Functional outcome and experiences concerning daily life after malunion of the distal radius and corrective osteotomy

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FUNCTIONAL OUTCOME AND
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ABSTRACT

BACKGROUND

Distal radius fractures are common injuries that occur at all ages. The commonest complication is that the fracture heals in malunion. This can negatively affect function and the ability to perform activities.

A malunion can be corrected surgically, with the aim of restoring the anatomy of the wrist as effectively as possible, to subsequently reduce pain and regain functional ability. The fracture is re-created and the ratio between the fragment of the distal radius and the carpal bones and between the radius and the ulna is corrected. A common surgical approach is open-wedge osteotomy with volar plating. To increase stability at the osteotomy site, the osteotomy gap is often filled with a graft. The void can also be left open.

AIM

To explore patients' experiences of how a malunited, symptomatic, distal radius frac- ture affects their ability to perform activities in daily life, before and one year after corrective osteotomy. The aim was also to evaluate whether the use of a graft or no graft influences functional outcome after corrective osteotomy, during the first post- operative year, and to evaluate radiographic and functional outcome in the long term.

METHODS

In Studies I and III, interviews were conducted. The interviews were analysed using qualitative content analysis. In Study II, patients were randomly allocated to receive a bone-substitute or no graft. Functional outcome was assessed and PROMs were filled in preoperatively and three, six and 12 months postoperatively. In Study IV, pa- tients were assessed radiographically and with respect to functional outcome and PROMs three to 10 years after corrective osteotomy for malunion of the distal radius.

RESULTS

A symptomatic malunion of the distal radius affects broad areas of daily life. It affects body function/structure, activities, participation and environmental factors as well as

personal factors (Study I). Function and the ability to perform activities improve and there are no differences with respect to functional outcome or the ability to per- form activities, during the first postoperative year, regardless of whether or not a graft is used (Study II). One year post-operatively, patients experience a decrease of symptoms. They also report of improvements in activities, participation and environ- mental factors as well as personal factors (Study III). The radiographic and functional improvements, as well as improvements in the ability to perform activities, are main- tained in the long term, although the patients may experience some residual pain (Study IV).

CONCLUSIONS

A symptomatic malunion of a distal radius fracture may have a negative impact on body function/structure, activity and participation, as well as environmental factors and personal factors. During the first year after corrective open-wedge distal radius osteotomy, where cortical contact is maintained and volar plates are used, there was no difference in pain, functional outcome or the ability to perform activities, regard- less of whether or not a bone substitute was used to fill the void. A year after surgery, the majority of the patients experienced an improvement in their ability to perform activities and that the everyday life functions again. In the long term, function and the ability to perform activities are restored to a high degree. Patients may experience some residual pain, but they still deem it worthwhile to have undergone surgery.

KEYWORDS

Distal radius fracture, *Malunion*, *Corrective osteotomy*, *Functional outcome*, *Activities of daily life*, *Interviews*, *First post-operative year*, *Long term*

SAMMAN -FATTNING PÅ SVENSKA

BAKGRUND

Distal radius fraktur är en vanlig skada som förekommer i alla åldrar. Den vanligaste komplikationen är att frakturen läker med felställning. Detta kan inverka negativt på handledens funktion och förmågan att utföra aktiviteter i det dagliga livet.

En felställning kan korrigeras genom operation och målet för det operativa ingreppet är att återställa de anatomiska förhållandena så gott det går för att minska smärta och öka möjligheten till att återfå funktionell kapacitet. Frakturen återskapas och läget mellan fragmenten och mellan distala radius och karpalbenen samt mellan radius och ulna korrigeras. En vanlig metod är open-wedge osteotomi där volar platta an- vänds för att stabilisera osteotomin. För att skapa stabilitet i operationsområdet fylls ofta den spalt som bildas vid operationen med graft. Osteotomispalten kan också lämnas öppen.

SYFTE

Att utforska patienters erfarenheter av hur vardagsliv och förmåga att utföra vardag- liga aktiviteter påverkas av en symptomatisk felläkning av en distal radiusfraktur, samt patienters erfarenheter av förmåga att utföra vardagliga aktiviteter ett år efter korrektions osteotomi. Syftet var också att utvärdera om det har någon inverkan på det funktionella resultatet under det första året efter operationen, om graft används vid operationen, eller inte. Syftet var även att utvärdera radiologiskt och funktionellt utfall på lång sikt.

METOD

Studie I och III genomfördes med intervjuer. Intervjuerna analyserades med kval- itativ innehållsanalys. I Studie II slumpades patienterna till behandlingsgrupp, där de erhöll benersättningsmedel, eller kontrollgrupp, där osteotomispalten lämnades öppen. Rörlighet och styrka mättes och PROMs fylldes i inför operationen, samt 3, 6 och 12 månader efter operationen. I Studie IV undersöktes patienterna radio- logiskt och avseende funktionellt utfall 3-10 år efter osteotomi för felläkning av distala radius.

RESULTAT

En symtomatisk felläkning av en distal radiusfraktur påverkar många områden av det dagliga livet, såsom kroppsfunktion/struktur, aktivitet, delaktighet och omgivnings-faktorer samt personliga faktorer (Studie I). Funktionen förbättras och det är inga skillnader i funktionellt utfall eller förmågan att utföra aktiviteter under det första post-operativa året relaterat till om graft används eller inte (Studie II). Ett år efter operationen upplever patienterna minskade symptom. De rapporterar också förbättring gällande aktivitet, delaktighet och såväl omgivnings- som personliga faktorer (Studie III). Den post-operativa förbättringen av radiologiska- och funktionella parametrar bibehålls på lång sikt, men det förekommer att patienter har en viss kvarvarande smärta (Studie IV).

KONKLUSION

En symptomatisk felläkning av distala radius inverkar negativt på kroppsfunktion/ struktur, aktivitet, delaktighet och omgivnings- samt personfaktorer. Under det första året efter open-wedge osteotomi, där kortikal kontakt bibehålls och volar platta används för stabilisering, föreligger ingen skillnad avseende smärta, funktionellt utfall eller aktivitetsförmåga, beroende på om graft används eller inte för att fylla osteotomispalten. Ett år efter operationen upplever majoriteten av patienterna en förbättrad aktivitetsförmåga och att det dagliga livet fungerar igen. På lång sikt är funktionen och aktivitetsförmågan i hög grad återställda. Patienterna kan uppleva viss kvarva- rande smärta, men de anser som regel att det varit värt att genomgå operationen.

LIST OF PAPERS

This thesis is based on the following studies, which are referred to in the text by their Roman numerals.

I. Andreasson I, Kjellby-Wendt G, Fagevik Olsén M, Karlsson J, Carlsson G. (2019). Life has become troublesome – my wrist bothers me around the clock: an interview study relating to daily life with a malunited distal radius fracture.
Disability and Rehabilitation. doi:10.1080/09638288.2018.1561954

II. Andreasson I, Kjellby-Wendt G, Fagevik Olsén M, Aurell Y, Ullman M, Karlsson J. (2020). Functional outcome after corrective osteotomy for malunion of the distal radius: a randomised, controlled, double-blind trial.
International Orthopaedics. doi:10.1007/s00264-020-04605-x

III. Andreasson I, Carlsson G, Kjellby-Wendt G, Karlsson J, Fagevik Olsén M. Daily life one year after corrective osteotomy for malunion of a distal radius fracture: an interview study.
In manuscript.

IV. Andreasson I, Kjellby-Wendt G, Fagevik Olsén M, Aurell Y, Ullman M, Karlsson J. (2019). Long-term outcomes of corrective osteotomy for malunited fractures of the distal radius.
J. Plastic Surgery and Hand Surgery. doi: 10.1080/2000656X.2019.1693392

ABBREVIATIONS

ADL	Activities of daily living
CMOP-E	Canadian Model of Occupational Performance and Engagement
COPM	Canadian Occupational Performance Measure
CRPS	Complex regional pain syndrome
CTS	Carpal tunnel syndrome
DASH	Disability of the Arm, Shoulder and Hand Questionnaire
EPL	Extensor pollicis longus
EQ-5D	Euro Quality of Life-5 dimensions' questionnaire
HRQL	Health-related quality of life
ICF	The International Classification of Functioning, Disability and Health
MCID	The minimal clinically important difference
QuickDASH	Short version of the DASH
MOHO	Model of Human Occupation
ORIF	Open reduction and internal fixation
PA	Posterior-anterior
RAND-36	Instrument from the RAND Corporation for the evaluation of HRQL
ROM	Range of motion
PROM	Patient-reported outcome measurements
PRWE	Patient-rated Wrist Evaluation
SF-36	The MOS 36-Item Short-Form Health Survey
S-GSE	Swedish version of the general self-efficacy scale
WHO	World Health Organisation
WHOQoL	World Health Organization Quality of Life

INTRODUCTION

Anyone can slip on an ice patch and break their wrist. People generally believe that, when you sustain a fracture, life goes on as it did before the injury, after treatment. The patients in this thesis had a different experience; they sustained a fracture to the distal radius and then life was not the same, at least – in many cases – not until they had undergone corrective surgery and postoperative rehabilitation, a few months or years later.

