of the arm (Figure 1). It was introduced during the 1970's as a development of different pinning and casting techniques.[47] Two metal rods are introduced in the diaphysis of the radius, and two metal rods are inserted into the second metacarpal bone. The fracture is manipulated without being surgically exposed and after successful

Figure 1: External fixation of a distal radius fracture. (©Cecilia Mellstrand Navarro)

closed reduction, the external fixator is locked and the wrist is stabilised in slight traction and the fracture is held in place.[47,48] The fixation may be enhanced by percutaneous Kirschner wires. The reduction of fracture fragments is dependent on ligamentotaxis,[49] and the fact that volar ligaments are thicker and shorter than their dorsal counterparts explains why anatomical reduction of the dorsal angulation is not always possible with this method.[50] The external fixation is maintained until the unstable fracture has healed enough to allow range-of-motion exercise, usually after 5 to 6 weeks.

An advantage of the external fixation is that it is minimally invasive, and when the fixator is removed, no more hardware is present in the wrist. The surgical technique is easy to learn and the risk of intra-operative surgical complications is low[37]. A negative aspect of external fixation is that most patients find the fixation device frightening and uncomfortable. The stability of the fracture fixation is relative with a risk of secondary displacement.[37,48] The risk of serious nerve and tendon injury is low, but superficial infection in vicinity of the external fixation is reported to be around 10%. [48,51]

Open reduction and internal fixation of a distal radius fracture is becoming increasingly popular.[24,52-55] With implants developed during the 1990's,[56] plating of fractures can be performed from the volar side virtually regardless of the fracture pattern.[56] The volar side is preferred to the dorsal side for plating because the implant can be hidden under soft tissues, with the pronator quadrates forming a shelter between the implant and passing nerves and tendons.[56-58] The skin is opened by an approximately 7-cm longitudinal incision over the volar aspect of the distal radius (Figure 2), the fracture is exposed, reduced and fixed by a plate held in place by screws.

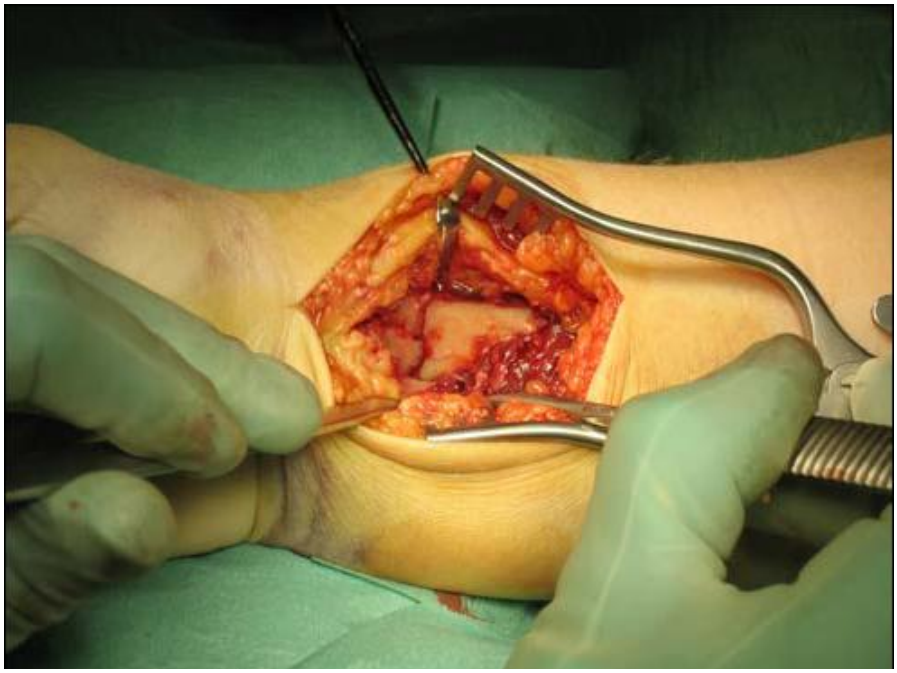


Figure 2: Exposure of the fracture site through a straight volar incision *ad modum* Henry. The median nerve is retracted to the ulnar side and the radial artery to the radial side. (©Fotogruppen Södersjukhuset)

The great advantage with this method is that the fracture is exposed and, in addition to the ligamentotaxis manoeuvre, the different fracture parts can be manipulated directly and placed in their exact position.[56] It also allows early range-of-motion exercises.[56] Some of the disadvantages are that it is a technically challenging technique[37] with the risk of nerve- and tendon injury during the procedure itself and the hardware must be ideally placed to avoid future problems in terms of tenosynovitis and stiffness.[54] Long screws or protruding metalwork may cause nerve and/or tendon irritation or damage.[59-63]

Other fixation techniques for distal radius fractures involve dorsal plating, radial plating,[64] and intramedullary nailing,[65] but these methods will not in detail be further described in this thesis.

Clinical trials comparing different surgical techniques

The highest level of evidence for comparison of treatments is a blinded, controlled, randomised trial.[66] It should be conducted according to the CONSORT criteria,[67] which consist of a check-list of important criteria that must be fulfilled to achieve an adequate design, performance, and documentation of a study. The CONSORT principles were developed in the late 20th century to increase the quality of clinical research studies[68]. A review of the current literature on wrist fractures reveals an abundance of studies. As yet, there is no publication available with adequate evidence to claim that any surgical method for treating distal radius fractures is unequivocally advantageous over another one.[37,69-75] Randomised controlled studies have been performed, but few studies have a design to adequately answer the question of which method is the best surgical procedure for dorsally displaced distal radius fractures (Table 1).

Statistical Power

Statistical power is an expression indicating how many patients or observations are needed in order to demonstrate a statistically significant difference in the matter being studied. The number of patients needed in a trial must be decided beforehand, based on a calculation of known facts about the subject of the study. As in the case of distal radius fractures, a pilot study of a few patients, or the outcome measurements in a formerly performed study, may serve as a template for calculating the adequate number of patients needed in the trial. If the difference in clinical findings between groups is expected to be very large, only a few patients are needed, in order to achieve statistically significant findings. If the differences are, however, expected to be small, a large number of patients must be studied in order to confirm or reject the hypothesis that differences between the groups really exist. When studying wrist fractures, many authors have reported small, if any difference, between groups. One must be cautious when interpreting the findings with few patients in the trials, as in the case of Grewal[76]. Rozental[77], Wei[78], and Abramo[64] who have included less than 30 patients in each arm of their studies (Table 1).

Selection of the study population

When studying diseases, the ideal investigation would include all patients with that particular disease in order to report the true conditions for these patients. It is, however, impossible to perform such a study and a selection of patients is necessary. In order to achieve relevant and trustworthy conclusions, one must carefully define the study population. It should represent the population that one wants to study, and on which one can draw inferences concerning the findings after drawing conclusions from the study, all of which is often referred to as the generalisability of a study. As in the case of distal radius fractures, it is a well known fact that fractures are more common in elderly osteoporotic women than in young and healthy males. Injury mechanisms and adjuvant injuries differ largely between these patient groups. There are also vast differences in the expectations and demands on the wrists. Surgical challenges in osteoporotic bone include pronounced comminution of fracture systems, and poor grip for osteosynthesis, regardless of which method one chooses. In contrast, challenges in young patients may consist in evaluating concomitant ligamentous injuries or facilitating early recovery of grip strength and range of motion. One must therefore consider studying these populations separately. Many randomised trials comparing treatments after distal radius fractures have included a mix of old and fragile patients with young patients who have been subjected to high-energy trauma, e g Rozental,[77] Egol,[79] Wei,[78] Wilcke,[80] Grewal,[76] Karantana,[81] and Williksen[82] (Table 1). Egol[79] and Leung[83] included open and closed injuries, and Leung also included both dorsally and volarly displaced fractures. Some of the patients in Leung's study were reported to have concomitant elbow dislocations, scaphoid fractures and humeral neck and condyle fractures. The generalisability of a study can be improved by selecting a more homogeneous population with similar bone quality, injury patterns and demands on the wrist.

Definition of intervention

When designing a randomised trial the aim is to prove or discard a difference between groups after a defined event, such as, in the case of wrist fractures, the results after two different treatment methods. It is important that the treatments or interventions under study are as well defined and as uniform as possible, in order to facilitate the drawing of conclusions from the findings. It is well-established that volar and dorsal plating have different characteristics when it comes to surgical techniques, risks and complications. The same is true for percutaneous techniques in terms of pinning, which can be performed in a variety of ways. Moreover, percutaneous pinning is a percutaneous procedure, just as external fixation is, but, in the latter, the wrist joint is blocked for 5 - 6 weeks during fracture healing, as opposed to pinning where the wrist is left with a variable degree of motion depending on additional casting regimens. Moreover, external fixation consists in a wrist spanning device as described earlier, but also exists as a non-bridging external fixation, leaving the wrist joint to free motion. When studying wrist fractures, it is important to study each surgical method separately. This has not been done in the studies by Leung[83] and Grewal,[76] who compare external fixation with volar *or* dorsal *or* combined plate techniques, with or without a bone graft. Rozental[77] and Karantana[81] compare volar locking plates with external fixation *or*

percutaneous pinning. Kreder[84] compared percutaneous pins *or* percutaneous separate screws *or* an external fixator, all methods with or without bone allografts, and volar *or* dorsal plating. Wei[78] randomised 46 patients to three treatment arms: external fixation and Kirschner wires with or without bone graft; volar fixation (in which some patients received additional dorsal implants); and radial plates (where one patient also received a volar implant) (Table 1). It is difficult to interpret the results from these studies owing to the mixing of surgical methods within treatment groups.

Interpretation of results

When analysing the results of a randomised trial it is important to focus on the primary outcome as should have been defined *a priori*. If too many outcomes and variables are analysed, the investigator risks attaining false positive findings due to chance.

In the study by Kreder et al,[84] the primary outcome was chosen to be the Muscular Functional Assessment (MFA)[85] and the 36-item Short Form Survey (SF-36)[86]. The results showed a statistically significantly better result for the closed reduction and percutaneous fixation group. In contrast to Kreder's findings, Leung et al.[83] drew the conclusion that plate fixation was better than external fixation based on statistically significant differences in the primary outcome, defined as the Gartland and Werely score.[87] This score is a non-validated physician-led questionnaire,[88] and the appropriateness of its use for distal radius fractures has been questioned.[89] However, Egol et al.[79] reported no clear advantage with either treatment methods. In Egol's study, many outcome measures were noted but none was defined as primary outcome measure. Moreover, the patients allocated to one intervention but for one reason or another were treated by the other method, were not analysed according to the intention-to-treat-analysis, but were excluded from the study analysis. Rozental et al.,[77] Wilcke et al.,[80] and Wei et al.[78] used the Disability of the Arm, Hand and Shoulder (DASH) questionnaire as a primary outcome measure. They all concluded that the result after volar plating was superior to that after percutaneous procedures during the early postoperative period. At one year however, the outcomes in both groups were similar. In accord with their findings, Grewal et al.[76] found no difference between plated and externally fixated cases in the primary outcome measure, Patient Rated Wrist Evaluation (PRWE), beyond 3 months. The most recent studies by Karantana et al.[81] and Williksen et al.[82] used quick-DASH,[90] a shortened version of the DASH, as a primary outcome measure. They found no difference in results after treatment with percutaneous or plating procedures, not even in the short term.

Table1: Summary of a selection of recent RCT's comparing plating and percutaneous techniques. EF=External Fixation. VLP=Volar Locking Plate.

	No. of patients	Age limits	Allocations	Fracture type	End-result
Kreder et al, JBJS (Br) (2005) [84]	179	16-75	EF or pins or screws *or* ORIF (volar or dorsal plate)	Dorsal, intra-articular	Favours EF
Grewal et al, J Hand Surg 2005[57]	62	18-70	EF *or* dorsal plate	Dorsally displaced intra-articular	Favours EF
Leung et al, JBJS (Am) 2008 [83]	144	17-60	EF *or* ORIF (volar and/or dorsal plate)	Volarly or dorsally displaced, Intra-articular	Favours plate
Rozental et al, JBJS (Am)2009[77]	45	19-79	Percutaneous pinning or EF *or* VLP	Dorsally displaced, no or minimal intra-articular engagement	No difference
Egol et al JBJS (Br) 2008 [79]	77	18-78	EF *or* VLP	Open/closed fractures, dorsally displaced, intra/ extra-articular,	No difference
Wei et al, JBJS (Am) 2009 [78]	46	18-79	Radial plate *or* volar plate *or* x-fix	Dorsally displaced, intra extra-articular	Favours plate
Abramo, ACTA 2009 [64]	50	20-65	Radial and volar plate (Trimed) *or* EF	Dorsally displaced, intra/ extra-articular	Favours plate
Wilcke, ACTA 2011 [80]	63	20-70	EF *or* VLP	Dorsally displaced. Intra/ extra-articular	No difference
Grewal, J Hand Surg 2011[76]	53	18-75	EF *or* ORIF (volar or dorsal plate)	Dorsally displaced. Intra or extra-articular	No difference
Karantana, JBJS (Am) 2013 [81]	130	18-73	Percutaneous pinning or EF *or* VLP	Dorsally displaced. Intra or extra-articular	No difference
Williksen, J Hand Surg 2013 [82]	111	20-84	EF *or* VLP	Dorsally displaced, intra-articlar	No difference

CLINICAL EVALUATION

Traditionally, the fracture of the distal radius was believed to heal without remaining disability. I quote Abraham Colles description of the distal radius fracture in 1814:[1] 'One consolation only remains, that the limb will at some remote period again enjoy perfect freedom in all its motions, and be completely exempt from pain: the deformity, however, will remain undiminished through life.'

A careful evaluation of wrist fracture patients reveals, however, persisting problems and disabilities in 15 - 30% of cases.[87,91-95] The function and alignment of the radiocarpal joint is central for all finger motions, grip strength and dexterity. Furthermore, the level of expectations for the wrist greatly affects the level of disability after injury; a severe injury to the non-dominant wrist in an elderly patient with a sedentary lifestyle and dementia does not produce any loss of function, as opposed to a seemingly innocent injury in a professional violinist in his or her forties, which may be the end of a successful career.

An adequate evaluation of wrist function after injury should include radiography; range of motion; grip strength; stability; pain; and function in daily activities. I will touch on each subject as listed below.

Radiology

The wrist is examined by x-ray typically in two projections; the anterioposterior (AP) and the lateral view (Figure 3).

Figure 3: Anterioposterior and lateral view of a wrist.

In the AP view you can see the distal articular surface of the radius as it forms the joint to the carpus, the radiocarpal joint. The AP view of the radius taken by a standard protocol more clearly illustrates the volar rim of the joint surface than the dorsal one. The distal articular surface of the radius, representing the radiocarpal joint, is formed by two separate joint fossae, one triangular in shape, in the radial half, which forms the joint towards the scaphoid bone and one quadrate surface more ulnarly situated, facing towards the lunate. When injured, these two surfaces need to be restored and congruent to avoid future disability and posttraumatic arthritis.[96,97] The distal radius also has an articular surface towards the ulnar head, and this joint surface must be congruent and aligned in order to restore range of motion in pronation and supination.[9] In the AP view, one can also evaluate the anatomy of the distal radius in terms of radial inclination, a description of the angle in which the radial distal end represented by the radial styloid protrudes more distally than the ulnar limit of the radius. The angle between the radial slope and the perpendicular plane of the long axis of the radius is measured, and is normally between 22 and 25 degrees of inclination. The clinical importance of this angle is debatable.[87] A minor loss of inclination is not of great importance but with a large loss of radial inclination angle, a less satisfactory result can be expected.[94] Lastly, the radial length may also be evaluated in the AP view of the radius. It can be measured in two ways. Either it is measured as the distance between the levels of the distal joint surfaces of the radius and ulna, and is then referred to as ulnar variance.[98] It may also be measured as the distance from the level of the joint surface of the distal ulna to the level of the most distal end of the radial styloid, and is then referred to as the radial height.[99] The radius is normally slightly longer than the ulna. A shortening of the radius caused by malunion of a distal radius fracture is known to result in a less satisfactory clinical outcome[96,97,100,101] with ulnar impingement and pain as a consequence (Figure 4). It is also an important predictor of fracture instability,[34] and a finding of radial shortening should alert the surgeon to the risk of future symptomatic malunion. Positioning of the wrist affects the radiographic depiction of the radial length, and negative ulnar variance increases in supination and decreases in pronation.[102]

Figure 4: Radial shortening causing ulnar impaction into the carpus.

In the lateral view of the distal radius (Figure 3), the ulnar part of the radiocarpal joint, or the lunate fossa, is clearly visible. It is normally angulated 10–12˚ volarly. Dorsal displacement of the joint surface in this view, is distinctive for a Colles' fracture. It is considered of importance to restore this displacement, when treating distal radius fractures, to a minimum of 10-15 degrees from the anatomical position, in order to avoid future dysfunction of the wrist.[9,87,101] In the lateral view, one can also observe the position of the carpus with the lunate facing the lunate fossa. With a hand in a neutral position, the carpus should be positioned on the volar third of the joint surface (along the volar line of Lewis) to ensure a good transition of force from the hand into the forearm, which is reflected clinically in good grip-strength. What is seemingly the dorsal limit of the radius is the protrusion of the tubercle of Lister, which is the hinge that the extensor pollicis longus tendon passes on its way from the thumb to the muscle in the forearm. It is important to recognise the triangular shape of the distal radius, and that dorsally protruding screws cannot be ruled out on a simple lateral view (Figure 5).