In my mind, there is, for example, this young mother, who had sustained a fracture some years before, who was hardly able to dress and lift her child, when the little one did not want to leave kindergarten in the afternoon. In my mind, there is also the elderly lady who had recovered from cancer and a myocardial infarction. The same year, she sustained a distal radius fracture, seemingly a small injury, but it bothered her for the rest of her days.

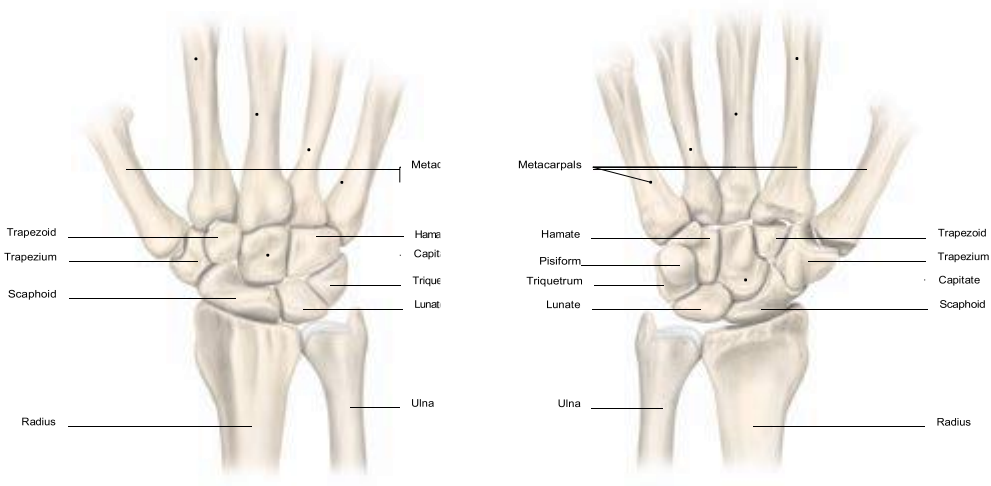
During my work at the Hand Therapy Unit at Mölndal Hospital, Sahlgrenska University Hospital, I have met many patients with a distal radius fracture. Most patients recover well within three to 12 months, but there are also individuals who have a permanent disability, which is difficult to overcome.

I felt that we needed to know more about this patient group, both before and after surgery.

1 BACKGROUND

1.1 ANATOMY OF THE WRIST

The hand is an intricate tool of fine dexterity, used in everyday life activities and also for communication and to express emotions [1]. For optimal use of the hand, the wrist needs to be stable, movable and free of pain [2]. To enhance our understanding of the possible impact of a fracture of the distal radius, a basic knowledge of the anatomy of the wrist is essential. The wrist consists of the distal radius, the ulna and the carpal bones, including their articulations with the metacarpals [3].



Dorsal view Palmar view

Figure 1 a, b. Normal anatomy of the wrist

1.2 DISTAL RADIUS FRACTURES

Fractures of the distal radius occur at all ages, account for approximately 17% of all fractures and are among the most common fractures encountered in both paediat- ric and elderly populations [4]. The fracture is mostly due to a fall on an outstretched arm. Three fracture patterns describing the characteristics of the injury, named

after the men who first described them, are the most common; Barton, Smith and Colles.

A Barton fracture is an intra-articular fracture where a volar or dorsal part of the radius remains intact, while a Smith fracture is a complete fracture of the distal radius with a volar dislocation of the distal fragment. The most common of the three types, the Colles fracture, includes a dorsally displaced fragment of the distal radius, often accompanied by an avulsion of the ulnar styloid [5-8].

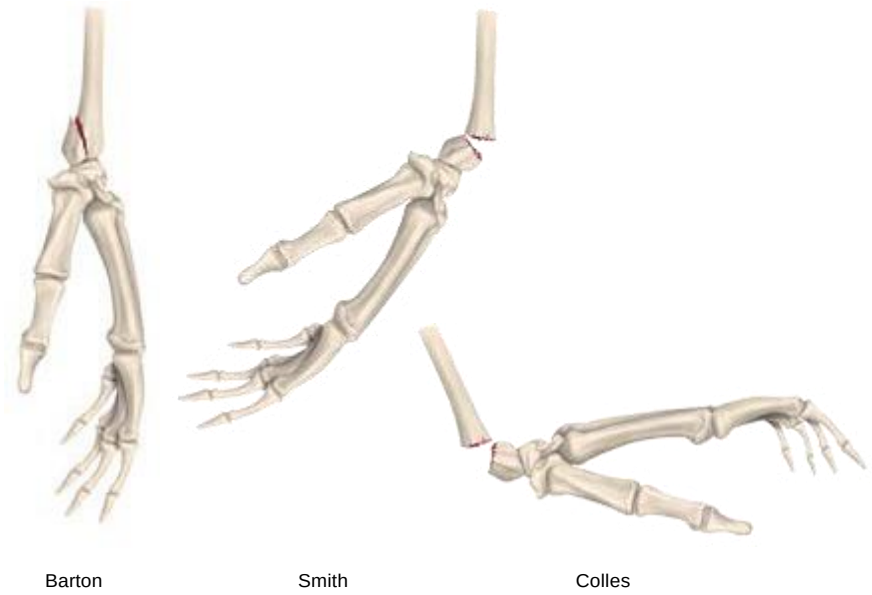


Figure 2. The Barton, Smith and Colles fracture types

The amount of energy transmitted to the bone when it is fractured is important, because injuries resulting from high-energy trauma are more likely to include more complex fracture patterns and also involve injuries to the ligaments of the wrist as well [9].

The quality of the bone is another important factor. Low bone mass density and greater-than-normal bone loss are signs of osteopenia or, in more severe cases, osteoporosis. Osteoporosis is sometimes defined as a bone density of 2.5 standard deviations below that of a young adult [10, 11]. In the presence of osteoporosis, even a

moderate trauma can lead to complicated fractures that are difficult to treat, with a high risk of a poor outcome [12].

Moreover, the fracture pattern seen in the radiological examination of the fracture is important; there are stable fracture patterns and unstable ones. Various classification systems aiming to classify fractures exist, such as the Fernandez classification, which is based on the injuring forces applied to the wrist at the time of fracture [13]. Anoth- er example is the Frykman classification, which divides fractures into eight groups based on intra-articular engagement and the involvement of the ulnar styloid [14]. The classification of the Swiss "Arbeitsgemeinschaft für Osteosynthesefragen" (AO) is another example of a widely used classification system that divides fractures into intra-articular and extra-articular fractures, grading them based on the presence of comminution [15]. Nonetheless, despite classification, the systems do not provide an exact guide for the choice of treatment method, neither do they give a full picture of the prognosis [16].

1.2.1 EPIDEMIOLOGY

The incidence of distal radius fractures is high in children and adolescents, approxi-mately 40-90/10,000 person-years. Play and sports are large contributory factors, re-sulting in moderate-energy injuries in this age category [17-21]. In young healthy adults, where the skeleton is strong, the incidence is lower [22, 23] and the fractures are often due to a moderate- or high-energy trauma [23, 24]. Due to osteopenia, the incidence in women increases from the age of 50 and is then approximately 66-110/10,000 person-years, while, in men, it increases from the age of 70 and is then about 12- 25/10,000 person-years [18, 24].

1.2.2 TREATMENT OPTIONS

There are various treatment options for a distal radius fracture, depending on the properties of the fracture and the characteristics and lifestyle of the patient. The most common treatment choice for uncomplicated fractures is a cast [25, 26]. The cast should allow free range of motion of the elbow and fingers and is worn for approximately four weeks [26, 27]. In the event of initial displacement, the fracture is manipulated under anaesthesia/analgesia, to return to a position as close to the an- atomical as possible. In the event of a stable fracture pattern, a cast is then sufficient to maintain alignment during healing [26, 28]. Follow-up, including radiographs, of the fracture position within seven to 10 days is important, before fracture healing reduc- es the opportunity for reduction [29]. In the event of an unstable pattern, a surgical intervention is undertaken to avoid healing in malunion [26, 30, 31]. Surgery should be undertaken within approximately 10 days after the injury [29]. There are many different

fixation techniques for distal radius fractures [32] and the ones mentioned below are the most frequently used.

- Fracture fixation using pins, or Kirschner wires, a minimally invasive surgical method, where the fracture is stabilised percutaneously after reduction. This technique is often combined with a cast [33-35]. Since the hardware is not stable, the pins may loosen and there is a risk of secondary displacement [33].

- External fixation, a metal scaffold worn outside the arm, normally for five to six weeks. 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 then manipulated and, after reduction, the external fixator is locked. The wrist is held in slight traction and the frac- ture is thereby held in place during healing [36, 37].

- Open reduction and internal fixation (ORIF), a technique in which the skin is opened on the volar side of the wrist, the fracture is reduced and it is then fixated with a volar plate and screws. ORIF is being used increasingly [38]. ORIF can be undertaken in most frac- ture patterns and is reported to be the best solution for displaced fractures because the plates are designed to provide reliable fixation [39, 40]. Another advantage is that ORIF allows early range-of-motion exercises [41].

Figure 3. Volar plate

1.2.3 EVALUATION OF OUTCOME AFTER DISTAL RADIUS FRACTURE

To evaluate the patients' progress during the rehabilitation process, different out- come measurements are being used. In the acute phase after a fracture, oedema in the hand and wrist are essential to evaluate, and there are different methods de- scribed, such as using volumetry [42] or the "figure of eight" [43]. Reduction of oedema is commonly not presented as an outcome and therefore not further described in this thesis.

Outcome assessments after distal radial fractures previously focused on radiograph- ic results and physical examination, such as range of motion and grip strength. How- ever, measurements of this kind do not take the patients' experiences or well-being into account, aspects that are of great importance to the patients [44]. The focus in assessments of outcome has therefore shifted towards combining functional and radiographic assessments with assessments based on the patients' opinions of their functional ability, level of pain and well-being. For these measurements, patient- reported outcome measurements (PROMs) are used [45, 46]. Commonly used methods for evaluating outcome after a distal radius fracture are described below. The out- come measurements are described in detail in the methods section.

1.2.3.1 RADIOGRAPHS

To initially assess the fracture and, after reduction or surgery, conventional radio- graphs of the wrist are taken. The standard clinical protocol includes a posterior-an- terior (PA) and a lateral exposure of the wrist [47, 48]. In the PA projection, the length of the distal radius is measured in relation to the distal ulna (radial height), as shortening of the distal radius after a fracture is often present. Ulnar variance, the difference in millimetres between the axial plane of the ulnar edge of the lunate facet and that of the seat of the ulna, is also measured. The inclination of the articular surface of the radius in relation to the vertical axis of the radius (radial inclination) is also measured, as it often decreases after a fracture. In the lateral view, the tilt of the articular surface of the distal radius is measured in relation to the perpendicular plane of the vertical axis of the radius (radial tilt) [47, 49].

Figure 4 a-d. Radial height, ulnar variance, radial inclination, radial tilt

1.2.3.2 RANGE OF MOTION

Wrist motion is important, as the role of the wrist is to position the hand while using it in different activities [2, 50]. The range of motion (ROM) of the wrist is measured in de- grees with a goniometer in the following movement directions: pronation, supination, dorsal extension, volar flexion, radial deviation and ulnar deviation [51]. Normal wrist motion consists of more than 150° of forearm rotation, 120° of wrist flexion/extension and 50° of wrist radial/ulnar deviation [52, 53]. Approximately 70% of wrist motion is used for normal use of the hand in different tasks and activities of daily living [54].

Figure 5. Measuring range of motion with a goniometer

Figure 6. Measuring grip strength with a Jamar dynamometer

1.2.3.3 GRIP STRENGTH

Grip strength is essential for the ability to perform activities of daily life [55, 56]. Since grip strength is often affected after a distal radius fracture, in both the short and the long term, it is an important outcome measurement. There are several ways of measuring grip strength and a Jamar dynamometer is often used [57].

1.2.3.4 PAIN AND ABILITY TO PERFORM ACTIVITIES

Several different PROMs are available to measure patient-reported pain and the ability to perform activities that can be used after wrist injuries [58]. One of the most extensively used PROMs for evaluating functional outcome after distal radius frac- tures and subsequent treatment is the Disabilities of the Shoulder and Hand (DASH) questionnaire [59]. This questionnaire is a self-administered score that was developed by the American Academy of Orthopaedic Surgeons and the Institute for Work and Health. The items relate to gripping ability, the ability to reach and accomplishing different tasks. There are also items related to pain and other symptoms [60]. It can be used to evaluate any damage to the upper extremities and is applicable for evaluation after distal radius fractures [61]. Another PROM that is frequently used is the short ver- sion of the DASH, the QuickDASH [62, 63]. The short form has been shown to correlate well to the original DASH [26, 62, 64, 65].

The Patient-rated Wrist Evaluation (PRWE) questionnaire is an outcome question- naire for the evaluation of pain and self-perceived ability to perform activities. It was developed with the emphasis on patients with pathological conditions of the wrist,

such as distal radius fractures [66]. It is easy to fill in and has been shown to have an even greater responsiveness to wrist-specific pathological conditions than, for example, the DASH, which evaluates the whole upper extremity and therefore has a more generic focus [59, 61].

Another instrument is the Canadian Occupational Performance Measure (COPM). It was developed as a client-centred tool to evaluate a patient's ability to perform activities and to detect changes over time. This tool also evaluates the patient's sat- isfaction with his or her capability to perform the selected activities [67].

1.2.3.5 HEALTH RELATED QUALITY OF LIFE

A wrist that is painful and stiff after a fracture may have a major impact on the per- formance of activities of daily life, as well as the patient's mood and well-being and health-related quality of life [68, 69]. To evaluate health-related quality of life (HRQL), different PROMs can be used. The Euro Quality of Life-5 dimensions' questionnaire (EQ-5D) [70], the MOS 36-Item Short-Form Health Survey (SF-36) [71] and the RAND-36 [72] are examples. To fulfil the requirements of the World Health Organization Quality of Life (WHOQoL) group, the instrument should be multidimensional [73].

1.2.3.6 SELF-EFFICACY

Self-efficacy is a central concept in Bandura's social psychological theory [74]. It refers to the belief a person has in her/his own strength and ability to achieve certain goals and to handle unexpected situations and problems [74]. Self-efficacy influences the result after orthopaedic surgery in general [75] and after surgical intervention for distal radius fractures [76, 77]. For evaluations of self-efficacy, the General Self-efficacy scale can be used, or the Swedish version of the scale, the Swedish General Self-efficacy scale (S-GSE) [78].

1.2.3.7 OBTAINING AN UNDERSTANDING OF PATIENTS' EXPERIENCES

With different PROMs, aspects such as the patients' self-perceived ability to perform activities and HRQL are assessed and evaluated.

Other aspects that are not captured by different functional assessments or by using PROMs may be highlighted when the patients are encouraged to speak from the heart. In clinical work, conversations with patients about their ability to perform ac- tivities and how they experience their functional ability are important. Interviews are suitable as a tool to comprehend the scale of the impact a malunited distal radius fracture may have on different aspects of life and the thoughts and emotions related to this [79, 80].

1.2.4 OUTCOME AFTER DISTAL RADIUS FRACTURES - WHAT TO EXPECT?

1.2.4.1 PAIN AND ABILITY TO PERFORM ACTIVITIES

Initially after a distal radius fracture, pain and disability are common, but they are less dominant after two to three months for the majority of both non-surgically treated and surgically treated patients. Most of the recovery is achieved within six months [81], but recovery continues during the first year [81-83] or even longer [55, 84]. After two years or more, according to one study by Lalone et al., the majority of patients (85%) report no change in the level of pain and disability or less pain and disability, compared with the outcome at one year, whereas about one sixth (15%) report a poorer PRWE score [85].

According to a study by MacDermid et al., [81], which included both non-surgically and surgically treated patients, 32% reported no pain, 37% minimal pain, 19% mild pain, 5% moderate pain and 6% reported severe to very severe pain one year after the fracture. With respect to the ability to perform activities, 26% reported no disability, 53% minimal disability (PRWE 1-20 points), 14% mild disability (PRWE 21-40 points), 3% moderate disability (PRWE 41-60 points) and 5% reported severe to very severe disability (PRWE 61-100 points) one year after the fracture [81]. A study by Lalone et al. [86] showed that PRWE scores at the one-year follow-up tended to deteriorate with more complex treatment. For example, in the group treated with only a cast, the PRWE score was 11.5 points (±15.7), whereas, in the ORIF group, the PRWE score was 32.0 (±28.1) [86].

In a register study with one-year outcome, conducted by Landgren et al., using the DASH and QuickDASH scores in non-surgically and surgically treated patients, about half (52%) the patients reported minor disability (DASH 0-10 points), about one third (31%) reported moderate disability (DASH 11-35 points), whereas almost one fifth (17%) reported major disability (DASH >35 points) [87].

1.2.4.2 GRIP STRENGTH

Grip strength is restored to a great extent one year after the injury/surgery, but, for the majority, it does not reach the level of the uninjured side [82]. In spite of this, research indicates that recovery continues and the mean difference between the injured side compared with the uninjured side at 24 months is small (approximately 2 kg) for both non-surgically treated and surgically treated patients [88]. According to one study of non-surgically treated patients and patients treated with external fixation, there is no longer any significant difference between the grip strength on the injured side compared with the uninjured side after two to four years [89].