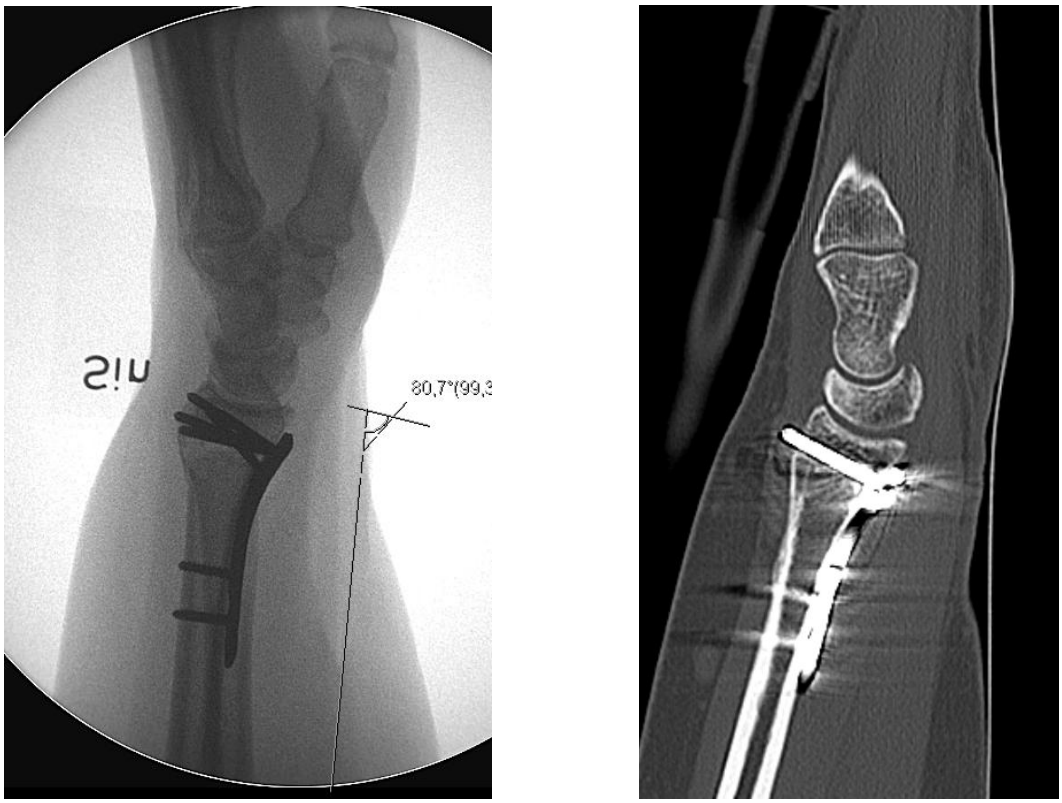


Figure 5: Computed tomography revealing inadequate screw length.

A so-called sky-line view or dorsal tangential view (DTV) has been suggested for post-operative radiographical investigation of distal radius fracture patients.[103,104] The wrist is held in 75˚ flexion and moved by the surgeon into the imaging field of the intraoperative fluoroscopy, thus obtaining a dorsal tangential view of the distal radius. This method is believed to reduce the risk of unintentionally long screws.[63]

Range of Motion

An uninjured wrist offers a wide range of motion (ROM). The range of motion of a fractured wrist is measured with a goniometer and the degrees of motion are noted and often compared to those of the healthy uninjured wrist. The motions measured involve dorsal extension and volar flexion, radial and ulnar deviation, and pronation and supination. Normal values for wrist ranges of motion are described in Table 2. There are differences between genders and age groups.[105,106] Most activities of daily living only demand approximately a range of motion of 40º in flexion and extension, 25º of ulnar and radial deviation and 100 º of pronation/supination.[105,107-109]

Table 2: Normal values for wrist range of motion adapted from Boone.[106]

Dorsal extension	74 º
Volar flexion	75 º
Radial deviation	21 º
Ulnar deviation	35 º
Pronation	75 º
Supination	81 º

Grip strength

The grip strength is a measure of the force that the fingers can produce in flexion. Even if this is not a direct investigation of wrist function, the fingers are highly dependent on the anatomy of the wrist and are therefore evaluated after distal radius injury. Grip strength is measured by a vigorimeter, whereby the patient grips a ball or a handle with maximum force. The vigorimeter has a pressure gauge and the mean of three measurements is documented in kilopascals or kiloponds.[9] The measurement is often compared to that of the uninjured side. The dominant hand is approximately 10% stronger in right-handed patients but left-handed patients are usually equally strong in both hands.[110] A correction for this difference in grip-strength is not necessary in clinical studies, since it would not produce more than an 0.5% overestimation of the grip-strength outcome.[37]

Stability

The wrist joint is a complex structure with a multitude of ligaments supporting the bony structures. A displaced distal radius fracture inevitably leads to concomitant ligamentous injuries.[12] The ligaments most frequently requiring specific treatment after wrist fractures include the triangular fibrocartilage complex (TFCC) and the scapholunate ligament (SL).[12] Signs of serious ligamentous injury involve pain on rotational or flexion loads on the wrist. The diagnosis and treatment of ligamentous injuries to the wrist go beyond the scope of this thesis.

Pain and function in daily activities

All fractures highly affect the patients in their normal lives. It is not possible to measures pain and disability objectively, and the investigator is dependent on the patient's description of the condition. To standardise measurements of pain and loss of function, patient-reported outcome measures (PROM) are very valuable for the assessment. These instruments consist in questionnaires that the patient fills in, usually by grading his or her pain or problems on a scale. The questionnaires have been created and validated by regional specialists and consist of questions regarding different aspects of the injured limb. There are many functional scoring instruments designed for the locomotor system, e. g. WOMAC for the otheoarthritic knee, Harris' hip score for evaluations after hip-replacement, the Visual Analogue Scale (VAS) for pain, and the Oswestry Disability Index for lower back pain.

The Disability of the Arm, Shoulder, and Hand (DASH) questionnaire[111] is an acknowledged upper extremity scoring instrument, which has been thoroughly validated and tested. It was created by the American Academy of Orthopaedic Surgeons to assess disability in the whole upper extremity. It has been translated and validated in Swedish.[112] It can be referred to as a gold standard for measuring outcome in the upper extremity. Thirty questions regarding personal care, housing, gardening, sports and social events, are graded on a 1 to 5 point scale. A total is calculated from the sum of 30 items minus 30 divided by 1.2. The maximum score representing a worst possible outcome is 100 points and a perfectly well working wrist yields zero points. This score was used as the primary outcome in Study 4.

The Patient Rated Wrist Evaluation (PRWE) score was developed in Canada in the 1990's. It was specifically constructed to measure the function of the wrist after distal radius fractures.[113] It consists of 15 questions divided into two sections covering pain and disability, respectively. Each item concerns situations in daily living that affect the wrist, for example, getting dressed, pushing up from a chair, cutting with a knife and carrying heavy objects. Each question is answered on a 0 to 10 scale, and the total score is the sum of 5 questions regarding pain, plus the sum of 10 questions regarding function divided by two. A maximal score of 100 indicates a worst possible outcome and zero indicates no problems or pain from the wrist. This score was validated in Swedish in Study 1.

The Musculoskeletal Functional Assessment (MFA)[85] was designed to evaluate injuries to any part of extremities. It is a 100-item patient-reported questionnaire evaluating functional loss after fractures, soft-tissue injuries, osteoarthritis or rheumatism. It was later developed into the Short-MFA, SMFA,[114] a more comprehensive version with 46 questions, out of which 31 items concern the upper extremity.

The Green O'Brien score[115] is an investigator-led assessment of the wrist. It is a combination of two questions in response to which the patient reports pain and his/her return to daily activities on a 4-degree scale, and two questions aimed at calculating radiological results and range of motion as a percentage of those of the uninjured side.

The Gartland and Werley scoring system[87] is another physician-led outcome often used in the literature before the development of the DASH and PRWE.[37] It is a demerit scale on which the result is ranked after assessment of residual deformity, subjective evaluation of pain, range of motion and complications. It has not been validated[88] and the appropriateness of its use for distal radius fractures has been questioned.[89]

A disadvantage of the PRWE and other injury-specific evaluation instruments is that the results cannot be compared with those for other injuries and/or treatments in order to assess differences in effect of a specific injury on the health-related quality of life (HRQoL). For this purpose, non-injury-specific instruments have been developed which measure and describe the patients' self-rated quality of life. EQ-5D (EuroQoL 5 Dimensions)[116] is a general health and life quality measuring device. It has been validated against several injury-specific instruments, including such instruments as for proximal humerus fractures[117] and hip fractures,[118] and it showed high validity and reliability. It consists of five questions with a 1 to 3 scale evaluating different dimensions of daily life, namely, walking ability, pain, self-care ability, work and daily activities and anxiety. Different combinations of answers yield a score ranging from 0 to 1 where 0 is worst possible state of health and no quality of life and 1 is a perfect state of health and quality of life.

The 36-item Short Form (SF-36)[119] is another patient-reported questionnaire used as a general health and quality-of-life instrument. The scale has eight subscales that describe physical function, physical role, bodily pain, vitality, general health perception, and emotional, mental and social function. It has been validated for use for wrist-fractures.[120]

COMPLICATIONS

Whatever treatment modality one chooses for a distal radius fracture, all patients are at risk of some complication caused by the treatment itself. Some symptoms after distal radius fractures are a natural step in the healing process, and one can debate whether it should be considered to be a complication or only a normal encumbrance encountered after treating a wrist fracture.

Some degree of joint stiffness for example, is seen after all distal radius fractures.[9] It is due to joint bleeding, swelling and pain, and usually diminishes over the first days to weeks after injury. However, there are some patients who develop extreme swelling and pain, with dysaesthesia, disturbed sensation and swetting of the hand, and sometimes hand temperature and skin quality may change. These are all signs of the Complex Regional Pain Syndrome (CRPS), formerly called Sudeck's sympathetic reflex dystrophy, which is a disabling and painful state of impairment of hand function.[9,121] The pathophysiology is not known, but it is thought to involve an impairment of a combination of autonomic, sensory and vasomotor nerves. Treatment involves physiotherapy and occupational therapy (Figure 6), and judicious use of oral analgetics. Preventive measures to avoid CRPS include good perioperative analgesia, short operative time and limited use of tourniquet. Daily intake of vitamin C may diminish the risk of developing CRPS.[121]

Figure 6: Early mobilisation after injury is beneficial for wrist fracture patients. (©Fotogruppen SöS)

Infection may be seen after all types of surgical procedures, and is a dreaded complication to orthopaedic interventions. Fortunately, deep infections in the area of wrist fracture surgery are very rare and normal preventive measures with a single dose antibiotics peroperatively usually reduces the risk to near zero. However, after percutaneous pinning and external fixation, when hardware is left protruding the skin, the risk of superficial infection rises to 10-33 %.[43,51,122] Preventive measures involve good position of hardware and judicious cleaning of the pin site.[43,122-124]

Rupture of tendons around the wrist after a distal radius fracture is a known phenomenon, even when surgery has never been performed.[9] The tendon highest at risk is the extensor pollicis longus (EPL) tendon. It passes around the tubercle of Lister, and it lies directly on the dorsal cortical bone. It may rupture due to friction from fracture fragments but also even after minimally displaced fractures, implicating an ischaemic injury as a cause of rupture. After surgery, the tendons passing the dorsal aspect of the distal radius are at risk for rupture when implanting dorsal hardware,[56,57,125] or after volar plating when screw tips protrude through the dorsal cortex.[126] On the volar side, the Flexor Pollicis Longus (FPL) is most at risk as it passes over the distal rim of the volar radius, only protected by the thin pronator quadratus muscle. Rupture of the flexor pollicis longus is most frequently seen after volar plating, usually due to a protruding hardware which causes friction to the tendon[60,126] (Figure 7). FPL ruptures have been reported even after proper positioning of the implant.[59] These iatrogenic tendon injuries are sometimes treated with direct suturing but they often necessitate treatment with a free tendon graft or tendon transfer owing to retraction and atrophy of the injured tendon edges.

Figure 7: Protruding distal end of volar plate causing risk of nerve entrapment and tendon ruptures.

Nerve dysfunction is a frequently reported complication in wrist injuries. The median nerve is at risk as it passes volar to the distal radius, and sharp fracture edges may cause direct injury to the nerve. More often, the nerve itself is intact but the pressure from swelling, fracture edges, callus formation or implants cause dysfunction of the median nerve. The symptoms involve signs of carpal tunnel syndrome including tingling and/or pain in the first to fourth finger. When performing operative treatment with a volar plate one must also consider the volar sensory branch of the median nerve that exits the median nerve approximately 5 cm proximal to the radiocarpal joint and passes ulnar to the flexor carpi radialis tendon on its way to the palmar skin. Injury to this nerve may cause hypersensitivity in the scar and/or dysaesthesia of the skin in the palm. Another nerve at high risk is the sensory cutaneous branch of the radial nerve. It may be injured after external fixation of the wrist, on introduction of the two proximal Steinman rods into the diaphysis of the radius. It may also be injured when performing percutaneous pinning of the fracture from the radial aspect of the wrist. Proper longitudinal skin incisions with retraction and protection of tendons and nerves are recommended for percutaneous techniques.

Malunion of the fracture is diagnosed by x-ray as the healing of a fracture in an unanatomical position. This is known to cause pain and disability.[127] However, surprisingly many patients among the elderly present with obviously disfigured wrists, and very slight symptoms.[128-132] A common phenomenon after distal radius fractures is reporting of ulnar pain. This can often be explained by a shortening of the fractured radius which leaves the ulna long and protruding into the ulnar side of the carpus (Figure 4). A corrective osteotomy with restoration of the anatomy of the radius is often a successful salvage procedure. If the anatomical alignment of the radius is good, except for the length, a shortening osteotomy of the ulna may suffice to diminish the pain.

RATIONALE FOR THIS THESIS

There is a need for validated regional injury-specific outcome measuring devices for all musculoskeletal injuries.[133] When these studies started, DASH had been translated to and validated in Swedish,[112] but the PRWE had not.

The epidemiology of and treatment regimens for wrist fractures have been reported to be changing.[25,31,53,55] Analyses from Swedish registries have been performed,[16,19,24,32] but nation-wide analyses of distal radius fractures have not been attempted. Swedish national health-care registries constitute an important asset for studying large un-selected cohorts.[134] Complications after distal radius fracture surgery are not uncommon but so far, they have been studied to a limited extent.

In two meta-analyses,[37,75] it was clearly stated that until 2005 there was a paucity of studies comparing the outcomes after percutaneous and open reduction and internal fixation of wrist fractures. The studies published since then do not prove any clear advantage of either method.[69] It is still unknown what treatment option is best for dorsally displaced distal radius fractures.

The studies in this thesis were designed to provide more knowledge on the abovementioned subjects.

AIMS

The overall aim of this thesis was to evaluate what surgical treatment is most appropriate for a dorsally displaced distal radius fracture, taking into consideration clinical outcome and complications.

Study 1

The aim of Study 1 was to translate the Patient Rated Wrist Evaluation (PRWE) questionnaire from English into Swedish in order to use it as an outcome measurement in future clinical randomised studies.

Study 2

The aim of Study 2 was to calculate the incidence of wrist fractures in Sweden. A secondary aim was to calculate the incidence of different treatment methods for wrist fractures. A tertiary aim was to describe the evolution of incidences and treatment preferences over time.

Study 3

The aim of Study 3 was to calculate the incidence of reoperations after wrist fracture surgery and to present incidences separately for the three most frequently used surgical methods. A secondary aim was to calculate the time from surgery to reoperations.

Study 4

The aim of Study 4 was to compare clinical and radiological outcomes after treatment with external fixation with the optional addition of Kirschner wires or a volar locking plate for patients 50–74 years of age who had sustained a dorsally displaced distal radius fracture after a low-energy trauma.

METHODS

Study 1 – Translation and validation

A translation and validation of the Patient-Rated Wrist Evaluation (PRWE) questionnaire was performed according to recommendations by the American Association of Orthopaedic Surgeons (AAOS).[135] The PRWE questionnaire was translated from English into Swedish by two independent bilingual translators with Swedish as their mother tongue. Both translators were medically trained, but only one was fully informed of the aim of the use of the questionnaire and the translation. The two translators met to discuss the differences between the two forward translations. Differences were resolved by consensus between the two translators. This version of the Swedish PRWE (PRWE-Swe) was given to two independent native English-speaking translators for back translation into English. Correspondence with the original English version of the PRWE was noted and differences were analysed. The final Swedish version was then made after reviewing the pre-final version and by analysing comments made when testing the questionnaire on healthy volunteers.

The validation process

When validating a health measuring device, one must consider validity, reliability and responsiveness.