1.2.4.3 RANGE OF MOTION

Range of motion increases during the first two years in both non-surgically treated and surgically treated patients, but the change is minimal after one year [90]. Accord- ing to a study by MacDermid, the ROM one year after intervention for both extra- and intra-articular distal radius fractures reaches 151° of pronation/supination, 112° of dorsal extension/volar flexion and 43° of radial deviation/ulnar deviation [82]. These values are within the normal arc of ROM for forearm rotation and close to normal for the other movement directions.

1.2.4.4 HEALTH-RELATED QUALITY OF LIFE

The physical domains of HRQL are affected, but they improve during the first six months after the injury [91]. No differences in HRQL due to the initial treatment of the fracture are presented [92, 93]. Chronic co-morbidities, several socio-demographic and psychological characteristics influence quality of life during the first year after a distal radius fracture [92]. According to a study with a mean follow-up of 22.7 months (SD 10.6), fracture severity correlates negatively with restricted ulnar deviation. This in turn correlates with lower scores in several HRQL domains [93]. Malunion is not shown to influence the QoL one year after the injury [94].

1.2.4.5 SELF-EFFICACY

The mutual influence between self-efficacy and outcome after distal radius fractures has not been studied extensively, but recent studies have shown that self-efficacy and anxiety mediate pain intensity and wrist function after volar plating [76] and that higher levels of self-efficacy correspond to better results, with respect to functional outcome, in the short term after surgical treatment for distal radius fractures [77].

1.2.5 POOR FUNCTIONAL OUTCOME

Poor functional outcome, with persisting pain, low grip strength and limited self-perceived ability to perform activities after a distal radius fracture, is often associated with poor radiographic appearance after intervention. Radial shortening and an artic- ular gap or step-off larger than 2 mm [90, 95] and volar tilt have been shown to be im- portant aspects [96]. Moreover, poor functional outcome is also associated with older age, being female [97-99] and several socio-economic factors, such as low income [96], education and third-party compensation claims [100, 101] and co-morbidities [101]. This indicates that many aspects must be considered when it comes to rehabilitation after a distal radius fracture.

1.3 PERSPECTIVES ON HEALTH

There are several perspectives on "health" that take different factors into consid- eration and that can place rehabilitation and outcome in a context. One of them was defined by the World Health Organisation (WHO) in 1946 and entered into prac- tice in 1948. The WHO defines health as "a state of complete physical, mental and social well-being, not merely the absence of disease or infirmity" [102]. In line with this definition of health, the WHO has formulated "The International Classification of Functioning, Disability and Health" (ICF) [103], a classification that aims to provide a uniform language and structure to describe health and health conditions. It classifies non-hierarchical domains that are interrelated and interact on health: body function/ structure, activity, participation and environmental and personal factors.

The ICF offers a framework for rehabilitation and the evaluation thereof. When it comes to the rehabilitation of injuries to the wrist, all the domains in the ICF are rele- vant, as the injury often influences all of them. The different tools that are used for the evaluation relate to different domains and a comprehensive evaluation therefore con- sists of different evaluation tools. Body function/structure is evaluated by radiographs and measurements of grip strength, ROM and sensation. PROMs, such as the PRWE, evaluate both body functions and the performance of activities and participation [104].

Psychological and social aspects of a disease state are considered to be just as important as the physical ones in the biopsychosocial model, presented by Engel in 1977. The three aspects are related to each other, affect the health and must all be considered in both investigations and treatment [105, 106]. Pain, for example, is seen as a complex interaction between biological actors, such as genetics and the natural pain-killing compounds in the body, and psychological factors, like mood and coping strategies and social factors, such as gender roles, ethnic identity and healthcare provider bias. Radiographs may show a fracture and its features but do not explain the amount of pain experienced by the individual. The other factors must be taken into account to explain why people respond differently to pain [106, 107]. In rehabilitation, these aspects give an indication of the individuals who might be in special need of an early intervention to prevent the pain from becoming long-standing and to prevent the hand not being used in daily life. This model, as well as the WHO's definition of health, fit in with an occupational therapy perspective on health, because they adopt an holistic stance.

In the occupational therapy framework, described, for example, in The Model of Hu- man Occupation (MOHO) [108], or The Canadian Model of Occupational Performance and Engagement (CMOP-E) [109], the individual is seen as interacting with both the

physical and the social environment. Health is achieved and maintained through the performance of, and participation in, meaningful and culturally valued occupations [108-111]. The term “occupation” refers to the everyday activities that people do as individuals, in families and within communities to occupy time and bring meaning and purpose to life [112]. Occupations include things people need to, want to and are ex- pected to do. The term “occupation” relates to the individual’s experience of certain activities; for example, “eating breakfast” relates to the individual’s experience of eat- ing breakfast every morning with the family [113]. The term “activity” refers to general categories of actions, such as “eating breakfast” and “working” [114]. In the ICF, the term “activity” is defined in a similar way, as the performance of a task or an action by an individual [103]. The meaning of the term “occupation” can also be interpreted as having a profession. In the occupational therapy context the term "occupation" has a wider meaning. To avoid misunderstanding, the term “activity” has been used to cover both “occupation” and “activity” in this thesis.

The ability to perform activities is influenced by personal factors, such as bodily impairment, and psychological aspects, like motivation and will. It is also related to fac- tors in the physical environment and the social environment, such as social life roles. Both the physical and the social environment can hinder or enable the performance of activities. The goal of rehabilitation is to enhance activity performance to enable patients to participate in different activities, which are important to them [108-110]. The wrist positions the hand to engage effectively with the environment [2, 115]. This means that the functionality of the wrist is of great importance for the ability to perform everyday life activities, and be able to communicate in a sociocultural context and, thereby, according to the occupational therapy framework, experience good health [116].

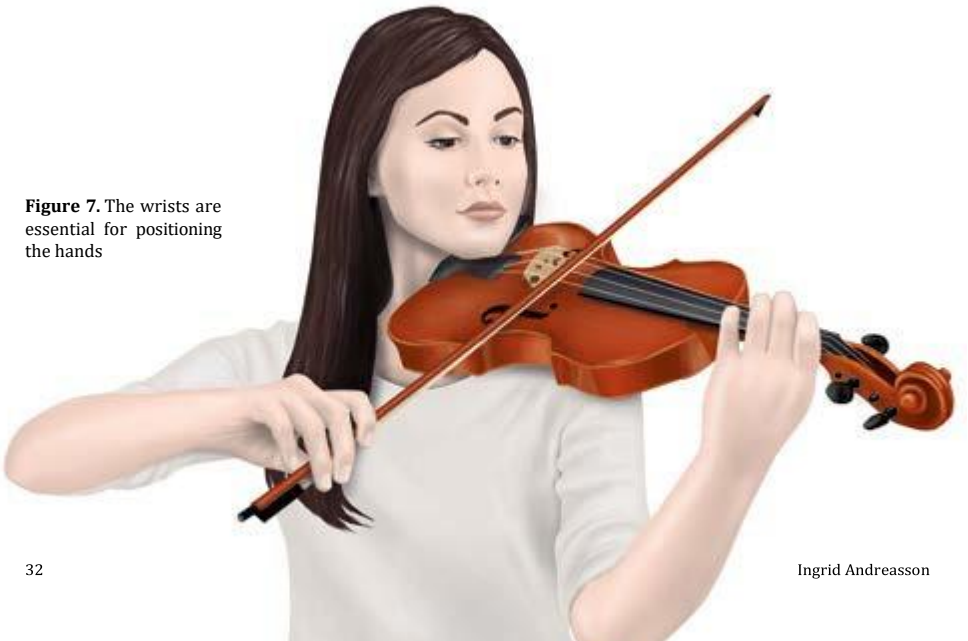


Figure 7. The wrists are essential for positioning the hands

1.4 REHABILITATION FOLLOWING A DISTAL RADIUS FRACTURE

The rehabilitation after a distal radius fracture is complex and influenced by several factors, such as the severity of the injury and the amount of oedema and pain [117, 118], the patient's age and compliance with guidelines [119]. Adopting the perspectives described above, the patient's personality and motivation, socio-economic situation and culturally perceived thoughts about injuries and healing also influence the rehabilitation process [105, 108, 110]. The CMOP-E is a model that can be applied for the rehabilitation process, as it emphasises the importance of defining the gap between the activities and tasks the patient needs and wants to accomplish and the activities and tasks the patient is actually able to perform. Interventions are then chosen to improve the patient's ability [109]. For example, if the patient's most valued leisure time activity is to play the violin, but the ability to do this is hampered by stiffness in the wrist following a distal radius fracture, ROM exercises are chosen. The intervention addresses the domain of body function, according to the ICF, and the goal is to regain the ability to play the violin, which addresses activity.

In terms of the CMOP-E, the core of the person is a central concept. The patient's personal goals, as well as a collaborative partnership between the therapist and the patient, are the focal point. The therapist is there to enable the patient to achieve his or her goals [109]. To meet the patients' needs, the rehabilitation after a distal radius fracture is monitored individually but also follows well-established strategies and certain time points with respect to fracture healing [117, 118]; the inflammatory phase (0-2 weeks), the repair phase (2-6 weeks) and the remodelling phase (6 weeks to 6 months) [120].

The practice in Sweden generally follows guidelines described in several online routine documents [121-123]. During the rehabilitation process, the main emphasis is on regaining the use of the hand in daily activities and the occupational therapist or physiotherapist guides the patient through the process. The greater part of the rehabilitation takes the form of increasing the use of the hand in daily life in combination with ROM home-exercise programmes for the upper extremity, chosen with respect to the patient's status. When the patient has high levels of pain and swelling, or is afraid of using the hand or needs instructions to carry out exercises correctly, he or she is scheduled for therapist-supervised exercises. The rehabilitation process can be divided into different phases, the immobilisation phase, the mobilisation phase and the strengthening phase [124].

1.4.1 IMMOBILISATION PHASE

The below-elbow cast should be in slight dorsiflexion [27, 125], allow full flexion of the metacarpophalangeal joints and abduction and opposition of the thumb [117, 118]. The cast is checked, adjusted or changed, as needed.

Patients suffering from injuries to the upper extremity often suffer from oedema, which is excess fluid in the extra- and intracellular spaces within the body. Oedema sometimes progresses to a sub-acute or, if it lasts for three months or more, a chron- ic state [126]. The importance of early reduction in the amount of oedema to avoid complications is well documented and measures should be undertaken as quickly as possible [117, 118, 124]. The treatment for oedema includes elevation, compression and functional training with pumping exercises of the arm and fingers and exercises for the intrinsic muscles [117, 124, 127]. These exercises are continued throughout the entire rehabilitation process, as needed [117, 128]. The importance of using both hands in a natural way in light daily activities is stressed from the beginning to reduce oedema and to encourage the patients to regain the most normal use of the hand possible [117, 124, 127].

1.4.2 MOBILISATION PHASE

Gentle range-of-motion exercises of the wrist are started approximately two weeks after surgery [119, 129], according to the surgeon's decision, and approximately four weeks after non-surgical treatment [26, 27]. A commonly used protocol is three to four times a day with 10 repetitions, depending on the patient's level of pain and stiffness. Light loading in different activities of daily life is started approximately six weeks after the injury or the surgical treatment and is gradually increased, when it is tolerated without too much pain and discomfort [117, 119, 124]. After removal of the cast, exercises are continued to reduce oedema [117, 124, 128]. Manual oedema mobilisation, soft massage with light skin traction, may also be used in this phase [124, 130, 131]. Splints are worn when needed, during the night to reduce oedema and during the day for support and pain relief, to enhance the use of the hand [117, 118, 124].

Figure 8 a, b. Splints are used for support.

1.4.3 STRENGTHENING PHASE

The increasing use of the hand in activities of daily life is encouraged, because this is the main goal of the rehabilitation, but also because the use of the hand is a means of regaining ROM and grip strength. The use of splints is gradually discontinued when the tenderness subsides. ROM exercises are continued to restore as much of the ROM as possible. Exercises that apply loads and gradually put a greater load on the wrist are initiated when healing has progressed sufficiently, generally at approximate- ly eight weeks after the injury or surgery [117, 118, 124].

1.5 COMPLICATIONS FOLLOWING DISTAL RADIUS FRACTURES

Complications following distal radius fractures were defined, in a study by McKay et al. [132], as diagnoses that are concomitant with the fracture and have resulted from the fracture or its treatment. They may occur in the short or long term [132]. A variety of complications are reported following distal radius fractures. Overall complication rates (wound complication, infection, neurovascular injuries, tendon rupture, mal- union, non-union, stiffness) after closed treatment have been shown to be between 15%, for younger patients (40-49 years) and 27% in older patients (90 years). After ORIF, the complication rates in the same study were 42% in the younger patient group and 27% in patients older than 90 years. Co-morbidities, such as high blood pressure, were more often associated with complications than age [38]. Complications following distal radius fractures are described below.

- Damage to the wrist ligaments is common. One study, using arthroscopic evaluation in displaced fractures, reported a complication rate of 98%. The triangular fibrocartilage complex was damaged in 75% and the scapho-lunate ligament in 54% of the fractured wrists [9].

- Complex regional pain syndrome (CRPS) is a severe complication. It may have a later onset than the time of the injury. The main features are continuing pain, disproportion- ate to the harmful event. It also includes symptoms in at least three of the following categories [133]:
  - sensory (hyperalgesia/allodynia)
  - vasomotor (temperature asymmetry and colour changes)
  - sudomotor (oedema and sweating changes)
  - motor/trophic (reduced range of motion, weakness, changes to hair, nails or skin)

The incidence of CRPS is reported to be 0.3-8% after distal radius fractures, following different treatment modalities [132]. After ORIF, the incidence is 0.88%, according to a large register study by Young-Hoon [134], or 1.6% according to a review by Bentohami et al. [135]. The numbers should be interpreted cautiously because of the differences in the criteria that are used to establish the diagnosis. Long-standing pain and oedema are factors contributing to the development of CRPS [133].

- A rupture of the extensor pollicis longus (EPL) occurs in approximately 5% of non-displaced distal radius fractures [136] and in approximately 2% of fractures requiring a reduction or surgical treatment [137, 138]. Different aetiologies have been proposed for this complication, including injury to blood vessels causing thrombosis, injury during reduction, adhesions [139], hampered nutrition to the tendon at the level of Lister's tubercle [140] and insufficient reduction [138].

- Carpal tunnel syndrome (CTS) is characterised by progressive pain and paresthesia in the median nerve-innervated area of the hand. The syndrome is acute, transient or delayed. Acute CTS develops within hours or days after a fracture. It has an incidence of between 5.4% and 8.6% after a distal radius fracture. It is presumably due to elevated pressure in the carpal tunnel. Immediate release of the carpal tunnel is recommended [141-145]. Transient CTS is likely due to nerve contusion. It can be present at the time of fracture and usually improves over days to weeks. The incidence of transient CTS is 4% [146]. Delayed CTS can present months to years after the harmful event and is most often related to anatomical factors. The incidence of delayed CTS is 0.5% to 22% [143, 147-149].

- Hardware-related complications of different kinds, such as hardware failure, tenosynovitis, tendon rupture and infection, occur in approximately 4% of surgically treated patients [150].

- The non-union of distal radius fractures may occur in unstable situations, but this is very uncommon; an incidence of 0.2% has been reported. Non-union is treated surgically [151,152].

- Malunion occurs when a fractured bone heals with articular incongruity, incorrect alignment or incorrect length. There are no firmly established parameters to define a malunion, but similar criteria have been presented in different studies and in practice guidelines [47,153, 154]:
  - Radial inclination < 10°
  - Volar tilt > 20°, dorsal tilt > 10-20°
  - Radial height < 10 mm
  - Ulnar variance > 2 mm +
  - Intra-articular step or gap > 2 mm

Researchers have suggested that the malunion is moderate to severe if the dorsal tilt is 15° or more and/or the ulnar variance is 3 mm or more [89, 155, 156]. Malunion is the most common complication following a distal radius fracture. It is more common in non-surgically treated fractures; the malunion rate after cast immobilisation has been reported to be between approximately 24% and 35% [90, 157] and after volar plating, between 4% and 11% [90, 158].

- Osteoarthritis may develop at the fracture site as a complication secondary to mal- union with joint incongruity. According to a study with a mean follow-up time of 6.7 years after the injury (range 2.2-11.1 years), the incidence of osteoarthritis was 65% [159].

Figure 9 a, b. Malunion of a distal radius fracture

1.5.1 MALUNION - HOW DOES IT INFLUENCE WRIST FUNCTION AND THE ABILITY TO PERFORM ACTIVITIES?

Previous trials have found that not all malunions are symptomatic [90, 160-162]. In spite of this, the research is inconclusive, while other studies indicate that the number of residual deformities is associated with the functional outcome both in younger pa- tients [163, 164] and in older patients [165-167]. The self-reported ability to perform activities measured with the DASH has been shown to correlate with radiographic findings of malunion [165]. Moreover, the increased severity of malunion is correlated with poorer DASH scores [50]. One fifth of non-surgically treated patients experience function- al impairment following malunion [84]. Reduced radial inclination is associated with decreased grip strength [168]. Dorsal and palmar angulation, as well as disturbances in radial length and ulnar variance, are related to the loss of forearm rotation [169, 170]. A supination deficit has been identified as the most disabling symptom following malunion [171, 172].