Validity

Face validity: Face validity is a description of whether the questionnaire seems adequate and relevant from the patient's point of view. If a patient suffers from disability of the wrist, he or she wants to be questioned about activities that are affected by the dysfunction. To evaluate face validity of our translated questionnaire, the prefinal version of the PRWE-Swe was tested on 18 healthy individuals employed in our department and 32 patients with a variety of orthopaedic injuries randomly chosen during their out-patient-clinic visit in our hospital. They were left alone with the questionnaire and later they were interviewed by our research nurse for comments on the readability, whether or not the test seemed rational and relevant and if the language chosen was easily understood and pertinent.
Content validity: If you are a teacher and are to construct a test at the end of the semester, you have to construct your test on the basis of the contents and curriculum of the course that you have been giving. If you have been teaching for the capitals of Europe, the final exam must include questions for Paris, Madrid and Rome, and not Tokyo, Nairobi or Buenos Aires. For the PRWE-Swe we evaluated whether the questionnaire included pertinent questions when it comes to evaluating wrist function by discussion in an expert group consisting of three orthopaedic surgeons, one methodologist and one research nurse.
Criterion validity: A criterion is defined as a standard against which a test or a test score is evaluated. It is ideally reliable, relevant, valid and uncontaminated. It is easy to find a criterion when constructing for example an instrument for measuring outside temperature or shoe size. To evaluate criterion validity for the PRWE questionnaire we made a comparison with the Disability of the Arm, Shoulder and Hand (DASH) questionnaire - by many investigators considered to be the gold standard for

measurements of upper extremity disability. We let 124 patients with a variety of degrees of symptoms from the wrist fill in the PRWE and the DASH twice, and the correlation between the results of the two questionnaires was analysed.

Reliability

Reliability describes the ability of a test to yield consistent and reproducible results. For example, a ruler made of a solid material gives the same measurement of an object 10 cm long, every time it is measured, regardless of whether the measurement is performed today, tomorrow or within a year. If one makes a ruler out of a material such as wet clay or out of ice, the ruler will not keep its size and the measurement will differ when repeated.

Internal consistency: Reliability was investigated in our study in terms of internal consistency. A test that investigates a quality should be homogeneous, which is represented by high internal consistency. All the questions in the test should cover that special quality or trait. For example, a test testing skills in fracture surgery of the wrist would be more homogeneous than a test for testing skills in orthopaedic surgery in general. When testing a single and well-identified skill or quality one gets a more straight-forward test-score interpretation than is the case if the test is heterogeneous (low internal consistency). We used the total score of the first PRWE measurement in 124 patients for our internal consistency analysis.

Test-retest stability: Another facet of the reliability investigation is the analysis of test-retest stability. If a pupil remembers half of the capitals of Europe, he or she should achieve half of the maximum of the test, regardless whether the test was held on a Monday or on a Friday; or as in our investigation, a patient with a chronic disability of the wrist should score the same when tested twice. The patients chosen for the reliability analysis were 62 patients treated for a fracture around the wrist during the year preceding the study. They had been treated surgically or with a cast, but were beyond one year after injury. Thus, the patients were expected to have some remaining symptoms from the injured wrist, but the problems were in a steady state and no improvement or worsening of the symptoms was expected. The PRWE questionnaire was distributed twice, with a week between the tests, and an analysis was performed for test-retest stability.

Responsiveness

Responsiveness is a description of whether or not a clinical change is reflected by a proportional change in the questionnaire scale. If a pupil remembers half of the capitals of Europe, he or she should achieve half of the maximum of the test. If the pupil remembers all of them, maximum points in the test should be achieved. We analysed responsiveness by including 62 patients with an acute injury to the hand or wrist. All patients were sent the PRWE and DASH questionnaires one week after removal of the plaster cast or external fixation. A month later, they were sent another set of questionnaires and the results of the two assessments were compared. The expected clinical improvement during this period is rather large. We investigated if the PRWE reacted with improvement of the result proportionally to the external and validated criterion: the DASH score.

Studies 2 and 3 – Epidemiology, Cohort studies

Swedish National health-care registries constitute an invaluable asset for investigations of epidemiological patterns. The strengths involve large populations, long follow-up times, 100% death registration and presence of unselected series of patients. Limitations involve possible under- or over-reporting of diagnoses, monetary reasons for reporting surgical interventions and lack of information of clinical and radiological data. Distal radius fractures have been studied earlier in counties [20,21,32,136-138] and cities,[19,25,28-31] but this study is, to my knowledge, the largest of few nationwide investigations of registry material on distal radius fractures.[52,53,139,140] For my epidemiological studies, I retrieved data from the Swedish National Board of Health and Welfare (Socialstyrelsen) on all patients registered with a distal radius fracture during 1987 - 2010.

Coding in Swedish Patient Registries

The coding for disease before 1987 was such that a fracture to the forearm was coded as 813XX regardless of whether it was a fracture to the radius proximally, diaphyseally or, as I needed to find out for the purpose of my studies, to the distal part of the radius. In 1987 the ICD 9 was introduced, and this modernised classification system provided coding of the fractures of the radius in more detail. Fractures of the distal part of the radius were noted as 813E or 813F. In 1997 the ICD 10 was started in all regions but Skåne (which started in 1998), and distal radius fractures were noted as the appearance of S52.50 (closed fracture to the distal radius), S52.51 (open fracture to the distal radius, S52.60 (closed fracture to the distal radius and ulna) and S52.61 (open fracture to the distal radius and ulna). For in-patient care, there are registry data from some regions in Sweden dating back to the 1960's. For the purpose of these studies, however, I also needed data on patients treated in out-patient clinics, since only a minority of patients with distal radius fractures are hospitalised, and, for the period 1964 – 1997 there are no such registry data available. In 1997 it became compulsory to report surgical procedures in both out- and in-patient care. In-patient surgical procedures were registered in the Swedish National Patient Registry (Patientregistret, PAR) and for out-patient surgical procedures the Registry for Day Surgery (Dagkirurgiregistret) was started in 1997. In 2001 however, a new registry, the Registry for Out-patient Care (Öppenvårdsregistret) was started and included all vistits to all out-patient caregivers, regardless of the diagnosis or presence of a surgical procedure. Therefore, the Day Surgery Registry was fused with the newly started Registry for Out-patient Care, and surgical procedures performed in out-patient clinics were registered there (Figure 8). All registries report problems with missing values during the registry start-up, and the data in the Registry for Out-patient Care was of rather low quality during the first years. However, nowadays the registration in the Registry for Out-patient care is considered to be good, except for psychiatry and plastic surgery. I received ethical permission for this study in early 2011 and the dataset I received from the National Board of Health and Welfare contained 441 757 patients with distal radius fractures registered from 1987 to 2010.

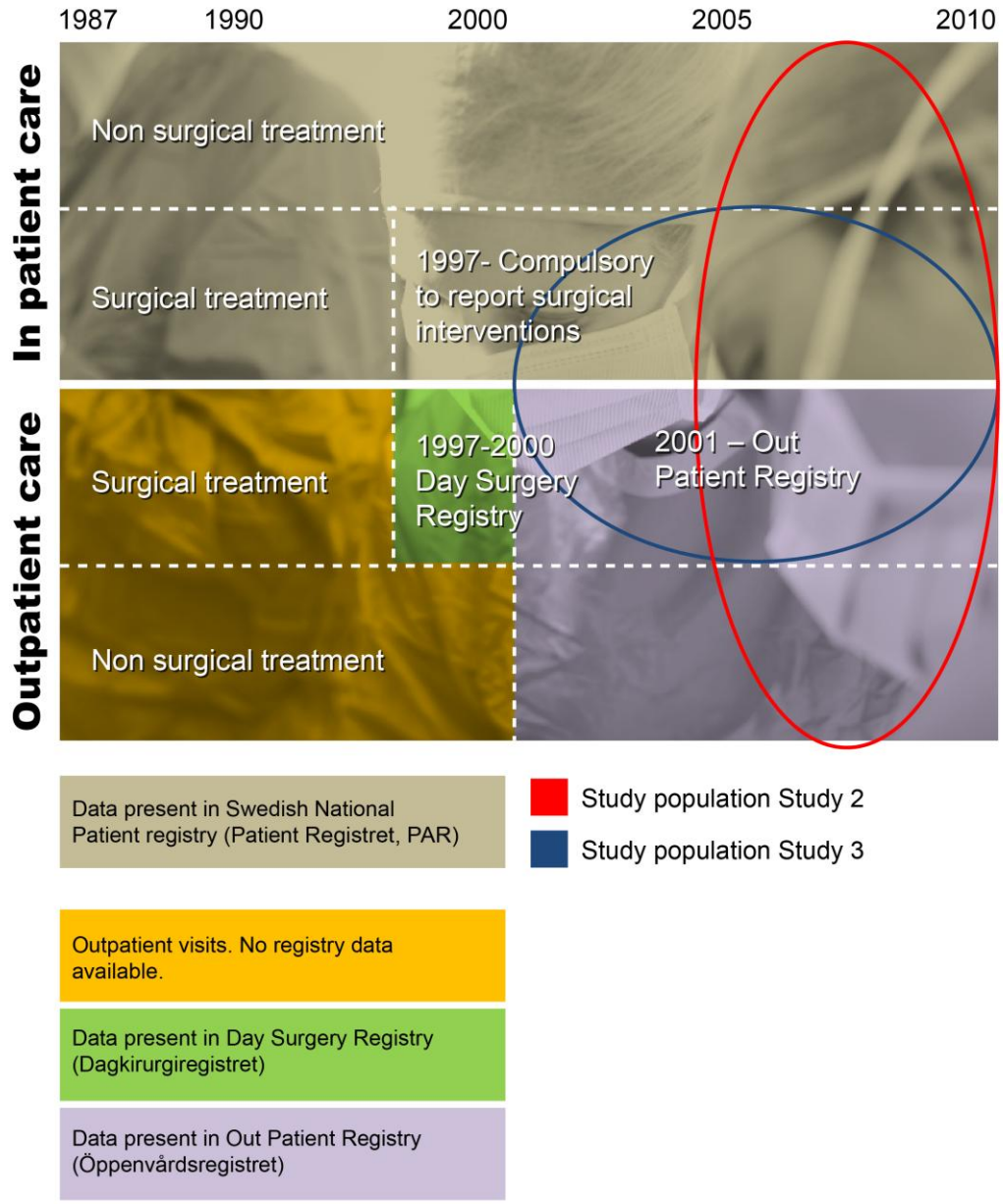


Figure 8: Illustration of registry data available in Sweden since 1987. The data used for Studies 2 and 3 have been marked with a circle.

Study population of Study 2

The cohort of Study 2 consists of all patients with a distal radius registered from 1 January 2005 to 31 December 2010 (Figure 8). This period was chosen to avoid the first start-up years of the Out-patient Registry (Öppenvårdsregistret) with the risk of obtaining false results due to poor registry quality. A fracture was defined as being the first time the diagnosis S52.5/6 appeared in the register. Only patients with a new fracture during the defined period contributed to the study population, i.e., if a patient was listed in the register with a distal radius fracture before 1 January 2005, he/she was removed and did not contribute to the follow-up time in this study. A re-fracture was defined as when S52.5/6 appeared in the register more than 18 months after the last visit for a previous fracture. Bilateral fractures occurring on the same date were only counted as one fracture. A registered surgical procedure with fracture surgery within 28 days from the fracture date was defined as primary fracture surgery. A fracture was considered to be non-surgically treated (treatment with a cast) if no code for surgical intervention appeared within 28 days from the fracture date. We linked the dataset to the Swedish Cause of Death Register and deceased patients did not contribute to the follow-up time after death.

Outcome measurements, Study 2

In Study 2 the epidemiology of distal radius fractures in Sweden was described in terms of incidence and distribution of age and gender. Incidences for different treatment methods for distal radius fractures were analysed as was the development of treatment preferences over time.

Analyses and statistical methods of Study 2

The age and sex distribution is shown for the entire population. The main results were also presented separately for the paediatric and the adult population. Incidences for fractures and surgical procedures were calculated as the number of cases divided by the mean annual population in Sweden as reported from SCB Statistics Sweden (Statistiska Centralbyrån). In clinical research, the most common investigation involves a selection of patients: a study population. The study population of any clinical study is ideally a reflection of the total population, with a distribution of age, sex, risk factors and other features closely corresponding to those in the total population. When studying differences within a study population, a p-value is calculated to express the probability that the cohort estimate represents the true value in the total population. The study population of this study included, however, the entire population of Sweden. Thus, no cohort estimates were made and all findings were presented without p-values or confidence intervals.

Study population of Study 3

The cohort of Study 3 consists of all patients with a surgical treatment of a distal radius fracture registered from 1 January 2001 to 31 December 2009 (Figure 8). All patients were followed until 31 December 2010 to ensure a minimum follow-up time of at least one year for all patients. We limited our analysis to patients aged 18 or older diagnosed

with a fracture to the wrist according to the ICD-10, as described previously for Study 2. We linked the dataset to the Swedish Cause of Death Register and deceased patients did not contribute to the follow-up time after death. Patients were identified as the appearance of an ICD-10 coding of a distal radius fracture in combination with a code for fracture surgery to the forearm or hand. Bilateral fractures occurring on the same date were counted only as one fracture. An individual was only counted once and recurring fractures were not analysed.

Outcome measurements, Study 3

The outcome in Study 3 was the occurrence of a complication after distal radius fracture surgery serious enough to cause a reoperation. A surgical intervention with a coding for any of the following operations was defined as a complication: extraction of internal fixation material; corrective osteotomy; suture, reinsertion or transposition of tendon; release of the median nerve in the carpal tunnel; arthrodesis of the radiocarpal joint; fasciotomy; surgical debridement due to deep infection; or reoperation with a new osteosynthesis within 28 days. All patients were followed from the wrist fracture operation to the occurrence of either a reoperation, a new surgically treated distal radius fracture, death, or 31 December 2010, whichever occurred first, and the follow-up time was calculated for each individual.

Analyses and statistical methods of Study 3

The proportion of reoperations was calculated as the number of reoperations divided by the total number of surgically treated patients. Confidence intervals for proportions were calculated using the Wilson score interval. Incidence was calculated as the number of reoperations divided by the sum of follow-up time and is presented as the incidence per 10 000 person-years. Confidence intervals for incidences were calculated according to the normal approximation to the Poisson distribution. Kaplan Meier curves were calculated to study the time from surgery to reoperation. The log-rank test was used to compare the Kaplan Meier curves for pins, external fixation and plates, both for all three curves and also for each possible pair of curves. A stratified log rank analysis was performed adjusting for sex and age, one after another (age groups defined as age 18-49, 50-74 and >75 years). The results were considered significant at $p < 0.05$ or when confidence intervals were not overlapping.

Study 4 – Randomised Controlled Trial

A prospective randomised trial was performed according to the CONSORT criteria. 140 patients presenting with a dorsally displaced distal radius fracture were randomised to either fixation with a volar locking plate (n = 70) or an external fixation (n = 70).

Study population

All patients treated at Södersjukhuset in Stockholm scheduled for wrist fracture surgery were eligible. Inclusion criteria were patient age 50 – 74 for females and 60 – 74 for male patients; fall from a standing height; wrist radiography of ≥20° dorsal angulation in the lateral view and/or ≥5 mm axial shortening in the AP view; a good knowledge of written and spoken Swedish; the fracture was diagnosed within 72 hours from the injury; and the patients were residentials within the catchment area of our hospital. Exclusion criteria were former disability of either wrist; other concomitant injuries; rheumatoid arthritis or other severe joint disorders; dementia or a Pfeiffer score[141] ≤5; drug or alcohol abuse; psychiatric disorder; dependency in ADL; or a medical condition that did not allow general anaesthesia.

Intervention

All patients included gave their written consent to participate in the study prior to randomisation. Allocation consisted in the opening of opaque, sealed envelopes. The envelopes were sorted into batches of 20 with 10 of each allocation randomly mixed, thus ensuring an even distribution over the inclusion period. Randomisation did not take place until the research team had assigned an orthopaedic surgeon who was well experienced in both procedures. Surgery was performed within 10 days from the fracture date by any of 23 different surgeons employed at our department, all of whom had a minimum of five years of orthopaedic surgery training.

The external fixator was applied using a 4-cm dorsolateral incision proximal to the extensor pollicis longus muscle. The extensor carpi radialis longus and brevis tendons were retracted and the radius was exposed for the application of two threaded pins (Figure 9). Dorsolaterally, on the second metacarpal bone, two threaded pins were introduced through stab incisions. The blocks were attached and the fracture was reduced under fluoroscopic control by ligamentotaxis. Additional 1.6-mm Kirschner wires were applied at the surgeon's discretion. The external fixator and Kirschner wires were extracted without using anaesthetics in an out-patient office 5–6 weeks post-operatively.

Figure 9: Application of an external fixator. (©Cecilia Mellstrand Navarro)

The volar plating was performed via a straight incision over the flexor carpi radialis tendon (FCR), which was retracted ulnarly. The flexor tendon sheath was opened and the flexor pollicis longus tendon (FPL) was held with retractors ulnarly. The pronator quadratus muscle was split and the fracture was exposed and reduced under fluoroscopic control. Fracture stabilisation was achieved by applying a volar locking plate (Figure 10). Repair of the pronator quadratus was based on the judgment of the operating surgeon. The wrist was immobilised in a dorsal plaster cast for four weeks except in one patient who was immediately prescribed free range-of-motion exercises owing to a misunderstanding between the research team and the treating surgeon.

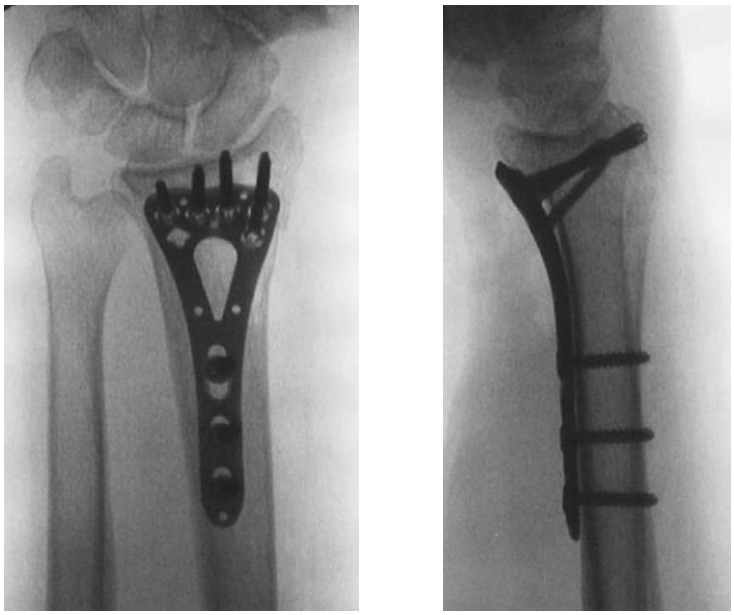


Figure 10: Radiograph showing the implant used in the volar locking plate group in Study 4.