When malunion is symptomatic, it often has a major impact on the daily life of the individual patient. Further, 12-14 years after the fracture, a malunion can be associ- ated with a poorer DASH score and pain [173]. When deciding on whether or not to undertake surgery in the event of a malunion, both radiological parameters and the perceived pain and disability of the patient should be taken into account.

1.6 CORRECTIVE OSTEOTOMY

Corrective osteotomy of the distal radius is performed in the event of symptomatic malunion to relieve symptoms and improve function [28, 174]. There are several different surgical approaches for this procedure. The correction aims to restore the anatomy of the wrist, as effectively as possible, by re-creating the fracture close to the frac- ture site. The ratio between the fragment of the distal radius and the carpal bones, and between the radius and the ulna, is then corrected [174]. Open-wedge osteotomy with volar plating is a common surgical approach. It restores the length of the radius effectively but creates a void at the osteotomy site [175]. Fixed-angle volar locking plates allow rigid fixation and are commonly used because of their anatomical de- sign and the low risk of extensor tendon irritation [128, 176]. To increase stability at the osteotomy site, the osteotomy gap is often filled with an autologous graft from the crista iliaca. This method has some disadvantages, such as pain and the risk of other complications at the donor site [177]. Different kinds of bone substitute can also be used to fill the void [178, 179]. A graft may not be required in cases where cortical contact is maintained [47, 180].

1.6.1 TIMING

There is no consensus about the most suitable time point at which to perform an osteotomy. Jupiter et al. [181] showed that an intervention at six weeks may be benefi- cial and that patients corrected at an early stage returned to work earlier than those corrected later [181]. After four to six months of healing, the correction becomes more difficult since the callus is remodelled, thereby increasing morbidity for the patient [182]. One study by Pillukat et al. [175], which compared early osteotomies, performed at eigth [3-13] weeks after injury, and late osteotomies, performed at 52 [24-229] weeks, reported that both early and late osteotomies improve functional outcome and the outcome was similar. The author concludes that, for the early corrections, less graft was needed, which might be an advantage, but the question of timing is still an indi- vidual matter [175].

1.6.2 COMPLICATIONS

Complications that follow corrective osteotomies are reported to be the same as those seen in fractures initially treated surgically; delayed union/non-union, tendinop- athy, neuropathy, loss of reduction, implant failure, infection, persistent pain, nerve injury, tendon injury, CRPS [180, 183, 184] and CTS [185, 186]. A study by Haghverdian et al. [184] of osteotomies performed for extra-articular, initially non-surgically treated distal radius fractures compared osteotomies in which cortical contact was not maintained with osteotomies in which it was maintained. For the type in which cortical contact was not maintained, the complication rate was 65% (95% CI range, 40.6%-81.2%). For osteotomies where cortical contact was maintained, the complication rate was 28% (95% CI range,13.1%-42.4%) [184]. The osteotomies in this thesis were of the latter type and cortical contact was maintained at the osteotomy site.

1.6.3 CONTRAINDICATIONS

The contraindications for radial osteotomy are poor general health and marked degenerative changes in the radiocarpal joint. Volar locking plates allow the rigid fixation of osteotomies, but really severe osteoporosis constitutes a contraindication to surgery [174].

1.6.4 REHABILITATION

No uniform protocol has been formulated for rehabilitation after corrective osteotomy for malunion of the distal radius. The postoperative regimen is often based on the discretion of the treating surgeon [183] and the rehabilitation following osteotomy gen- erally follows the same principles as after ORIF. The wrist is immobilised for approx- imately two to four weeks and gentle ROM exercises are then begun. After removal of the cast a removable splint is worn as needed, until the tenderness of the wrist

has ceased [153, 174, 180, 183, 187]. Strength training is started between six and eight weeks postoperatively [188].

1.6.5 OUTCOME

Reconstructive procedures after malunion of the distal radius may not completely restore normal function [156, 189, 190]. The functional outcome one year or more follow- ing corrective osteotomy varies between different studies. Grip strength has been reported to be between approximately 80% and 85% of the contralateral side [183, 187, 188]. In terms of ROM, a mean pro-supination arc between 145° and 158°, a mean flexion-extension arc between 87° and 120° [181, 188, 191] and a mean radial-ulnardeviation arc of 43° [191] have been reported.

With respect to pain and the ability to perform activities, mean QuickDASH scores of 17 points [192] and mean DASH scores of 20 and 23 points, corresponding to mod- erate perceived disability, have been presented one year after osteotomy [187, 191]. One study of the outcome following osteotomy of initially non-surgically and surgically treated patients, with follow-up at a minimum of six months postoperatively, reported a median PRWE score of 18.5 (IQR 6.5-37) points [193], which means the patients re- ported minimal disability [81]. Six months' follow-up is short, as it has been shown that improvement in functional outcome continues for at least one year following a distal radius fracture. It can be presumed that this is also the case after surgical procedures and studies should therefore have a follow-up of at least 12 months.

According to a review by Mugnai et al. [194], functional outcome is usually good and grafting is not necessary for osteotomies after extra-articular malunited fractures of the distal radius, when a volar locking plate is used for fixation. Nonetheless, none of the studies included in the review used the PRWE. Another aspect of interest to evaluate following corrective osteotomy is HRQL. Still, the studies evaluating outcome after corrective osteotomy has not included this variable.

In the long term, the improvement in alignment is preserved, but patients with intra-articular involvement may develop osteoarthritis [195]. DASH scores at the long- term follow-up are comparable to scores one year post-surgery [189, 195]. A recent study of long-term results, with a median time to follow-up of 27 months (range 6-82), by Mulders et al. [193], however, presents a better result, with a median DASH score of 10 points (IQR 5.8-23.3). The same authors have also presented a PRWE score with a median of 18.5 points (IQR 6.5-37), which corresponds to minimal perceived disability. According to that study, there were no differences in terms of functional outcome between groups based on the use of grafting and non-grafting [193].

2 RATIONALE OF THE THESIS

Distal radius fracture is a common injury that occurs at all ages [4]. One of the most common complications after a distal radius fracture is malunion, with incorrect length, incorrect alignment or articular incongruity or a combination of all these [196]. As the wrist plays an important role in positioning the hand while using it, a change in the anatomy of the wrist carries a higher risk of difficulties in daily life [2, 54].

A malunion can be corrected surgically. The decision to undertake surgery is based on both the patient's complaints of pain and functional deficit and the radiographic appearance of the wrist [174]. Not all patients with a malunited distal radius fracture require an osteotomy, but some suffer to such a degree that they seek care and consider undergoing surgery. There is a lack of knowledge of how patients in this category experience their difficulties in daily life in relation to their wrists. The ways in which the patients' ability to perform activities is affected or the circumstances in which they are affected by the injury, or the symptoms or difficulties that are expe- rienced as being the worst are not clear. To gain further understanding and more detailed knowledge of their experiences, qualitative studies are needed.

When performing surgery, a gap is created at the osteotomy site [175]. This can be filled with grafts of different kinds [177, 179], or left open [197]. More studies of pain and functional outcome after surgery are warranted. It is especially important to evaluate whether there is any difference with respect to whether or not a graft is used.

When evaluating functional outcome after surgery, for example, different PROMs are used to evaluate the patients' self-perceived ability to perform activities. However, PROMs might not always capture the small details in daily life that are affected or might perhaps fail to cover certain activities that are of great personal value to the individual patient. Qualitative studies of how patients describe their daily life after surgery are needed.

In the long term, the radiographic alignment achieved by surgery is preserved and the functional outcome appears to be comparable to the outcome one year post-surgery [195]. In spite of this, further studies of the long-term results relating to the ability to perform activities are needed.

3 AIMS

The overall aim of this thesis was to explore patients' experiences of the way a malunited, symptomatic, distal radius fracture affects their ability to perform activities in daily life, before and one year after corrective osteotomy. The overall aim was also to evaluate functional outcome after corrective osteotomy, during the first postoperative year and in the long term.

The specific aims of the individual studies were as follows.

- Study I: to explore the everyday life experiences of people suffering from a symptomatic, malunited, distal radius fracture
- Study II: to evaluate functional outcome during the first year after corrective osteotomy for a malunited distal radius fracture, with or without filling the osteotomy void
- Study III: to explore the everyday life experiences of patients one year after a corrective osteotomy following a symptomatic, malunited, distal radius frac- ture
- Study IV: to investigate the long-term outcome, defined here as more than three years, after corrective osteotomy for malunion of distal radius frac- tures, in terms of radiological findings, function, activity performance, pain, health-related quality of life and self-efficacy

4 PATIENTS AND METHODS

4.1 DESIGN

This thesis is based on data from four studies with various methodological approach- es. Two of the studies adopted a qualitative approach and two studies followed quantitative research methods. A brief overview of the study design, samples and methods used for data collection is given in Table 1.

Table 1. Overview of study design, samples and methods of data collection

	Study I	Study II		Study III	Study IV
Study design	Qualitative explorative design	Randomised controlled double blind trial		Qualitative explorative design	Cross-sectional study
Study samples	n=20	n=38		n=20	n=37
Gender	65% female	68% female		80% female	54% female
Age median (range)	59 (16-85)	*Age at surgery*		65 (range 22-81)	*Age at surgery*
		Group I	Group II		
		59 (21-80)	65 (16-68)		57 (24-76)
Data collection	Semi-structured interviews	Assessment of functional status *Questionnaires* (PRWE, QuickDASH, COPM, RAND-36)		Semi-structured interviews	Assessment of functional status *Questionnaires* (PRWE, QuickDASH, S-GSE, RAND-36)

4.2 CONTEXT OF THE STUDY

At the hand therapy unit where the studies were conducted, occupational therapists and physiotherapists work together or interchangeably, with patients who have sus- tained an injury to the wrist. After removal of the cast, the rehabilitation is monitored either at the hospital or in primary care. Patients with an uncomplicated course, or who live far from the hospital, are referred to primary care. With respect to distal radius fractures, the following time schedule presented in Table 2 is followed at the hand therapy unit.

Table 2. Rehabilitation protocol after distal radius fractures

Time point	Rehabilitation
During immobilisation	Oedema reduction, use of the hand in light daily activities, ROM of free joints of the upper extremity
2 weeks postoperatively (surgically-treated patients)	Removal of cast, continuation of oedema reduction, start of gentle ROM exercises of the wrist, splint during activities and at night
4 weeks after injury/postoperatively	Continuation of oedema reduction, ROM exercises and use of hand without splint during light daily activities, splint when needed
6 weeks after injury/postoperatively	Start of light loading in daily activities, continuation of oedema reduction, ROM exercises and use of hand in daily activities. Splint when needed
12 weeks after injury/postoperatively	Full loading if not exacerbating pain When needed: continuation of oedema reduction, ROM exercises

4.3 PATIENTS

All the studies were conducted on the Mölndal Campus at Sahlgrenska University Hospital, Gothenburg. Patients with a malunited distal radius fracture were recruited from the surgery queue system for planned orthopaedic interventions and patients who had undergone surgery were selected from the medical records. The age limit was 16 years.

Study I

Patients suffering from a symptomatic malunion after an initially non-surgically treat- ed distal radius fracture who were waiting for corrective osteotomy. The exclusion criterion was not being able to communicate in Swedish without an interpreter.

Study II

Patients undergoing corrective osteotomy between December 2014 and May 2018. The indication for osteotomy was a malunion after a non-surgically treated distal radius fracture in patients suffering from pain and functional limitations affecting their ability to perform activities of daily living. The malunion was assessed radiographically by an or- thopaedic surgeon and was deemed to warrant surgery if there was a dorsal tilt of > 20°.

Dementia or not being able to communicate in Swedish without an interpreter were exclusion criteria.

Study III
Patients who had undergone corrective osteotomy one year earlier. The exclusion criteria were not being able to communicate in Swedish without an interpreter or suffering from co-morbidities that were deemed to interfere with hand function.

Study IV
Patients who underwent an open wedge corrective osteotomy after a symptomatic malunion of a distal radius fracture with a dorsal tilt of > 25° or a volar tilt of > 20 °, fixed with a volar plate, between 2007 and 2014. The exclusion criteria were not being able to communicate in Swedish without an interpreter, fixation with a dorsal plate or concomitant surgery on the ulna.

Twenty-six patients participated in more than one study:
6 participated in Studies I and II
7 participated in Studies I, II and III
12 participated in Studies II and III
1 participated in Studies II, III and IV

4.3.1 DROP-OUTS

Study I
One interview was not analysed because the patient met the exclusion criterion.

Study II
Forty-four patients were included in the study. In the treatment group, one was lost to follow-up before three months because of implant failure and one was excluded from analysis because of implant failure before six months. In the control group, one patient was lost to follow-up after an EPL rupture and two patients due to implant failures before three months. One patient was excluded from the analysis due to an implant failure before six months.

Study III
Two interviews were not analysed because the patients met the exclusion criteria.

Study IV
Thirty-nine patients were enrolled in the study. Two met the exclusion criteria and were excluded from analysis. One patient declined a radiological examination but took part in the functional assessment.

4.4 ETHICS

The studies were all approved by the Regional Ethical Review Board in Gothenburg, Sweden (Dnr 044-16 Studies I and III, Study II Dnr 472-14 and Dnr 153-17 Study IV). Study IV was also approved by the local committee for radiation protection (Dnr SU 2017-01064 17-06). Oral and written information was given about the study and informed written consent was obtained from all the participants prior to the start of the studies. Patients were informed that participation was voluntary and that withdrawal at any time point would not affect their future care. To avoid dependence in the relationship between the participants and the researcher, the researcher did not monitor the rehabilitation of the participants.

All the data material that was collected has been stored anonymously according to the regulations and guidelines at Sahlgrenska University Hospital. The results have been published anonymously.

The interviews in Studies I and III were tape-recorded after permission from the participants. An injury to the wrist causes difficulties in many personal situations, such as using toilet paper and in intimate situations. The participants were there- fore informed, prior to the start of the interviews, that they could choose the level of personal information they were prepared to share. During the interviews, open-ended questions were used in order not to control the participants. However, as the mutual interaction between the participant and the researcher constitutes the context of the interviews, interplay during the interview session is essential. The participants were encouraged to speak from the heart and the researcher encouraged them to continue and say more by, for example, nodding. Follow-up questions, such as "Would you please tell me more about that?", were also used. To ensure an understanding of what the participant meant, the researcher confirmed her understanding of what was said with the participant, during the interviews. At the end of the interviews, the participants were asked if there was anything else they would like to add.

In Studies II and IV, PROMs were used. These were not thought to constitute any risk of being regarded as offensive. The PROMs were selected with care so as not to add any that were not necessary for the research questions and not to waste the participants' time. This was important, especially in Study II, as the participants visited the hospital on various occasions. In Study IV, the participants who required a consultation with a physician were referred without delay.

4.5 METHODS

4.5.1 STUDIES I AND III

An orthopaedic surgeon determined whether surgery was indicated due to symp- tomatic malunion. The patients who chose to undergo surgery were added to the queue for corrective osteotomy after the assessment and were invited consecutively to take part in Study I by the main author.

For Study III, participants were recruited from Studies I and II.

To capture the variety of experiences with respect to the aims of the studies, the number of twenty subjects was decided a priori to be a suitable number for the study groups [198]. A sample size of twenty was also considered large enough, based on the principles of information power, given the broad aims of the studies [199].

In order for the interviews to be conducted undisturbed, a separate room at the occupational therapy unit was used. One interview was held in the participant's home due to the participant's choice. The semi-structured interviews began with the ini- tial question: "Would you please tell me about your experiences of suffering from a malunited wrist fracture?" in Study I and "Would you please tell me how your wrist functions in your daily life now that one year has passed after surgery for malunion of a wrist fracture?" in Study III.

During the interviews, the respondents were encouraged to speak from the heart. When needed, open-ended follow-up questions such as "Would you please elabo- rate on this?" were used [200]. Activity performance in personal care, housework, work, transportation and leisure were areas of questioning. Other topics covered during the interviews were economy, relations, social life, appearance of the hand, rest and sleep. The areas of questioning were based on the main author's pre-understanding as an occupational therapist working with this patient group. The interviews were tape-recorded and transcribed as close to verbatim as possible. To facilitate under- standing, all minor comments such as "Mm" and "Aha" made by the interviewer were not transcribed and grammatical errors were corrected [200].

For the analysis, qualitative content analysis, as described by Graneheim and Lund- man [201], was used. An inductive, or data-driven, approach was adopted in which the researcher moves from the concrete and specific to the abstract and general [202]. The method aims to describe differences and similarities in texts, for example, transcribed interviews. In texts, there is a manifest content and also a latent content, which is related to the underlying meaning. Because there may be more than one

interpretation, the context in which the text was created, such as the interaction between the interviewer and the respondent and the non-verbal communication, is of importance. To obtain an understanding of the whole, the interviews were read through several times because the parts must match the whole and must not be taken out of context.

During the analysis, each interview was considered to be one unit of analysis. Sentences and paragraphs that were related through their content were deemed to constitute meaning units and were coded to describe their content. The codes were then sorted into subcategories based on differences and similarities in their content and then as categories, based on what they described. The last step analysed how the categories were connected in one main theme. Throughout the process, the parts were continuously compared with the whole so that the categories and themes were in line with the large picture of the experiences described by the participants [201]. Quotations were used to provide an understanding and enrichment of the result. To enhance trustworthiness, the main author and two of the authors, one occupational therapist and one physiotherapist, co-operated during the analysis [200].