Outcome measurement, Study 4

The primary outcome was the upper extremity score of Disability of the Arm, Shoulder and Hand (DASH). The patient-Rated Wrist evaluation (PRWE) and the EQ-5D were also assessed. Radiographic investigations and recordings of complications were performed at two and six weeks, at three months and at one year. Patients were investigated by un unblinded independent occupational therapist for range of motion and grip-strength at three months and one year.

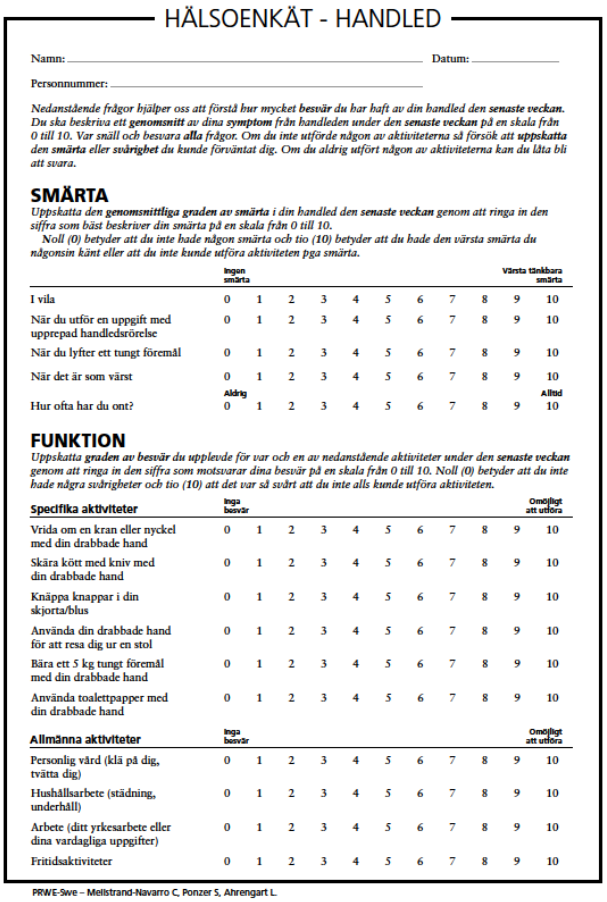
Analyses and statistical methods of Study 4

All results were calculated according to the intention-to-treat principle. Significance was set to $p < 0.05$ in two-sided tests. The Mann-Whitney U-test was performed for comparisons of medians for skewed distributions, but means were also presented. Student's t-test was used for comparisons of normally distributed means. Bonferroni's correction was made for multiple calculations. Chi-square tests were performed for comparisons of proportions. Fisher's exact test was used for comparisons of proportions when small numbers were expected.

RESULTS

STUDY 1

The analysis showed that our Swedish version of the PRWE (PRWE-Swe) was valid, in terms of face and content validity. Criterion validity was good with Spearman's rho measured as 0.88 and 0.92 ($p<0.001$). Cronbach's alpha was 0.97 which confirms an excellent internal consistency. Test-retest stability was tested by an intraclass correlation coefficient of 0.97. PRWE-Swe was also responsive, with a standard response mean (SRM) of 1.29 between the two measurements, which correlated quite well with the SRM of the external criterion DASH.



HÄLSOENKÄT - HANDLED

Namn: _____ Datum: _____

Personnummer: _____

*Nedanstående frågor hjälper oss att förstå hur mycket **besvär** du har haft av din handled den **senaste veckan**. Du ska beskriva ett **genomsnitt** av dina **symptom** från handleden under den **senaste veckan** på en skala från 0 till 10. Var snäll och besvara **alla** frågor. Om du inte utförde någon av aktiviteterna så försök att **uppskatta** den **smärta** eller **svårighet** du kunde förväntat dig. Om du aldrig utfört någon av aktiviteterna kan du låta bli att svara.*

SMÄRTA

*Uppskatta den **genomsnittliga graden av smärta** i din handled den **senaste veckan** genom att ringa in den siffra som bäst beskriver din smärta på en skala från 0 till 10.*

Noll (0) betyder att du inte hade någon smärta och tio (10) betyder att du hade den värsta smärta du någonsin känt eller att du inte kunde utföra aktiviteten pga smärta.

	Ingen smärta										Värsta tänkbara smärta
I vila	0	1	2	3	4	5	6	7	8	9	10
När du utför en uppgift med upprepad handledsrörelse	0	1	2	3	4	5	6	7	8	9	10
När du lyfter ett tungt föremål	0	1	2	3	4	5	6	7	8	9	10
När det är som värst	0	1	2	3	4	5	6	7	8	9	10
	Aldrig										Alltid
Hur ofta har du ont?	0	1	2	3	4	5	6	7	8	9	10

FUNKTION

*Uppskatta **graden av besvär** du upplevde för var och en av nedanstående aktiviteter under den **senaste veckan** genom att ringa in den siffra som motsvarar dina besvär på en skala från 0 till 10. Noll (0) betyder att du inte hade några svårigheter och tio (10) att det var så svårt att du inte alls kunde utföra aktiviteten.*

Specifika aktiviteter	Inga besvär										Omöjligt att utföra
Vrida om en kran eller nyckel med din drabbade hand	0	1	2	3	4	5	6	7	8	9	10
Skära kött med kniv med din drabbade hand	0	1	2	3	4	5	6	7	8	9	10
Knäppa knappar i din skjorta/blus	0	1	2	3	4	5	6	7	8	9	10
Använda din drabbade hand för att resa dig ur en stol	0	1	2	3	4	5	6	7	8	9	10
Bära ett 5 kg tungt föremål med din drabbade hand	0	1	2	3	4	5	6	7	8	9	10
Använda toalettpapper med din drabbade hand	0	1	2	3	4	5	6	7	8	9	10
Allmänna aktiviteter	Inga besvär										Omöjligt att utföra
Personlig vård (klä på dig, tvätta dig)	0	1	2	3	4	5	6	7	8	9	10
Hushållsarbete (städning, underhåll)	0	1	2	3	4	5	6	7	8	9	10
Arbete (ditt yrkesarbete eller dina vardagliga uppgifter)	0	1	2	3	4	5	6	7	8	9	10
Fritidsaktiviteter	0	1	2	3	4	5	6	7	8	9	10

PRWE-Swe – Mellstrand-Navarro C, Ponzer S, Ahrengart L.

Figure 11: The translated and validated Swedish version of PRWE (PRWE-Swe). The questionnaire is also available in the Appendix, page 59.

The Swedish version of the PRWE is user-friendly, it is easy to understand and quick to fill in. It is in a handy format and the score on a 100-point scale is easy to compute and easy to understand and interpret. The PRWE-Swe (Figure 11 and Appendix) is a useful tool for evaluating disabilities of the wrist by clinicians, researchers and patients.

STUDY 2

The incidence of wrist fractures in the adult Swedish population during 2005 - 2010 was 26 per 10 000 person-years. The incidence was slowly rising during the investigated time period. The incidence for surgical treatment as a primary treatment option for distal radius fractures increased from 5.8 to 7.4 per 10 000 person-years, which constitutess a proportional increase from 16% to 20% over a 6-year period. The proportion of non-operative treatments diminished correspondingly. The rise was largest in the 50-74 age group where the incidence of surgical treatment increased by 41%. The incidence of surgical treatment with plate fixation increased by more than threefold from 2005 to 2010 whereas the incidence for external fixation diminished by 67% (Figure 12). In the paediatric population, defined as an age <18 years, the incidence for wrist fractures decreased from 59 to 51 per 10 000 person-years. Six percent of the paediatric wrist fractures were treated surgically and there was no change in treatment tradition over the investigated time period.

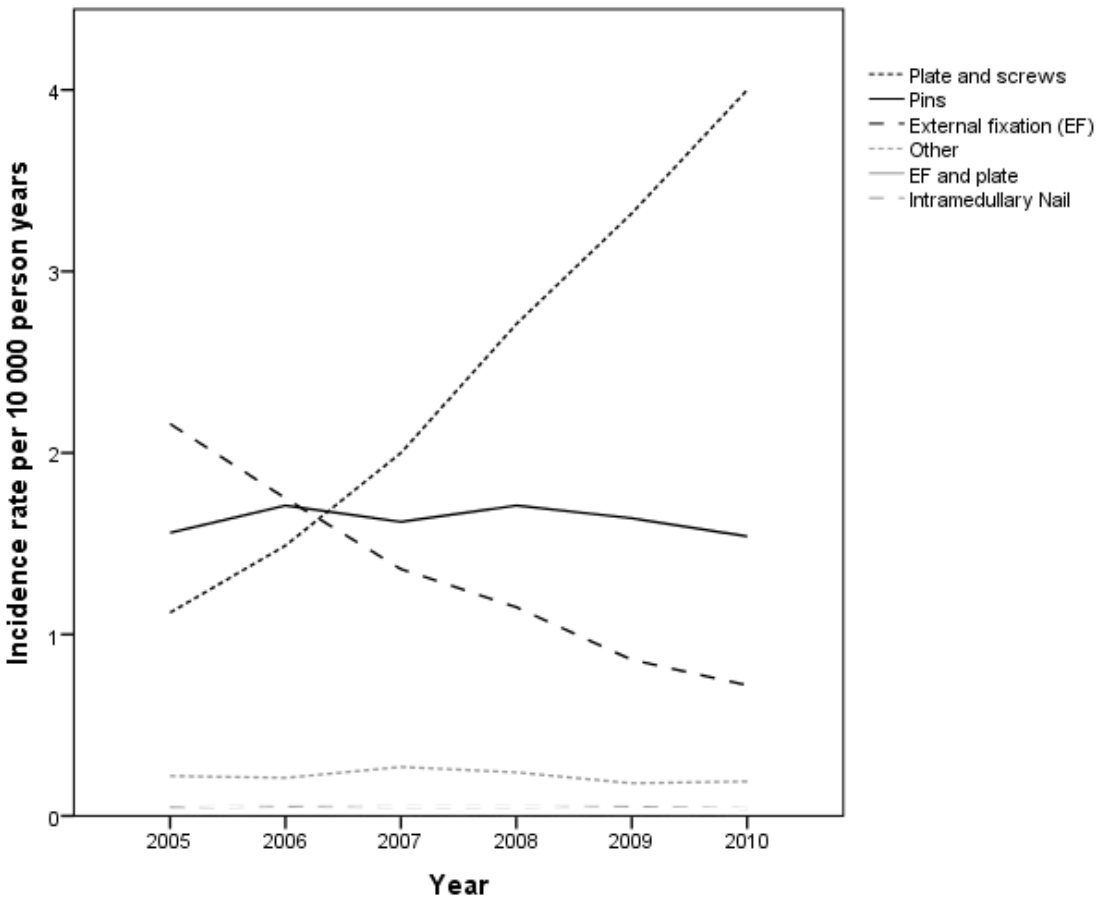


Figure 12: Incidence for different techniques for distal radius fracture surgery in adults in Sweden. Reproduced with permission and copyright © of the British Editorial Society of Bone and Joint Surgery

STUDY 3

36 618 patients were treated surgically due to a distal radius fracture in Sweden during the years 2001 – 2009. The mean age was 62 years and 78% of the patients were females. Reoperations on the wrist occurred in 6.6% of all patients who had undergone surgical procedures for wrist fractures. The incidence of reoperation after fracture surgery using external fixation, pins and plating, respectively, was 100 (95% CI: 93-107), 140 (95% CI: 127-153), and 222 (95% CI: 207-237) per 10 000 person years.

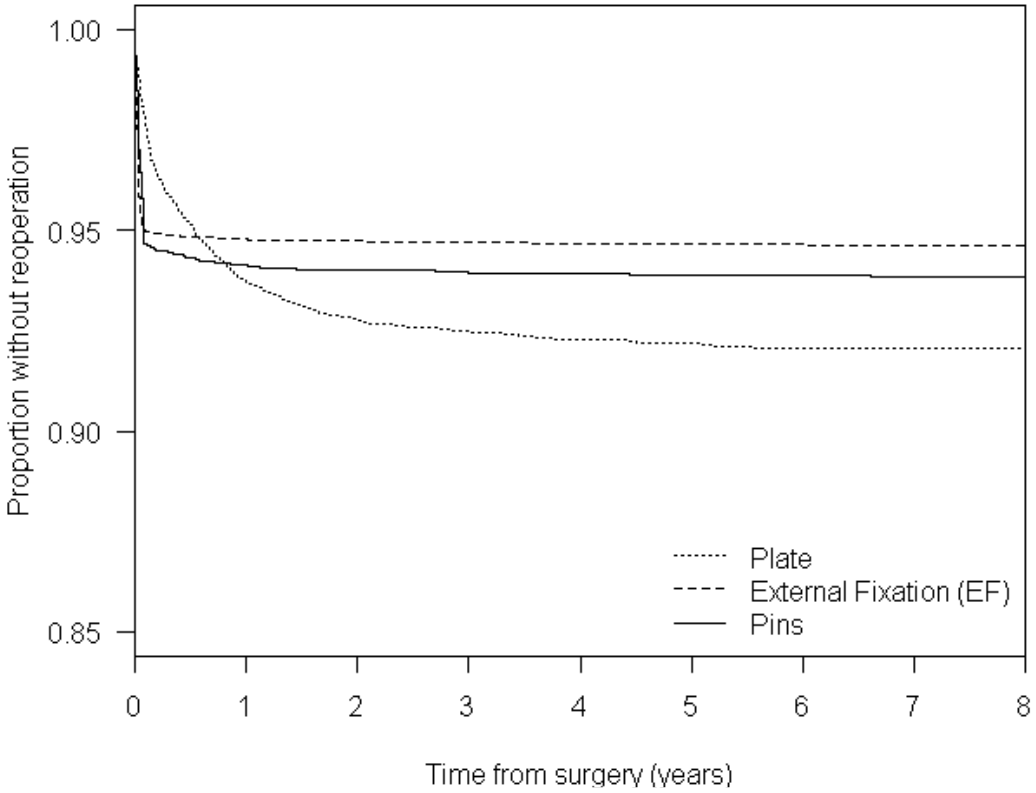


Figure 13: A Kaplan-Meier survival analysis describing reoperations after distal radius fracture surgery. Reproduced with the permission of the Journal of Orthopaedic Trauma.

Reoperations after external fixation and pinning typically occurred in the early postoperative period, and reoperation with renewed osteosynthesis within 28 days from the primary operation was by far the most frequent reoperation for these patients. Patients treated with plate fixation presented later for reoperations (Figure 13). Plate extraction was the most usual reoperation, followed by reoperation with renewed osteosynthesis within 28 days from the primary operation. Plated patients had an incidence of tendon injuries of 7.0 per 10 000 person-years and external fixation patients had an incidence of 0.62 per 10 000 person-years, i.e. plated patients had a tenfold higher incidence of surgery with tendon repair in comparison to externally fixated patients. Carpal tunnel release was also more frequent after plate fixation than after external fixation with incidences of 8.7 and 1.6 per 10 000 person-years, respectively.

STUDY 4

This is the largest randomised controlled trial on distal radius fractures comparing external fixation and volar locking plates yet published. 134 patients were examined at one year postoperatively. The primary outcome was the DASH score which showed that there were no significant differences between the groups at baseline, 3 months or 1 year ($p > 0.05$). The PRWE was also determined at the same time intervals and with the same results. However, the patient-reported quality of life, as measured by the EQ-5D, was lower for the external fixation group at 2 and 6 weeks ($p < 0.02$) but at three months and one year the difference was no longer significant (Table 3).

Table 3: Clinical outcome in Study 4 presented as Mean : *Median* (Range).

	Volar locking plate group		External fixation group		p-value*
DASH before injury	1.12 : *0.0*	(0-13)	1.28 : *0.0*	(0-24)	0.979
DASH, 3 months	18 : *14*	(0-66)	23 : *20*	(1.7-66)	0.067
DASH, 1year	11 : *7*	(0-77)	13 : *8*	(0-62)	0.244
PRWE before injury	0.6 : 0.*0*	(0-14)	0.5 : *0.0*	(0-25)	0.225
PRWE, 3 months	21 : *17*	(0-89)	25 : *21*	(0-69)	0.188
PRWE, 1year	13 : *9*	(0-80)	14 : *7*	(0-69)	0.599
EQ5D before injury	0.97 : *1*	(0.66-1)	0.93 : *1*	(0.41-1)	0.140
EQ5D day of surgery	0.49 : *0.59*	(0-1)	0.49 : *0.59*	(0-1)	0.950
EQ5D, 2 weeks	0.70 : *0.73*	(0.05-1)	0.63 : *0.66*	(0.05-1)	0.018
EQ5D, 6 weeks	0.75 : *0.80*	(0.08-1)	0.65 : *0.69*	(0-1)	0.001
EQ5D, 3 months	0.81 : *0.80*	(0-1)	0.77 : *0.80*	(0-1)	0.219
EQ5D, 1year	0.85 : *1*	(0-1)	0.89 : *1*	(0.62-1)	0.894

*Mann-Whitney 2-tailed asymptotic significance

The radiographic restoration of alignment was better for the volar locking plate group in terms of volar tilt at all measuring points, with a volar tilt immediately postoperatively of 7˚ in the plate group in comparison to 2˚ in the external fixation group ($p<0.001$). The volar tilt at one year was 4˚ in the plate group and -1˚ in the external fixation group ($p=0.02$). Radial shortening was equal at the first postoperative measurement but after two weeks, the external fixation group lost reduction. The volar plate group maintained ulnar variance of -0.57 and -0.41 mm at 3 and 12 months respectively whereas the external fixation group developed a radial shortening represented by an ulnar variance of 0.55 mm at 12 months ($p<0.01$). Radial inclination was equal in both groups at all measurements. Range of motion was equal in both groups at three and twelve months except for radial deviation which was better in the volar locking plate group at the one year follow-up. The total number of complications was equal for both groups.

GENERAL DISCUSSION

The aim of this thesis was to take a wide view of wrist fractures. It involves three completely different methodologies. All studies are large and carefully designed to answer *a priori* well-defined research questions. When these studies started, there was a lack of scientific evidence for the choice of treatment for distal radius fractures.[37,75] Study 1 has provided Swedish researchers with a valid region-specific evaluation tool for wrist fracture patients. Study 2 has described the epidemiology and treatment options for wrist fractures in a large unselected population. Study 3 has given interesting information regarding reoperation rates after wrist fracture surgery. Study 4 has added important knowledge concerning the results after two different surgical methods for the treatment of wrist fractures in osteoporotic patients.

Study 1 consists in a translation and validation of a wrist evaluation instrument, the PRWE. For future Swedish researchers in the field of wrist fractures, the existence of the Swedish version of the PRWE provides an opportunity to better evaluate the patient-rated outcome after wrist fractures. The questionnaire was translated and validated with the aim of using the PRWE as an outcome measuring tool in Study 4. The size of the study population was large, which is a strength of this study; 124 patients with a chronic or changing state of disability of the wrist were investigated on two occasions, which is considered to be a sufficiently large study population for validity and reliability analyses. Other translation and validation studies of the PRWE have used 50 – 117 patients for similar purposes.[142-146]

In spite of many experts' opinions that plates are superior to external fixation for surgical treatment of distal radius fractures, clinical studies have failed to prove this difference in patient reported outcome measurements. This may be an indication that the measurements used today are still too blunt. During the validation process it would have been interesting to evaluate the patients in Study 1 at three or more times in the early postoperative period to discern differences in responsiveness for small changes in clinical pictures, between the DASH and PRWE. A responsiveness analysis has been performed by MacDermid,[89] who showed that the PRWE was more sensitive to clinical change than the DASH. However, with the methodology they used, it was a very rough estimation of responsiveness. Almost any clinical evaluation form would have proved to be responsive for the large expected improvement between month 0 and months 3 and 6, respectively, in the rehabilitation process after a wrist injury. Even if the PRWE is more responsive than the DASH, it may be that a new outcome instrument, which not only takes the function of the injured wrist into account, but also considers handedness, expectations and needs, would greatly improve the detection of differences between treatment options for wrist fractures.

When creating a new measuring instrument it must be compared with a gold standard and it must be scaled and adjusted in order to please the manufacturer and user in terms of accuracy, reliability and reproducibility. When inventing a patient-reported outcome

measuring instrument there is no obvious gold standard to use. When the PRWE was created, MacDermid used a combination of the SF-36 and a sum of grip-strength and ROM impairment as an external criterion.[113] The DASH was also evaluated for criterion validity against the SF-36.[147] The SF-36 was in turn validated against general health appearances in terms of heart disease and general mental health.[148] For Study 1, the DASH was chosen as an external criterion. It was a reasonable choice since the DASH questionnaire provides a well established upper extremity score and has been validated in Swedish.[112]

Another feature that is important to consider when developing a patient reported outcome measuring tool, but difficult to evaluate, is face validity. The PRWE is shorter and more uniform than the DASH, which is an advantage. The DASH has many questions concerning gardening and sports, and even sexual activities, which do not seem relevant to many patients. Irrelevant or excessive questions introduce the risk of many unanswered items and thereby difficulties of interpretation. Moreover, the responsiveness analysis is difficult owing to many floor values, and a skewed distribution, with a majority of patients scoring low. Finally, there is no proportionality between results, and it is difficult to define a clinically relevant difference.

The findings in Study 2 confirm studies from the USA[55], Stockholm[24] and Finland [52] showing that external fixation as a primary surgical option for the treatment of an unstable distal radius fracture is going out of fashion. The new implants are thought to be so valuable for patients that the tendency to treat distal radius fractures surgically is increasing. This is a surprising finding, considering that clinical studies also have failed to confirm a better final outcome after surgery than after conservative treatment, especially in an elderly population[75,128,129,132,149]. Is it skilful marketing by the osteo-synthesis salesmen that affects our treatment preferences? [52,54] One can question the ethics of this development of the orthopaedic treatment rationales.

The Sahlgrenska University Hospital, a hospital treating approximately 5 000 fractures annually, has been collecting information on all fractures since 2011 in the Swedish Fracture Registry.[150] The use of the Fracture Registry has been spread all over Sweden and since 2014, approximately 20 hospitals in Sweden have been participating. Information is collected prospectively on all fractures regarding AO classification, injury mechanisms and the treatment given. The data from the registry show that approximately 30% of the distal radius fractures were treated surgically in 2013. Since the history of the registry does not go back further than 2011, it is impossible to draw any conclusions yet concerning the development of treatment preferences, but if the results from Study 2, showing that 20% of patients underwent surgery in 2010, are valid, one must suspect that the development of an increasing tendency to operate on wrist fractures has continued. The majority of registrations in the Fracture Registry originate from the city of Gothenburg and its surroundings. The discrepancies in findings between the Fracture Registry and Study 2 may also reveal large differences in treatment traditions between different regions. This is supported by Fanuele et al. [140]

who report a rate of surgical treatment of wrist fractures ranging from 60% to 96% depending on what region of the USA the patients were treated in.

In Study 3 we defined the complications to be reoperations due to infection, compartment syndrome, tendon injury or nerve entrapment. We further analysed the occurrence of corrective osteotomy, radiocarpal fusion and reoperation within 28 days as a sign of mechanical failure of osteosynthesis. The NOMESCO codes for surgical intervention could have easily been chosen otherwise. For analytical reasons, the search criteria must be limited in order to avoid analysing too many groups. Arora et al.[126] analysed complications after volar locking plates with an average follow-up of 15 months. In addition to the diagnoses that were recorded in Study 3, Arora reported tenosynovitis, delayed fracture healing, and CRPS. Ahlborg et al.[51] reported complications after external fixations and provide information on injuries to the sensory superficial radial nerve, surgery owing to napping scars, and superficial infections. These well-known complications after wrist fracture surgery were not taken into consideration in Study 3. Another study design than the one used in Study 3 would be necessary to study non-operatively treated complications.

Another definition formulated in Study 3 was that fracture surgery occurring within 28 days of the primary fracture operation was considered to represent redisplacement of fractures due to failure of the fracture surgery performed. It could just as well represent a new fracture, a minor mechanical complication of the hardware or a planned second intervention. It may also be the case that a redisplacement of a wrist fracture is adjusted by a surgical intervention later than 28 days after surgery. However, if the second surgical procedure takes place after 4 weeks, our experience is that the fracture is clinically healed, and even if the code for fracture intervention was chosen as fracture surgery, some action must have been taken intraoperatively to mobilise the healed fracture, thus transforming the surgical procedure into a corrective osteotomy, with its' inherent risks and characteristics. The chosen time limit of 28 days for early mechanical failure of fracture surgery may be questioned. However, other authors have suggested 3 or 6 weeks as an adequate time limit,[34,37,75] which is well in line with ours.

Many patients want their plates removed after wrist fracture surgery, even when no symptoms are present[151]. Should this be considered to be a complication, or is it just a normal and expected postoperative care of plated wrist fracture patients? In study 3, extraction of pins and external fixators were not regarded as complications since the metalwork must be extracted to regain wrist function. Some authors report that 10-30% of plated patients need plate removal for one reason or another.[80,82,151] Other authors report only a few percent with a need for volar plate removal.[79,81] Large patient cohorts, as provided in Study 3 or in the future in the Swedish Fracture Registry, are needed to reveal the true frequency of plate removal. If the current treatment regimens prevail, future wrist fracture care must be dimensioned for removal of plates.

Walenkamp et al.[72] report, in a meta-analysis of volar plates versus bridging external fixation, that the volar plate yielded statistically significantly better DASH scores at 3

and 12 months of 16 and 8 points, respectively. This finding is supported by a meta-analysis by Cui et al.[71], who investigated studies including radial or volar plates versus external fixation. The differences in DASH outcome reported by Cui et al. are 11 points at 3 months and 8 points at one year. Esposito et al. [74] reported in their meta-analysis a 6-point difference in DASH at one year. When considering the results of these meta-analyses, it is important to differentiate between statistical and clinical significance. A 10% difference in patient reported outcome has been proposed by many authors as a clinically significant difference in detection.[77,78,80,81,149,152,153] This also applies to measurements of range-of-motion.[154,155] It is not reasonable to present a less than 10-point difference in outcome scores as a difference, even if it is a statistically significant finding. The numbers needed to treat in order to yield a lasting and palpable improvement for distal radius fracture patients must be innumerable when hundreds of patients are needed to show these small differences in DASH scores.

It is obvious that other factors than the end result, such as complications, costs and time in the operating theatre, must be allowed to be considered when choosing the surgical method for wrist fractures. A major differentiation between surgical methods for wrist fractures consists in percutaneous methods versus open reduction and internal fixation. What percutaneous methods have in common is that the surgical technique is relatively simple, and the learning curve is short and steep. The time required for surgery is generally short and when the temporary fixation is removed, no remaining hardware is present in the injured area. On the other hand, the fact that pins and external fixators must be taken out, pin-sites must be handled with wound cleaning and superficial infections are common, are all resource-consuming phenomena that must be taken into consideration. In comparison, for a plated patient, it may suffice with one out-patient visit at two weeks postoperatively, for the removal of sutures and plaster, and thereafter no further clinical control is warranted. Perhaps larger amounts of out-patient care compensate for the longer time in the operating theatre and more expensive implants, which are subjects of criticism regarding the plating techniques. However, in Study 2, the mean number of out-patient care visits after wrist fracture surgery was calculated, and showed little difference between patients treated with plates and external fixation.

Complications after external fixation are common, but seldom serious. In the case of the plate, when imperfectly positioned, or with an incautious surgical technique, there is a risk of injury of the median nerve, and both flexor and extensor tendons of the fingers are at risk, especially in the thumb. Moreover, tendon complications after wrist fracture plating have been proved in Study 3 to present many years postoperatively. One must bear in mind that wrist fractures are the most common of all fractures, and when treated, the surgical technique must be straight-forward and safe. Wrist fracture patients will inevitably be treated by a wide variety of surgeons, all skilled but not all skilled to perfection. It is important to scrutinise experts' opinions concerning the choice of surgical techniques and possible side-effects of treatment. In some surgeons' hands, the implant may be more difficult to handle.

I got the idea for Studies 2 and 3 while I was a student in the Research School for clinicians at Karolinska Institutet. I was fascinated by the methodology used so often by oncologists, cardiologists and rheumatologists, but probably since the exposure in fracture research is always known, cohort studies and population based data are not part of the traumatologist's largest research interest. Large cohort studies, however, are the best studies for studying rare and late complications. Registry studies are easy in the sense that all information is already provided. But even if all figures were already in the file at delivery from the National Board of Health and Welfare, cleaning, organising and handling the large data files that I used for Studies 2 and 3 were very time-consuming.

The goldmine for the clinical researcher provided by the Swedish healthcare registries also gives rise to important considerations for the investigator. One cannot control for fracture classifications or injury mechanisms, there is a lack of knowledge as to whether the right or left side was treated, and no distinction can be made between volar and dorsal plates because of coding technicalities. Difficulties exist in determining what procedure has taken place when the treating surgeon has chosen to call it 'other or a combination of methods,' which causes trouble for the investigator. Another aspect to consider is that codes for some diagnoses or surgical interventions may be synonymous, as for the example of wrists, NCJ and NDJ codings for surgical interventions are interchangeably used for wrist fracture surgery. Economic interests may also direct the use of certain codes, since monetary compensation is dictated by the diagnosis and surgical intervention codes that are reported to the Swedish Patient Registry. One carries an important responsibility for large cohort studies, because the definitions one chooses beforehand will largely affect the results of the study. Changing or omitting one parameter in the syntax will make a possible exposure or outcome vanish from the dataset. The definition of a fracture, a treatment, a complication and all other information that was given in Studies 2 and 3 have been carefully thought out, by me and my co-authors. I am still the first to listen to any criticism, and I am humbly convinced that more research is needed to confirm my findings before they can be cast in stone. The future information of the Swedish Fracture Registry will greatly improve the accuracy of Swedish registry research in traumatology.

The highest level of evidence for comparison of treatments is, as mentioned earlier, a blinded controlled randomised trial. This study design, however, also yields problems with interpretation of results. Patients who are accepted for inclusion in a randomised trial are selected according to well defined criteria dictated by study protocols. The study participants are therefore not always representative for the everyday fracture patient. The optimal size of the study population may be impossible to achieve for practical and/or resource reasons. Long-term follow-up may be difficult owing to patients' or investigators' neglect. Moreover, study patients are expected to follow the clinical follow-up scheme set up in the trial, and if this does not correspond to standard clinical care, the generalisability of the study results diminishes. Another feature of a randomised trial, that makes results difficult to interpret, is that if the surgeons involved in the treatment of study participants are more skilled than average, regarding surgical

technique, and more notorious than others in their search for complications and need for additional surgical procedures, the results may be skewed.

The planning, designing and implementation of Study 4 took a tremendous lot of time, work and patience. The methodology is deceptively simple, and it is only when one is deeply involved that the dangers and annoyances that may be encountered along the way are apparent. Protocols must be complete and comprehensive but not exhaustive. Patients must be included and followed-up regardless of your planned (or unplanned) vacations, childbearing or other clinical commitments. X-ray protocols should preferably be standardised, as should clinical investigation and questioning of the patients. Complications must be evaluated thoroughly and with caution in order not to over- or underestimate the severity of the complication. One should define beforehand what is to be considered a complication and what should be considered an expected and normal condition after surgery. Regardless of thorough preparations, patients will present with symptoms or complaints that are obviously a result of the treatment, but had not been foreseen. Statistical files have missing or incoherent values and much time must be allocated to preparing the protocol material before any calculations can take place. Last, but not least, a statistically significant difference is not necessarily a clinically significant finding, as with the finding of better radial deviation for plated patients in Study 4. It is important to define a level of significance in advance, not only for the statistical calculations, but also in what aspect one expects it and appreciate a clinical difference between the two treatments studied.

In summary, treating a distal radius fracture is a routine duty of any orthopaedic surgeon. In standard care, one should use treatment options and surgical implants that the surgeon and the operating theater staff are well familiar with. Complex intra-articular fractures should preferably be taken care of by surgeons with a special interest in wrist fractures, to minimise the risk of complications from surgical hardware. It is only the results of well designed and adequately powered studies that should be allowed to affect the treatment regimens in the field of orthopaedic surgery.

CONCLUSIONS

External fixation and volar locking plates are both appropriate surgical methods for a dorsally displaced distal radius fracture. The clinical outcome is equal one year after surgery in patients aged 50 – 74 who acquired their wrist fracture after low- energy trauma. Plating procedures are more prone to produce late nerve and tendon complications than external fixation. During the early postoperative period, external fixation negatively affects the quality of life of wrist fracture patients.

Study 1

The Swedish version of the Patient Rated Wrist Evaluation (PRWE-Swe), translated and validated in Study 1, is an easily understood and quickly filled-in self-administered questionnaire with good validity, reliability, and responsiveness. The PRWE is a valuable tool for evaluating the results after treatment of a wrist injury.

Study 2

The incidence of wrist fractures in the total Swedish population during 2005 - 2010 was 32/10 000 person-years. The incidence was highest among boys around the age of 14 and women over the age of 60. The incidence of surgical treatment of a distal radius fracture increased during the investigated time period. The proportion of patients undergoing surgery due to a distal radius fracture increased from 16% to 20% from 2005 to 2010. The use of plates for fixation of a wrist fracture increased by more than threefold under the period of investigation, while surgery with external fixation diminished by almost 70%.

Study 3

The incidence of reoperations after wrist fracture surgery was higher after plating than after pinning procedures. The lowest incidence of reoperations was seen after external fixation. The most usual reoperation after plating was the extraction of osteosynthesis. Pinning and external fixation gave rise to a considerable amount of reoperations owing to early loss of reduction. Tendon repair and median nerve release were encountered most frequently after plating. The occurrence of reoperations after wrist fracture surgery differed in terms of timing, whereby external fixation patients displayed an earlier onset of complications compared to plated patients who underwent reoperations in the wrist area many years after surgery.

Study 4

Volar locking plates ensured an early return of grip strength after distal radius fracture surgery. HRQoL was negatively affected by an external fixation during the fixation period. Radiological restoration of the anatomical alignment of the wrist was achieved more often after volar locking plates than after external fixation. In all other outcome measurements, the results after volar locking plates and external fixation reinforced by Kirschner wires were equal at three months and at one year.

CLINICAL IMPLICATIONS

Based on the findings of my studies I recommend the use of the PRWE as an outcome instrument for distal radius fracture research. An external fixation is a safe surgical method for extraarticular wrist fractures and for intra-articular fractures without articular incongruity. External fixation provides a good final outcome with a low risk of secondary surgery or serious complications. A volar plate is a good option for intraarticular fractures and for patients with a medical condition, social position or concomitant injury necessitating a prompt return to function. A volar locking plate yields a fast and good recovery after a wrist fracture but one must be mindful of potential complications in the plating procedure.

FUTURE PERSPECTIVES

Our and several other randomised controlled studies have proved equal results after volar locking plates and percutaneous methods for distal radius fracture patients. Few authors, however, have studied the long-term effects in terms of development of post-traumatic arthritis or late complications. In Study 3 the suspicion arose that plated patients undergo surgery due to tendon irritation and hardware symptoms long after the primary surgery. We have therefore initiated a 3-year follow-up of the patients in Study 4, comprising evaluations of radiology, subjective wrist function and complications.

I have vividly argued that there is no scientific proof of volar plating being superior to external fixation. For an elderly population, however, very little is known at all about the benefit of surgery. A recent study from Austria[149] randomised 73 patients over the age of 65 and did not discern any clinical advantage of surgery in comparison with conservative treatment in a plaster cast. Inspired by this study, we have started a randomised controlled trial with a protocol very much like the protocol in Study 4, but with the inclusion of patients aged 75 or older. Patients are allocated to either treatment with a plaster cast or surgery with a volar locking plate. Inclusion started in April 2013.

When all outcome measures are alike, and complications not largely different, I continue to look for arguments for choosing either method as my preferred one for the treatment of dorsally displaced wrist fractures. With a worldwide economic concern for healthcare expenditure, one must integrate the aspect of costs in the decision-making process for this very common fracture. A study has been initiated for a cost analysis comparing external fixation and volar locking plates.

On analysing data in Study 2, I found interesting differences between regions in treatment preferences. We are planning to analyse treatment options, as has been done in Studies 2 and 3, and differentiate all results per region. Our research group is also designing a registry study in order to estimate the burden of non-operatively treated postoperative infections after distal radius fracture surgery.

Other aspects of distal radius fracture care that it would be interesting to investigate involve intra- and postoperative analgesics. Theoretically, percutaneous surgical methods should produce less postoperative pain than open plating procedures since the surgical trauma is less pronounced. Immediate postoperative pain is believed to be a trigger for CRPS. As treating surgeons, we perform surgery in a day surgery setting, we prescribe oral analgetics, and we presume that the patients will manage to treat the postoperative pain by themselves with an adequate dosage when the effect of local anaesthesia fades away. The design of future studies has been started with the aim of evaluating the effect of postoperative pain on wrist fracture rehabilitation.

Many surgeons and authors prefer volar locking plates to external fixation, even if studies cannot prove the benefits of the volar plates. Perhaps our evaluation instruments are too blunt to discern the true differences between treatment methods? I also believe

that the questions in the DASH and PRWE are good and pertinent in most instances, but no consideration is given to handedness. Many patients cannot be properly evaluated if they have injured their non-dominant hand. Many questions regard activities only performed with the dominant hand, and thus less disability is reported, even if the problems with the injured wrist are substantial. Expectations on the wrist are another feature of wrist evaluations that is not considered in either DASH or PRWE. If you have none, you will always be content. High-achieving patients may score low objective disability on the PRWE and DASH but may still be greatly dissatisfied with the recovery from their wrist fracture. I would like to develop a novel type of PROM for wrist fractures.

SAMMANFATTNING PÅ SVENSKA

Handledsfrakturen är den vanligaste frakturen som behandlas inom sjukvården. Behandlingsmetoder varierar från elastisk linda till en kombination av avancerade kirurgiska metoder. Många frakturer läker utan kvarstående men. Dock rapporterar 15-30% av patienterna någon form av funktionsnedsättning från hand eller handled efter skadan. Syftet med denna doktorsavhandling var att undersöka förekomsten av handledsfrakturer i Sverige, och att värdera slutresultatet för patienter som opererats på grund av en handledsfraktur.

I Studie 1 översattes en handledsenkät, den s k Patient Rated Wrist Evaluation (PRWE), från engelska till svenska. Den testades på 124 patienter med handledsfraktur. Den svenska versionen av PRWE (PRWE-Swe) visade sig vara pålitlig, stabil och ha god förmåga att upptäcka förändringar i handledsfunktionen. PRWE-Swe är ett värdefullt verktyg för forskare och behandlare som bedömer patienter med handledsfraktur.

I Studie 2 analyserades en datafil från Socialstyrelsen som innehöll information om alla sjukvårdsbesök som ägt rum i Sverige p g a handledsfraktur under åren 2005 – 2010. I den vuxna befolkningen förekom det 26 handledsfrakturer per 10 000 levda år. Andelen handledsfrakturer som opererats ökade från 16 till 20% under åren 2005 till 2010. Under samma period ökade operationer med en inopererad metallplatta mer än trefaldigt medan operation med en ställning, s k extern fixation, minskade med 67%.

I Studie 3 analyserades en datafil från Socialstyrelsen som innehöll information om all handledsfrakturkirurgi som ägt rum under åren 2001 – 2009. Det visade sig vara vanligare med omoperation efter operation med metallplatta, än efter operation med en ställning, s k extern fixation. Patienterna med extern fixation omopererades tidigt medan patienter som opererats med en platta opererades om så sent som mer än 3 år efter frakturoperationen. Tidig korrektion av frakturkirurgin var vanligast för patienterna med externfixation. Patienterna med platta drabbades ofta av att behöva opererera bort sin platta. Operation pga skador av senor och nerver var vanligare för plattopererade än för externfixerade patienter.

I Studie 4 lottades 140 patienter mellan 50 och 74 års ålder med felställd handledsfraktur mellan operation med antingen extern fixation eller metallplatta, i en kontrollerad forskningsstudie. Patienterna i båda grupperna var lika vid olyckstillfället avseende ålder, sjuklighet och frakturutseende. Funktionen i handleden mättes med handledsenkäten Disability of the Arm Hand and Shoulder (DASH) och ingen skillnad fanns mellan grupperna vid 3 och 12 månader efter skadan. Röntgenbilden blev något bättre för patienter som lottats till operation med platta. Rörelseomfånget blev detsamma i båda grupperna. Greppstyrkan blev bättre för patienterna med platta vid 3 månader efter operation men skillnaderna var utjämnade vid ettårskontrollen.

Slutsatsen är att PRWE är en bra enkät för att mäta funktion efter handledsfraktur. Operation med platta ger ett snabbare återhämtande av greppstyrka och livskvalitet än operation med extern fixation, men risken är högre för omoperation på lång sikt. Funktionsnivån blir densamma ett år efter skadan oavsett om man opererar med platta eller extern fixation, hos patienter mellan 50 och 74 års ålder.

POST SCRIPT

I am proud to be an orthopaedic surgeon. It is rewarding, meaningful, respected and reasonably well paid (please don't tell my boss I admitted this). But at times, the clinical everyday work in a fracture clinic is overwhelming. I have the feeling that I am working as a cashier in a supermarket the day before Christmas, taking care of an endless queue of stressed out and demanding clients, waiting for their turn. I take the item they are buying and – blip – I pass it in front of the machine that registers the bar code. Again and again and again. Blip. Blip. Blip. At these moments, I am happy to leave the clinical routine and set off to research land. I am in charge, I choose the pace and the path, I decide the hours and the themes. In my imaginary supermarket, I am the client, walking along the lanes of merchandise, carefully or at times recklessly choosing what brand of this or that that I will buy. I linger in front of the deli counter or I fill up necessities for my bakery stock. That is how and why I appreciate clinical research. It is stimulating, it takes creativity and endurance, it is hard work and requires discipline and it is pondering over wording during gardening in early summer evenings. I am proud to be a clinical researcher. I hope that you enjoyed reading my thesis.

ACKNOWLEDGEMENTS

Sari Ponzer, my main supervisor, co-author. You are an outstanding person! I admire your capacity, your never-ending enthusiasm and availability. You are a role model in leadership and management. You are a wise and patient supervisor, and I warmly appreciate your advice in all aspects *of* research! This thesis would never have been written without your support!!

Leif Ahrengart, co-supervisor, co-author. Thank you for clinical and theoretical instructions and advice during these years of wrist research. You are a firm and solid clinician with great knowledge in the field of wrist fracture surgery and research. I appreciate your escapes back to the clinic from the good life of retirement.

Hans Törnkvist, co-supervisor, co-author. Thank you for your friendship and mentorship. Thank you for your consolation in bad times and good clinical advice in all aspects of fracture surgery. You have been my orthopaedic father figure and I appreciate your support in my clinical, scientifical and personal development.

Gunnar Bergström, co-author. Thank you for making me understand the basics of SPSS and for introducing me to the methodology of validation.

Hans Järnbert Pettersson, Statistician, co-author. Thank you for your patient and hard work with Studies 2 and 3. Whatever difficult definition or modification of the immense dataset from Socialstyrelsen I demanded, you could make it happen! I admire your sharp eye for details and I look forward to future collaboration.

Anders Enocson, co-author. Thank you for your good advice and skilful proofreading of Study 3. Thank you for joining the wrist research group, and making it grow!

Paul Blomqvist, MD, PhD, Senior Lecturer. In memoriam. I remember your clever and humorous teaching in health economics. You introduced me to the idea of my epidemiological studies and without your initiative, Studies 2 and 3 never would have been started. I wish I would have had the opportunity to learn more from you.

All patients in my studies. Thank you for participating!

Elisabeth Skogman, research nurse. I cannot put into words how much you have contributed to this thesis. You have endless patience (with me at least), you have the best attitude to our patients and it is thanks to you that we have such a low drop-out rate in our studies! I deeply appreciate our friendship and co-operation.

Tina Levander, research nurse. You are a great collaborator. Thank you for answering all questions on SPSS that I don't dare pose to my statistician. I appreciate our chats on life, death and practicalities. I love my black Converse shoes: they will soon be worn out!

Birgitta Majlöv Björk, nurse and Operating Theater coordinator. Thank you for your invaluable help in identifying potential research patients! You are always helpful, professional and flexible. You are very skilled in your work, and, blissfully, you have a talent for reading between the lines in medical records.

Birgitta Häggmark, occupational therapist, who investigated all patients in Study 4 and in ongoing clinical studies outside this thesis. I appreciate your helpfulness in booking and performing all rehab and clinical measurements to our and the patients' satisfaction. I hope you know that our patients praise you!

Anita Söderqvist, research nurse and PhD. I seriously thought that my research career would end the day that you retired…! You led me through the first meetings with

research patients, helped me fill in charts and protocols, posted, phoned, visited patients at home…. I value your skills in taking care of patients, I admire your academic achievements, I enjoy your company!

Anneli Andersson, my dear secretary, the best there is! You keep track of every detail, you are always smiling, cordial, tactful. You make my life so much easier. Thank you! I wouldn't make it without you!

Isaac Austin, linguistic advisor. Thank you for quick and adequate scrutinising of my manuscripts. I warmly appreciate your support in the fight with editors!

Anita Ahrengart, MD, PhD, Senior Lecturer and **Joanna Ahlqvist**, MD. Thank you for good cooperation in translating the questionnaire in Study 1.

Gunilla Lapidus, MD, Dept of Radiology, St Görans hospital. Thank you for accurate and quick examination of all radiographs in Study 4.

Erik Elmstedt, former Head of Department of Orthopaedics, Södersjukhuset. You hired me when I first started at Södersjukhuset in 2002, thank you for that! You are a great personality, I appreciate your warm caring attitude towards your patients, I admire your wit, I love your humour. I do admit taking the lift once in a while. Even when the stairs are working!

Elisabet Hagert, my external mentor. Thank you for having been available. Who else than you can make an orthopaedic surgeon cry over nerve endings?

Göran Modin and **Ricard Miedel**, former Heads of the Department of Orthopaedics Södersjukhuset. Thank you for making it possible for me to pursue the track of clinical research.

Karolinska Institutet's Research School for Clinicians and **Karin Ekström Smedby**. Thank you for providing superb conditions for learning the do's and don't's in clinical research.

Richard Blomfeldt, my present boss. Thank you for giving me the time and possibilities to develop scientifically and clinically.

All staff in the **Södersjukhusets Operationsavdelning** and **Dagkirurgiskt Centrum.** Thank you for great cooperation, flexibility and friendship.

Sektion 34, and staff in avdelning 34. Thank you for your everyday professional handling of all patients, and for good cooperation.

All my dear colleagues in the Department of Orthopaedics Södersjukhuset. Thank you for more than ten years of great friendship, humour, music and hard work. I miss you guys who moved to Danderyd and elsewhere, and I include you in the above-mentioned tribute.

Christian, Erik and **Jenny,** my roomies. Thank you for providing great company in good and bad times, with the perfect balance between relaxing chit-chat and productive dead silence.

Johanna Rundgren and **Jenny Saving**. Thank you for taking part in the present and future adventures in wrist fracture research.

Maria Wilcke, hand surgeon, orthopaedic surgeon, mother of four and PhD. Anything I can do, you can do faster! Thank you for the fruitful discussions and co-operation. I look forward to possible future projects. Thanks for introducing me to the book-writing theme.

Hanna Südow, MD. Thank you for giving me the right push in the right time to apply for ethical permits for future studies.

Aron, David, Malin and **Sophie**, appearing in alphabetical order. You are my good and beloved friends from the Karolinska Institutet Research School for Clinicians. I recall our discussions over statistics and life with great affection.
Appearing in alphabetic order, **friends** and **families** in Bagarmossen, Bjursås, Bromma, Nacka, Sköndal, Sollentuna and Vancouver. Thank you for your loyal friendship and love.
My beloved parents, **Eva** and **Tore.** Thank you for giving me the right genes and upbringing, with love, patience, and support, to become a very happy daughter. Now, we are two doctors in the family!
Susanna and **Caroline**, my dear sisters. You are always there, in sickness and in health. I love you!
Amanda, Alicia, Adrian and **Vincent**, my beloved children. You are the true meaning of my life!
Denys, my husband, my best friend, the love of my life. Thank you for always being there, now and forever.

REFERENCES

1. Colles, A. On the fracture of the carpal extremity of the radius. Edinb Med Surg J. 1814;10:181. *Clin Orthop Relat Res* **445**, 5-7 (2006).
2. Court-Brown, C.M. & Caesar, B. Epidemiology of adult fractures: A review. *Injury* **37**, 691-7 (2006).
3. Barton, J.R. Views and treatment of an important injury of the wrist. . *Medical Examiner, Philadelphia* **1**, 365-368 (1838).
4. Smith, R.W. A Treatise on Fractures in the Vicinity of Joints and on Certain Forms of Accidental and Congenital Dislocations. *Hodges & Smith, Dublin* (1847).
5. Jupiter, J.B. & Fernandez, D.L. Comparative classification for fractures of the distal end of the radius. *J Hand Surg Am.* **22**, 563-71. (1997).
6. Flinkkila, T., Raatikainen, T. & Hamalainen, M. AO and Frykman's classifications of Colles' fracture. No prognostic value in 652 patients evaluated after 5 years. *Acta Orthop Scand.* **69**, 77-81. (1998).
7. Andersen, D.J. *et al.* Classification of distal radius fractures: an analysis of interobserver reliability and intraobserver reproducibility. *J Hand Surg Am.* **21**, 574-82. (1996).
8. Kural, C. *et al.* Evaluation of the reliability of classification systems used for distal radius fractures. *Orthopedics.* **33**, 801. doi: 10.3928/01477447-20100924-14. (2010).
9. Frykman, G. Fracture of the distal radius including sequelae--shoulder-hand-finger syndrome, disturbance in the distal radio-ulnar joint and impairment of nerve function. A clinical and experimental study. *Acta Orthop Scand* **108**(1967).
10. Müller, M.A., M. Scneider, R. et al. Manual of Internal fixation. 3rd ed. *Berlin Heidelberg New York: Springer-Verlag.* (1991).
11. Fernandez, D.L. Fractures of the distal radius: operative treatment. *Instr Course Lect* **42**, 73-88. (1993).
12. Lindau, T., Arner, M. & Hagberg, L. Intraarticular lesions in distal fractures of the radius in young adults. A descriptive arthroscopic study in 50 patients. *J Hand Surg Br.* **22**, 638-43. (1997).
13. Rennie, L., Court-Brown, C.M., Mok, J.Y. & Beattie, T.F. The epidemiology of fractures in children. *Injury.* **38**, 913-22. Epub 2007 Jul 12. (2007).
14. de Putter, C.E. *et al.* Trends in wrist fractures in children and adolescents, 1997-2009. *J Hand Surg Am.* **36**, 1810-1815.e2. doi: 10.1016/j.jhsa.2011.08.006. (2011).
15. Landin, L.A. Epidemiology of children's fractures. *J Pediatr Orthop B.* **6**, 79-83. (1997).
16. Hedstrom, E.M., Svensson, O., Bergstrom, U. & Michno, P. Epidemiology of fractures in children and adolescents. *Acta Orthop.* **81**, 148-53. doi: 10.3109/17453671003628780. (2010).
17. Cooper, C., Dennison, E.M., Leufkens, H.G., Bishop, N. & van Staa, T.P. Epidemiology of childhood fractures in Britain: a study using the general practice research database. *J Bone Miner Res.* **19**, 1976-81. Epub 2004 Sep 20. (2004).
18. Singer, B.R., McLauchlan, G.J., Robinson, C.M. & Christie, J. Epidemiology of fractures in 15,000 adults: the influence of age and gender. *J Bone Joint Surg Br.* **80**, 243-8. (1998).

19. Lindau, T.R., Aspenberg, P., Arner, M., Redlundh-Johnell, I. & Hagberg, L. Fractures of the distal forearm in young adults. An epidemiologic description of 341 patients. *Acta Orthop Scand.* **70**, 124-8. (1999).
20. Diamantopoulos, A.P. *et al.* The epidemiology of low- and high-energy distal radius fracture in middle-aged and elderly men and women in Southern Norway. *PLoS One* **7**, e43367. doi: 10.1371/journal.pone.0043367. Epub 2012 Aug 24. (2012).
21. Oyen, J., Rohde, G.E., Hochberg, M., Johnsen, V. & Haugeberg, G. Low-energy distal radius fractures in middle-aged and elderly women-seasonal variations, prevalence of osteoporosis, and associates with fractures. *Osteoporos Int.* **21**, 1247-55. doi: 10.1007/s00198-009-1065-0. Epub 2009 Sep 23. (2010).
22. Hernlund, E. *et al.* Osteoporosis in the European Union: medical management, epidemiology and economic burden. A report prepared in collaboration with the International Osteoporosis Foundation (IOF) and the European Federation of Pharmaceutical Industry Associations (EFPIA). *Arch Osteoporos.* **8**, 136. doi: 10.1007/s11657-013-0136-1. Epub 2013 Oct 11. (2013).
23. Kanterewicz, E. *et al.* Association between Colles' fracture and low bone mass: age-based differences in postmenopausal women. *Osteoporos Int.* **13**, 824-8. (2002).
24. Wilcke, M.K., Hammarberg, H. & Adolphson, P.Y. Epidemiology and changed surgical treatment methods for fractures of the distal radius. *Acta Orthop* **84**, 292-6 (2013).
25. Jonsson, B., Bengner, U., Redlund-Johnell, I. & Johnell, O. Forearm fractures in Malmo, Sweden. Changes in the incidence occurring during the 1950s, 1980s and 1990s. *Acta Orthop Scand* **70**, 129-32 (1999).
26. Siggeirsdottir, K. *et al.* Epidemiology of fractures in Iceland and secular trends in major osteoporotic fractures 1989-2008. *Osteoporos Int.* **25**, 211-9. doi: 10.1007/s00198-013-2422-6. Epub 2013 Jul 2. (2014).
27. van Staa, T.P., Dennison, E.M., Leufkens, H.G. & Cooper, C. Epidemiology of fractures in England and Wales. *Bone* **29**, 517-22 (2001).
28. Flinkkila, T. *et al.* Epidemiology and seasonal variation of distal radius fractures in Oulu, Finland. *Osteoporos Int.* **22**, 2307-12. doi: 10.1007/s00198-010-1463-3. Epub 2010 Oct 23. (2011).
29. Sigurdardottir, K., Halldorsson, S. & Robertsson, J. Epidemiology and treatment of distal radius fractures in Reykjavik, Iceland, in 2004. Comparison with an Icelandic study from 1985. *Acta Orthop.* **82**, 494-8. doi: 10.3109/17453674.2011.606074. (2011).
30. Schmalholz, A. Epidemiology of distal radius fracture in Stockholm 1981-82. *Acta Orthop Scand.* **59**, 701-3. (1988).
31. Bengner, U. & Johnell, O. Increasing incidence of forearm fractures. A comparison of epidemiologic patterns 25 years apart. *Acta Orthop Scand* **56**, 158-60 (1985).
32. Brogren, E., Petranek, M. & Atroshi, I. Incidence and characteristics of distal radius fractures in a southern Swedish region. *BMC Musculoskelet Disord* **8**, 48 (2007).
33. Simic, P.M. & Weiland, A.J. Fractures of the distal aspect of the radius: changes in treatment over the past two decades. *Instr Course Lect* **52**, 185-95. (2003).
34. Mackenney, P.J., McQueen, M.M. & Elton, R. Prediction of instability in distal radial fractures. *J Bone Joint Surg Am.* **88**, 1944-51. (2006).

35. Sarmiento, A., Pratt, G.W., Berry, N.C. & Sinclair, W.F. Colles' fractures. Functional bracing in supination. *J Bone Joint Surg Am.* **57**, 311-7. (1975).
36. Jupiter, J.B. Fractures of the distal radius. *Instr Course Lect* **41**, 13-23. (1992).
37. Margaliot, Z., Haase, S.C., Kotsis, S.V., Kim, H.M. & Chung, K.C. A meta-analysis of outcomes of external fixation versus plate osteosynthesis for unstable distal radius fractures. *J Hand Surg Am* **30**, 1185-99 (2005).
38. De Palma, A.F., Gartland, J.J. & Dowling, J.J. Colles' fracture. *Pa Med.* **69**, 72-5. (1966).
39. Carrozzella, J. & Stern, P.J. Treatment of comminuted distal radius fractures with pins and plaster. *Hand Clin.* **4**, 391-7. (1988).
40. Habernek, H., Weinstabl, R., Fialka, C. & Schmid, L. Unstable distal radius fractures treated by modified Kirschner wire pinning: anatomic considerations, technique, and results. *J Trauma.* **36**, 83-8. (1994).
41. Rosenthal, A.H. & Chung, K.C. Intrafocal pinning of distal radius fractures: a simplified approach. *Ann Plast Surg.* **48**, 593-9. (2002).
42. Shyamalan, G. Volar locking plates versus Kirschner wires for distal radial fractures-A cost analysis study [Injury 2009;40(December (12)):1279-81]. *Injury*.
43. Hargreaves, D.G., Drew, S.J. & Eckersley, R. Kirschner wire pin tract infection rates: a randomized controlled trial between percutaneous and buried wires. *J Hand Surg Br.* **29**, 374-6. (2004).
44. Dowdy, P.A., Patterson, S.D., King, G.J., Roth, J.H. & Chess, D. Intrafocal (Kapandji) pinning of unstable distal radius fractures: a preliminary report. *J Trauma.* **40**, 194-8. (1996).
45. Kirmani, S.J., Bhuva, S., Lo, W. & Kumar, A. Extensor tendon injury to the index and middle finger secondary to Kirschner wire insertion for a distal radial fracture. *Ann R Coll Surg Engl.* **90**, W14-6. doi: 10.1308/147870808X257201. (2008).
46. Steinberg, B.D., Plancher, K.D. & Idler, R.S. Percutaneous Kirschner wire fixation through the snuff box: an anatomic study. *J Hand Surg Am.* **20**, 57-62. (1995).
47. Cooney, W.P., 3rd, Linscheid, R.L. & Dobyns, J.H. External pin fixation for unstable Colles' fractures. *J Bone Joint Surg Am.* **61**, 840-5. (1979).
48. Cooney, W.P. External fixation of distal radial fractures. *Clin Orthop Relat Res.*, 44-9. (1983).
49. Vidal, J.B., C. Connes, H. Treatment of articular fractures by "ligamentotaxis" with external fixation. *In Brooker, A., and Edmards, C. External Fixation. The Current State of the Art. Baltimore, Williams & Wilkins* (1979).
50. Bartosh, R.A. & Saldana, M.J. Intraarticular fractures of the distal radius: a cadaveric study to determine if ligamentotaxis restores radiopalmar tilt. *J Hand Surg Am.* **15**, 18-21. (1990).
51. Ahlborg, H.G. & Josefsson, P.O. Pin-tract complications in external fixation of fractures of the distal radius. *Acta Orthop Scand.* **70**, 116-8. (1999).
52. Mattila, V.M. *et al.* Significant change in the surgical treatment of distal radius fractures: a nationwide study between 1998 and 2008 in Finland. *J Trauma* **71**, 939-42; discussion 942-3.
53. Chung, K.C., Shauver, M.J. & Birkmeyer, J.D. Trends in the United States in the treatment of distal radial fractures in the elderly. *J Bone Joint Surg Am.* **91**, 1868-73. doi: 10.2106/JBJS.H.01297. (2009).
54. Nellans, K.W., Kowalski, E. & Chung, K.C. The epidemiology of distal radius fractures. *Hand Clin.* **28**, 113-25. doi: 10.1016/j.hcl.2012.02.001. Epub 2012 Apr 14. (2012).

55. Koval, K.J., Harrast, J.J., Anglen, J.O. & Weinstein, J.N. Fractures of the distal part of the radius. The evolution of practice over time. Where's the evidence? *J Bone Joint Surg Am* **90**, 1855-61 (2008).
56. Orbay, J.L. & Fernandez, D.L. Volar fixation for dorsally displaced fractures of the distal radius: a preliminary report. *J Hand Surg Am* **27**, 205-15 (2002).
57. Grewal, R., Perey, B., Wilmink, M. & Stothers, K. A randomized prospective study on the treatment of intra-articular distal radius fractures: open reduction and internal fixation with dorsal plating versus mini open reduction, percutaneous fixation, and external fixation. *J Hand Surg Am.* **30**, 764-72. (2005).
58. Wei, J., Yang, T.B., Luo, W., Qin, J.B. & Kong, F.J. Complications following dorsal versus volar plate fixation of distal radius fracture: a meta-analysis. *J Int Med Res.* **41**, 265-75. doi: 10.1177/0300060513476438. Epub 2013 Feb 7. (2013).
59. Klug, R.A., Press, C.M. & Gonzalez, M.H. Rupture of the flexor pollicis longus tendon after volar fixed-angle plating of a distal radius fracture: a case report. *J Hand Surg Am.* **32**, 984-8. (2007).
60. Cho, C.H., Lee, K.J., Song, K.S. & Bae, K.C. Delayed rupture of flexor pollicis longus after volar plating for a distal radius fracture. *Clin Orthop Surg.* **4**, 325-8. doi: 10.4055/cios.2012.4.4.325. Epub 2012 Nov 16. (2012).
61. Koo, S.C. & Ho, S.T. Delayed rupture of flexor pollicis longus tendon after volar plating of the distal radius. *Hand Surg* **11**, 67-70. (2006).
62. Al-Rashid, M., Theivendran, K. & Craigen, M.A. Delayed ruptures of the extensor tendon secondary to the use of volar locking compression plates for distal radial fractures. *J Bone Joint Surg Br.* **88**, 1610-2. (2006).
63. Riddick, A.P., Hickey, B. & White, S.P. Accuracy of the skyline view for detecting dorsal cortical penetration during volar distal radius fixation. *J Hand Surg Eur Vol.* **37**, 407-11. doi: 10.1177/1753193411426809. Epub 2011 Nov 7. (2012).
64. Abramo, A., Kopylov, P., Geijer, M. & Tagil, M. Open reduction and internal fixation compared to closed reduction and external fixation in distal radial fractures: a randomized study of 50 patients. *Acta Orthop.* **80**, 478-85. doi: 10.3109/17453670903171875. (2009).
65. Chappuis, J., Boute, P. & Putz, P. Dorsally displaced extra-articular distal radius fractures fixation: Dorsal IM nailing versus volar plating. A randomized controlled trial. *Orthop Traumatol Surg Res.* **97**, 471-8. doi: 10.1016/j.otsr.2010.11.011. Epub 2011 Jun 11. (2011).
66. Concato, J., Shah, N. & Horwitz, R.I. Randomized, controlled trials, observational studies, and the hierarchy of research designs. *N Engl J Med.* **342**, 1887-92. (2000).
67. Rennie, D. CONSORT revised--improving the reporting of randomized trials. *JAMA.* **285**, 2006-7. (2001).
68. Moher, D., Jones, A. & Lepage, L. Use of the CONSORT statement and quality of reports of randomized trials: a comparative before-and-after evaluation. *JAMA.* **285**, 1992-5. (2001).
69. Day, C.S., Maniwa, K. & Wu, W.K. More evidence that volar locked plating for distal radial fractures does not offer a functional advantage over traditional treatment options. *J Bone Joint Surg Am.* **95**, e1471-2. doi: 10.2106/JBJS.M.01064. (2013).
70. Wei, D.H., Poolman, R.W., Bhandari, M., Wolfe, V.M. & Rosenwasser, M.P. External fixation versus internal fixation for unstable distal radius fractures: a

systematic review and meta-analysis of comparative clinical trials. *J Orthop Trauma.* **26**, 386-94. doi: 10.1097/BOT.0b013e318225f63c. (2012).
71. Cui, Z., Pan, J., Yu, B., Zhang, K. & Xiong, X. Internal versus external fixation for unstable distal radius fractures: an up-to-date meta-analysis. *Int Orthop.* **35**, 1333-41. doi: 10.1007/s00264-011-1300-0. Epub 2011 Jun 23. (2011).
72. Walenkamp, M.M. *et al.* Functional outcome in patients with unstable distal radius fractures, volar locking plate versus external fixation: a meta-analysis. *Strategies Trauma Limb Reconstr.* **8**, 67-75. doi: 10.1007/s11751-013-0169-4. Epub 2013 Jul 28. (2013).
73. Xie, X., Xie, X., Qin, H., Shen, L. & Zhang, C. Comparison of internal and external fixation of distal radius fractures. *Acta Orthop.* **84**, 286-91. doi: 10.3109/17453674.2013.792029. Epub 2013 Apr 18. (2013).
74. Esposito, J.S., EH.;Saccone, M.;Sternheim, A.;Kuzyk, PR. External fixation versus open reduction with plate fixation for distal radius fractures: a meta-analysis of randomised controlled trials. *Injury* **44**, 409-16. doi: 10.1016/j.injury.2012.12.003. Epub 2013 Jan 6. (2013).
75. Paksima, N. *et al.* A meta-analysis of the literature on distal radius fractures: review of 615 articles. *Bull Hosp Jt Dis* **62**, 40-6. (2004).
76. Grewal, R., MacDermid, J.C., King, G.J. & Faber, K.J. Open reduction internal fixation versus percutaneous pinning with external fixation of distal radius fractures: a prospective, randomized clinical trial. *J Hand Surg Am.* **36**, 1899-906. doi: 10.1016/j.jhsa.2011.09.015. Epub 2011 Nov 3. (2011).
77. Rozental, T.D. *et al.* Functional outcomes for unstable distal radial fractures treated with open reduction and internal fixation or closed reduction and percutaneous fixation. A prospective randomized trial. *J Bone Joint Surg Am* **91**, 1837-46 (2009).
78. Wei, D.H. *et al.* Unstable distal radial fractures treated with external fixation, a radial column plate, or a volar plate. A prospective randomized trial. *J Bone Joint Surg Am* **91**, 1568-77 (2009).
79. Egol, K. *et al.* Bridging external fixation and supplementary Kirschner-wire fixation versus volar locked plating for unstable fractures of the distal radius: a randomised, prospective trial. *J Bone Joint Surg Br.* **90**, 1214-21. doi: 10.1302/0301-620X.90B9.20521. (2008).
80. Wilcke, M.K., Abbaszadegan, H. & Adolphson, P.Y. Wrist function recovers more rapidly after volar locked plating than after external fixation but the outcomes are similar after 1 year. *Acta Orthop.* **82**, 76-81. doi: 10.3109/17453674.2011.552781. Epub 2011 Feb 1. (2011).
81. Karantana, A. *et al.* Surgical treatment of distal radial fractures with a volar locking plate versus conventional percutaneous methods: a randomized controlled trial. *J Bone Joint Surg Am.* **95**, 1737-44. doi: 10.2106/JBJS.L.00232. (2013).
82. Williksen, J.H., Frihagen, F., Hellund, J.C., Kvernmo, H.D. & Husby, T. Volar locking plates versus external fixation and adjuvant pin fixation in unstable distal radius fractures: a randomized, controlled study. *J Hand Surg Am.* **38**, 1469-76. doi: 10.1016/j.jhsa.2013.04.039. (2013).
83. Leung, F., Tu, Y.K., Chew, W.Y. & Chow, S.P. Comparison of external and percutaneous pin fixation with plate fixation for intra-articular distal radial fractures. A randomized study. *J Bone Joint Surg Am* **90**, 16-22 (2008).
84. Kreder, H.J. *et al.* Indirect reduction and percutaneous fixation versus open reduction and internal fixation for displaced intra-articular fractures of the distal radius: a randomised, controlled trial. *J Bone Joint Surg Br* **87**, 829-36 (2005).

85. Martin, D.P., Engelberg, R., Agel, J., Snapp, D. & Swiontkowski, M.F. Development of a musculoskeletal extremity health status instrument: the Musculoskeletal Function Assessment instrument. *J Orthop Res.* **14**, 173-81. (1996).
86. Ware, J.E., Jr. & Sherbourne, C.D. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. *Med Care* **30**, 473-83 (1992).
87. Gartland, J.J., Jr. & Werley, C.W. Evaluation of healed Colles' fractures. *J Bone Joint Surg Am* **33-A**, 895-907 (1951).
88. Changulani, M., Okonkwo, U., Keswani, T. & Kalairajah, Y. Outcome evaluation measures for wrist and hand: which one to choose? *Int Orthop* **32**, 1-6 (2008).
89. MacDermid, J.C., Richards, R.S., Donner, A., Bellamy, N. & Roth, J.H. Responsiveness of the short form-36, disability of the arm, shoulder, and hand questionnaire, patient-rated wrist evaluation, and physical impairment measurements in evaluating recovery after a distal radius fracture. *J Hand Surg Am* **25**, 330-40 (2000).
90. Beaton, D.E., Wright, J.G. & Katz, J.N. Development of the QuickDASH: comparison of three item-reduction approaches. *J Bone Joint Surg Am* **87**, 1038-46 (2005).
91. Foldhazy, Z. *et al.* Long-term outcome of nonsurgically treated distal radius fractures. *J Hand Surg Am* **32**, 1374-84 (2007).
92. Warwick, D., Field, J., Prothero, D., Gibson, A. & Bannister, G.C. Function ten years after Colles' fracture. *Clin Orthop Relat Res*, 270-4 (1993).
93. Villar, R.N., Marsh, D., Rushton, N. & Greatorex, R.A. Three years after Colles' fracture. A prospective review. *J Bone Joint Surg Br* **69**, 635-8 (1987).
94. Altissimi, M., Antenucci, R., Fiacca, C. & Mancini, G.B. Long-term results of conservative treatment of fractures of the distal radius. *Clin Orthop Relat Res*, 202-10 (1986).
95. Bacorn, R.W. & Kurtzke, J.F. Colles' fracture; a study of two thousand cases from the New York State Workmen's Compensation Board. *J Bone Joint Surg Am* **35-A**, 643-58 (1953).
96. Karnezis, I.A., Panagiotopoulos, E., Tyllianakis, M., Megas, P. & Lambiris, E. Correlation between radiological parameters and patient-rated wrist dysfunction following fractures of the distal radius. *Injury.* **36**, 1435-9. Epub 2005 Oct 27. (2005).
97. Knirk, J.L. & Jupiter, J.B. Intra-articular fractures of the distal end of the radius in young adults. *J Bone Joint Surg Am.* **68**, 647-59. (1986).
98. Palmer, A.K., Glisson, R.R. & Werner, F.W. Ulnar variance determination. *J Hand Surg Am.* **7**, 376-9. (1982).
99. van der Linden, W. & Ericson, R. Colles' fracture. How should its displacement be measured and how should it be immobilized? *J Bone Joint Surg Am.* **63**, 1285-8. (1981).
100. Beumer, A., Adlercreutz, C. & Lindau, T.R. Early prognostic factors in distal radius fractures in a younger than osteoporotic age group: a multivariate analysis of trauma radiographs. *BMC Musculoskelet Disord.* **14:170.**, 10.1186/1471-2474-14-170. (2013).
101. Lidstrom, A. Fractures of the distal end of the radius. A clinical and statistical study of end results. *Acta Orthop Scand Suppl* **41**, 1-118. (1959).
102. Epner, R.A., Bowers, W.H. & Guilford, W.B. Ulnar variance--the effect of wrist positioning and roentgen filming technique. *J Hand Surg Am.* **7**, 298-305. (1982).

103. Ozer, K. & Toker, S. Dorsal tangential view of the wrist to detect screw penetration to the dorsal cortex of the distal radius after volar fixed-angle plating. *Hand (N Y).* **6**, 190-3. doi: 10.1007/s11552-010-9316-2. Epub 2011 Jan 7. (2011).
104. Pichler, W., Windisch, G., Schaffler, G., Rienmuller, R. & Grechenig, W. Computer tomography aided 3D analysis of the distal dorsal radius surface and the effects on volar plate osteosynthesis. *J Hand Surg Eur Vol.* **34**, 598-602. doi: 10.1177/1753193409101471. (2009).
105. Brumfield, R.H. & Champoux, J.A. A biomechanical study of normal functional wrist motion. *Clin Orthop Relat Res.*, 23-5. (1984).
106. Boone, D.C. & Azen, S.P. Normal range of motion of joints in male subjects. *J Bone Joint Surg Am.* **61**, 756-9. (1979).
107. Ryu, J.Y., Cooney, W.P., 3rd, Askew, L.J., An, K.N. & Chao, E.Y. Functional ranges of motion of the wrist joint. *J Hand Surg Am.* **16**, 409-19. (1991).
108. Palmer, A.K., Werner, F.W., Murphy, D. & Glisson, R. Functional wrist motion: a biomechanical study. *J Hand Surg Am.* **10**, 39-46. (1985).
109. Morrey, B.F., Askew, L.J. & Chao, E.Y. A biomechanical study of normal functional elbow motion. *J Bone Joint Surg Am.* **63**, 872-7. (1981).
110. Crosby, C.A., Wehbe, M.A. & Mawr, B. Hand strength: normative values. *J Hand Surg Am.* **19**, 665-70. (1994).
111. Hudak, P.L., Amadio, P.C. & Bombardier, C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The Upper Extremity Collaborative Group (UECG). *Am J Ind Med* **29**, 602-8 (1996).
112. Atroshi, I., Gummesson, C., Andersson, B., Dahlgren, E. & Johansson, A. The disabilities of the arm, shoulder and hand (DASH) outcome questionnaire: reliability and validity of the Swedish version evaluated in 176 patients. *Acta Orthop Scand* **71**, 613-8 (2000).
113. MacDermid, J.C. Development of a scale for patient rating of wrist pain and disability. *J Hand Ther* **9**, 178-83 (1996).
114. Swiontkowski, M.F., Engelberg, R., Martin, D.P. & Agel, J. Short musculoskeletal function assessment questionnaire: validity, reliability, and responsiveness. *J Bone Joint Surg Am.* **81**, 1245-60. (1999).
115. Green, D.P. & O'Brien, E.T. Open reduction of carpal dislocations: indications and operative techniques. *J Hand Surg Am.* **3**, 250-65. (1978).
116. Brooks, R. EuroQol: the current state of play. *Health Policy.* **37**, 53-72. (1996).
117. Olerud, P., Tidermark, J., Ponzer, S., Ahrengart, L. & Bergstrom, G. Responsiveness of the EQ-5D in patients with proximal humeral fractures. *J Shoulder Elbow Surg.* **20**, 1200-6. doi: 10.1016/j.jse.2011.06.010. Epub 2011 Oct 20. (2011).
118. Tidermark, J., Bergstrom, G., Svensson, O., Tornkvist, H. & Ponzer, S. Responsiveness of the EuroQol (EQ 5-D) and the SF-36 in elderly patients with displaced femoral neck fractures. *Qual Life Res.* **12**, 1069-79. (2003).
119. Ware, J.E., Jr. & Sherbourne, C.D. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. *Med Care.* **30**, 473-83. (1992).
120. Amadio, P.C., Silverstein, M.D., Ilstrup, D.M., Schleck, C.D. & Jensen, L.M. Outcome after Colles fracture: the relative responsiveness of three questionnaires and physical examination measures. *J Hand Surg Am.* **21**, 781-7. (1996).
121. Perez, R.S. *et al.* Evidence based guidelines for complex regional pain syndrome type 1. *BMC Neurol.* **10:20.**, 10.1186/1471-2377-10-20. (2010).

122. Egol, K.A. *et al.* Treatment of external fixation pins about the wrist: a prospective, randomized trial. *J Bone Joint Surg Am.* **88**, 349-54. (2006).
123. Green, S.A. Complications of external skeletal fixation. *Clin Orthop Relat Res.*, 109-16. (1983).
124. Emami, A. & Mjoberg, B. A safer pin position for external fixation of distal radial fractures. *Injury.* **31**, 749-50. (2000).
125. Kambouroglou, G.K. & Axelrod, T.S. Complications of the AO/ASIF titanium distal radius plate system (pi plate) in internal fixation of the distal radius: a brief report. *J Hand Surg Am.* **23**, 737-41. (1998).
126. Arora, R. *et al.* Complications following internal fixation of unstable distal radius fracture with a palmar locking-plate. *J Orthop Trauma* **21**, 316-22 (2007).
127. McQueen, M. & Caspers, J. Colles fracture: does the anatomical result affect the final function? *J Bone Joint Surg Br.* **70**, 649-51. (1988).
128. Anzarut, A. *et al.* Radiologic and patient-reported functional outcomes in an elderly cohort with conservatively treated distal radius fractures. *J Hand Surg Am.* **29**, 1121-7. (2004).
129. Young, B.T. & Rayan, G.M. Outcome following nonoperative treatment of displaced distal radius fractures in low-demand patients older than 60 years. *J Hand Surg Am.* **25**, 19-28. (2000).
130. Barton, T., Chambers, C. & Bannister, G. A comparison between subjective outcome score and moderate radial shortening following a fractured distal radius in patients of mean age 69 years. *J Hand Surg Eur Vol.* **32**, 165-9. Epub 2007 Jan 16. (2007).
131. Beumer, A. & McQueen, M.M. Fractures of the distal radius in low-demand elderly patients: closed reduction of no value in 53 of 60 wrists. *Acta Orthop Scand.* **74**, 98-100. (2003).
132. Foldhazy, Z. & Ahrengart, L. External fixation versus closed treatment of displaced distal radius fractures in elderly patients: a randomized controlled trial. *Current Orthopaedic Practice* **21**, 288-295 (2010).
133. Beaton, D.E., Hogg-Johnson, S. & Bombardier, C. Evaluating changes in health status: reliability and responsiveness of five generic health status measures in workers with musculoskeletal disorders. *J Clin Epidemiol* **50**, 79-93 (1997).
134. Ludvigsson, J.F. *et al.* External review and validation of the Swedish national inpatient register. *BMC Public Health.* **11:450.**, 10.1186/1471-2458-11-450. (2011).
135. Guillemin, F., Bombardier, C. & Beaton, D. Cross-cultural adaptation of health-related quality of life measures: literature review and proposed guidelines. *J Clin Epidemiol* **46**, 1417-32 (1993).
136. Amin, S., Achenbach, S.J., Atkinson, E.J., Khosla, S. & Melton, L.J., 3rd. Trends in fracture incidence: A population-based study over 20 years. *J Bone Miner Res* **19**(2013).
137. Melton, L.J., 3rd, Amadio, P.C., Crowson, C.S. & O'Fallon, W.M. Long-term trends in the incidence of distal forearm fractures. *Osteoporos Int* **8**, 341-8. (1998).
138. Omsland, T.K. *et al.* More forearm fractures among urban than rural women: the NOREPOS study based on the Tromso study and the HUNT study. *J Bone Miner Res.* **26**, 850-6. doi: 10.1002/jbmr.280. (2011).
139. Chung, K.C. *et al.* Variations in the use of internal fixation for distal radial fracture in the United States medicare population. *J Bone Joint Surg Am.* **93**, 2154-62. doi: 10.2106/JBJS.J.012802. (2011).

140. Fanuele, J. *et al.* Distal radial fracture treatment: what you get may depend on your age and address. *J Bone Joint Surg Am.* **91**, 1313-9. doi: 10.2106/JBJS.H.00448. (2009).
141. Pfeiffer, E. A short portable mental status questionnaire for the assessment of organic brain deficit in elderly patients. *J Am Geriatr Soc* **23**, 433-41 (1975).
142. Schonnemann, J.O., Hansen, T.B. & Soballe, K. Translation and validation of the Danish version of the Patient Rated Wrist Evaluation questionnaire. *J Plast Surg Hand Surg.* **47**, 489-92. doi: 10.3109/2000656X.2013.787934. Epub 2013 Apr 18. (2013).
143. Kim, J.K. & Kang, J.S. Evaluation of the Korean version of the patient-rated wrist evaluation. *J Hand Ther.* **26**, 238-43; quiz 244. doi: 10.1016/j.jht.2013.01.003. Epub 2013 Feb 27. (2013).
144. Imaeda, T. *et al.* Reliability, validity, and responsiveness of the Japanese version of the Patient-Rated Wrist Evaluation. *J Orthop Sci.* **15**, 509-17. doi: 10.1007/s00776-010-1477-x. Epub 2010 Aug 19. (2010).
145. Wilcke, M.T., Abbaszadegan, H. & Adolphson, P.Y. Evaluation of a Swedish version of the patient-rated wrist evaluation outcome questionnaire: good responsiveness, validity, and reliability, in 99 patients recovering from a fracture of the distal radius. *Scand J Plast Reconstr Surg Hand Surg* **43**, 94-101 (2009).
146. John, M. *et al.* The patient-rated wrist evaluation (PRWE): cross-cultural adaptation into German and evaluation of its psychometric properties. *Clin Exp Rheumatol.* **26**, 1047-58. (2008).
147. SooHoo, N.F., McDonald, A.P., Seiler, J.G., 3rd & McGillivary, G.R. Evaluation of the construct validity of the DASH questionnaire by correlation to the SF-36. *J Hand Surg Am.* **27**, 537-41. (2002).
148. McHorney, C.A., Ware, J.E., Jr. & Raczek, A.E. The MOS 36-Item Short-Form Health Survey (SF-36): II. Psychometric and clinical tests of validity in measuring physical and mental health constructs. *Med Care.* **31**, 247-63. (1993).
149. Arora, R. *et al.* A prospective randomized trial comparing nonoperative treatment with volar locking plate fixation for displaced and unstable distal radial fractures in patients sixty-five years of age and older. *J Bone Joint Surg Am* **93**, 2146-53.
150. Frakturregistret, S. https://stratum.registercentrum.se/#!page?id=1094.
151. Esenwein, P. *et al.* Complications following palmar plate fixation of distal radius fractures: a review of 665 cases. *Arch Orthop Trauma Surg.* **133**, 1155-62. doi: 10.1007/s00402-013-1766-x. Epub 2013 May 10. (2013).
152. Kreder, H.J. *et al.* A randomized, controlled trial of distal radius fractures with metaphyseal displacement but without joint incongruity: closed reduction and casting versus closed reduction, spanning external fixation, and optional percutaneous K-wires. *J Orthop Trauma* **20**, 115-21 (2006).
153. Gummesson, C., Atroshi, I. & Ekdahl, C. The disabilities of the arm, shoulder and hand (DASH) outcome questionnaire: longitudinal construct validity and measuring self-rated health change after surgery. *BMC Musculoskelet Disord.* **4**, 11. Epub 2003 Jun 16. (2003).
154. Souer, J.S., Buijze, G. & Ring, D. A prospective randomized controlled trial comparing occupational therapy with independent exercises after volar plate fixation of a fracture of the distal part of the radius. *J Bone Joint Surg Am.* **93**, 1761-6. doi: 10.2106/JBJS.J.01452. (2011).
155. Lozano-Calderon, S.A., Souer, S., Mudgal, C., Jupiter, J.B. & Ring, D. Wrist mobilization following volar plate fixation of fractures of the distal part of the

radius. *J Bone Joint Surg Am.* **90**, 1297-304. doi: 10.2106/JBJS.G.01368. (2008).

APPENDIX

HÄLSOENKÄT - HANDLED

Namn: _____ Datum: _____

Personnummer: _____

*Nedanstående frågor hjälper oss att förstå hur mycket **besvär** du har haft av din handled den **senaste veckan**. Du ska beskriva ett **genomsnitt** av dina **symptom** från handleden under den **senaste veckan** på en skala från 0 till 10. Var snäll och besvara **alla** frågor. Om du inte utförde någon av aktiviteterna så försök att **uppskatta** den **smärta** eller **svårighet** du kunde förväntat dig. Om du aldrig utfört någon av aktiviteterna kan du låta bli att svara.*

SMÄRTA

*Uppskatta den **genomsnittliga graden av smärta** i din handled den **senaste veckan** genom att ringa in den siffra som bäst beskriver din smärta på en skala från 0 till 10.*

Noll (0) betyder att du inte hade någon smärta och tio (10) betyder att du hade den värsta smärta du någonsin känt eller att du inte kunde utföra aktiviteten pga smärta.

	Ingen smärta										Värsta tänkbara smärta
I vila	0	1	2	3	4	5	6	7	8	9	10
När du utför en uppgift med upprepad handledsrörelse	0	1	2	3	4	5	6	7	8	9	10
När du lyfter ett tungt föremål	0	1	2	3	4	5	6	7	8	9	10
När det är som värst	0	1	2	3	4	5	6	7	8	9	10
	Aldrig										Alltid
Hur ofta har du ont?	0	1	2	3	4	5	6	7	8	9	10

FUNKTION

*Uppskatta **graden av besvär** du upplevde för var och en av nedanstående aktiviteter under den **senaste veckan** genom att ringa in den siffra som motsvarar dina besvär på en skala från 0 till 10. Noll (0) betyder att du inte hade några svårigheter och tio (10) att det var så svårt att du inte alls kunde utföra aktiviteten.*

Specifika aktiviteter	Inga besvär										Omöjligt att utföra
Vrida om en kran eller nyckel med din drabbade hand	0	1	2	3	4	5	6	7	8	9	10
Skära kött med kniv med din drabbade hand	0	1	2	3	4	5	6	7	8	9	10
Knäppa knappar i din skjorta/blus	0	1	2	3	4	5	6	7	8	9	10
Använda din drabbade hand för att resa dig ur en stol	0	1	2	3	4	5	6	7	8	9	10
Bära ett 5 kg tungt föremål med din drabbade hand	0	1	2	3	4	5	6	7	8	9	10
Använda toalettpapper med din drabbade hand	0	1	2	3	4	5	6	7	8	9	10
Allmänna aktiviteter	Inga besvär										Omöjligt att utföra
Personlig vård (klä på dig, tvätta dig)	0	1	2	3	4	5	6	7	8	9	10
Hushållsarbete (städning, underhåll)	0	1	2	3	4	5	6	7	8	9	10
Arbete (ditt yrkesarbete eller dina vardagliga uppgifter)	0	1	2	3	4	5	6	7	8	9	10
Fritidsaktiviteter	0	1	2	3	4	5	6	7	8	9	10

PRWE-Swe – Melstrand-Navarro C, Ponzer S, Ahrengart L.