4.5.2 STUDY II

Patients were invited consecutively by the main author to participate in the study after being added to the waiting list for corrective osteotomy. Forty-four patients were included to compensate for expected drop-outs. The app known as "Randomizer" [203] was used during surgery, by a person independent of the study, to randomise the patients to either the treatment group or the control group. The ratio between the groups was 1:1. In the treatment group, the osteotomy void was filled with Hydro- Set, a synthetic bone cement consisting of hydroxyapatite (HydroSet®, Stryker Corp, Freiburg, Germany), whereas the void was left empty in the control group.

The osteotomies were performed as a dorsal open-wedge distal radius osteotomy. The cortical contact was maintained and the osteotomies were fixated with either a DiPhos R, or a DiPhos RM Plate (DiphosR®, Lima Corporation, Udine, Italy), volar locking plates made of polyetheretherketon (PEEK) polymer, which is radiolucent.
Because of the drop-outs, the treatment group and the control group each com- prised 15 women and four men. The mean age was 59 (SD 13) years in the treatment group and 55 (SD 16) years in the control group.

The patients wore a Softcast fibreglass cast (Softcast®3M, St. Paul. Minneapolis, Unit- ed States), for two weeks. The cast was then replaced by a brace (Wrist Lacer short 28571, Camp Scandinavia AB, Helsingborg, Sweden) and patients started gentle

range of motion exercises of the wrist according to a home exercise programme. The frequency of therapy sessions was individualised according to the patient's sta- tus with respect to oedema and progress in range of motion during the treatment period. After removing the cast, the patients were monitored either by therapists at the hospital or in primary care.

The patients were seen preoperatively and three, six and 12 months postoperatively for assessments of ROM, grip strength and PROMs. The outcome measurements and instruments are described below.

4.5.2.1 RANGE OF MOTION

To achieve reliability, the measurements of ROM were made in a standardised procedure, with the patient in a seated position and the elbow in 90° of flexion [51]. Goniometers are generally accepted as valid tools. However, the movements that are mea- sured do not have fixed axes of motion about which movement occurs. Nevertheless, this limitation is accepted, as measurements of ROM closely approximate movement around a central point. The inter-tester reliability for upper extremity motions is high (r=0.86), [204]. The intra-rater reliability is even higher (r=0.90-0.96), [101]. The accuracy using a manual goniometer has been shown to be within 8° [205]. Normal values for wrist range of motion exist for different genders and age groups [206]. The ROM of the injured wrist can be compared with normal values or with the contra-lateral wrist. In this thesis, the injured side was compared with the uninjured side. ROM was evaluat- ed both within and between the groups.

4.5.2.2 GRIP STRENGTH

Grip strength is dependent on body posture (sitting/standing) and the position of the elbow, forearm and wrist. To ensure reliability the patient was seated with the elbow flexed in 90° and the forearm and wrist in a neutral position. Both hands were assessed with a Jamar dynamometer and the mean of three measurements was calculated [207]. Using a standardised procedure, the assessment of grip strength has been shown to be reliable and valid in healthy subjects, as well as in populations with various health conditions, including musculoskeletal conditions [208]. Normal values for grip strength have been presented for different populations [209-211] and the minimal clinically important difference (MCID) for grip strength following ORIF after a distal radius fracture is estimated at 6.5 kg [212]. The grip strength of the injured wrist can be compared with normal values or with the contralateral side. In the studies in this thesis, the injured side was compared with the uninjured side. Grip strength was evaluated both within and between groups.

4.5.2.3 PAIN AND ABILITY TO PERFORM ACTIVITIES

The QuickDASH consists of 11 items, where each item is scored between 1 and 5 and a final score is calculated, ranging from 0 (no disability) to 100 (most severe disability) [63]. It has been validated in Swedish [62]. The minimal clinically important difference for the QuickDASH after distal radius fractures is 14 points [213]. The QuickDASH correlates well with the DASH [26, 62, 64, 65] and the cut-off values used for the DASH could be used for the QuickDASH. Landgren et al. [87] used cut-off scores of 0-10 for minor disability, 11-35 for moderate disability and 36-100 for major disability, based on cut-off values suggested by the initiator of the DASH [214]. Cut-off scores are valuable for interpreting a PROM. In Study II, the QuickDASH was used for comparison within and between groups preoperatively and 12 months postoperatively.

The PRWE consists of five questions on pain and ten on activities. Each question is scored on a categorical scale ranging from no pain/difficulty (0 points) to worst pain/unable to do (10 points). The pain score is the sum of the five items, whereas the function score is the sum of the ten items divided by two. The scores can be used separately. The total score is the sum of the pain score and the function score and ranges from 0 (a perfectly well-functioning wrist free of pain) to a total of 100 (a completely dysfunctional and painful wrist). The PRWE has been tested for validity and sensitivity to change [66, 215]. The minimal clinically important difference for the PRWE for patients with a distal radius fracture has been shown to be 11.5 points. For the PRWE pain scale, the MCID is 1.5 points [216]. When evaluating progress after an injury or after surgery, normative values are valuable for comparison. Age- and gender-specific normative values have been presented in a Dutch study. The mean score on the PRWE was 7.7 points (SD 15.0) and women had a slightly higher mean score, 8.6 (SD15.9), than men, for whom the mean score was 6.5 (SD 13.6). For the subscales, the mean pain score was 4.3 (SD 8.6) and the function score was 3.3 (SD 7.5) [217]. The PRWE was used for comparison within and between the groups on all follow-up occasions.

The COPM is a client-centred outcome measurement that was developed to detect changes in the self-perceived ability to perform activities [67]. It has been tested for validity and test-retest reliability in several populations and countries [218]. The COPM has standardised instructions for the administration and scoring of the test. During a semi-structured interview, the patient selects three to five activities of personal im- portance and assesses his/her own capability to perform them and how satisfied he/ she is with his/her ability. The performance and satisfaction are graded on a numeri- cal scale of 1-10. The patient's ratings are summarised and a mean score is calculated

for the total score and for the two sub-scales, performance and satisfaction [67, 219]. In Study II, the COPM was used for comparison within and between the groups on all follow-up occasions.

4.5.2.4 HEALTH RELATED QUALITY OF LIFE

The RAND-36 is a generic measurement for evaluating health-related quality of life, which has been translated into Swedish. It consists of 36 items, measuring eight different domains of health. The score for each domain ranges from 0-100 points, where a higher score indicates better health. The tool is responsive to change and has been tested for reliability and validity. The internal consistency has been shown to be high, with an alpha of over 0.7 for all domains and up to 0.9 for some domains [72, 220]. The RAND-36 was used for comparisons within and between groups preoper- atively and 12 months postoperatively.

4.5.3 STUDY IV

The participants were evaluated once. The median time from osteotomy to follow-up was 64 months (range 33-119). The radiographic evaluation was made by a senior radiologist. The functional assessment was made by the main author. If the patient needed an examination by a physician, he/she was referred to a specialist in ortho-paedics.

4.5.3.1 IMAGE ACQUISITION AND EVALUATION

The patients underwent a conventional radiographic investigation of the wrist according to the standard protocol. In the lateral exposure of the wrist, the distal inclination of the radiographic tube was 10-15°. Radiographs, taken before and within the first postoperative week after the corrective osteotomy, were identified retrospectively through the medical records. The three sets of radiographs from each patient (preoperative, postoperative and long-term images) were evaluated twice with an interval of at least one week between evaluations. On the AP view, the radial height, radial inclination and ulnar variance were measured, while, on the lateral view, dorsal/palmar tilt was estimated [48]. The radial height was measured in millimetres. The radial inclination, the inclination of the articular surface of the radius in relation to the vertical axis of the radius, was measured in degrees. Ulnar variance, the difference in millimetres between the axial plane of the ulnar edge of the lunate facet and that of the seat of the ulna, was also measured. The tilt of the articular surface of the distal radius was measured in relation to the perpendicular plane of the vertical axis of the radius.

Normal values for the radiographic parameters are [47, 49]:

- Radial height 12 mm (8-17 mm)
- Radial inclination 22° (12.9°-35°)
- Ulnar variance 0.4 mm (-2.5 to +3.1 mm)
- Radial tilt 11° (3°-20°)

The Knirk and Jupiter scale was used to rate the degree of osteoarthritis as follows: grade 0 = none; 1 = slight joint space narrowing; 2 = marked joint space narrowing; 3 = bone on bone [159].

4.5.3.2 RANGE OF MOTION AND GRIP STRENGTH

Range of motion was measured with a goniometer and grip strength was evaluated using a Jamar dynamometer, as described in Study II.

4.5.3.3 PAIN AND ABILITY TO PERFORM ACTIVITIES

The scores from the Quick-DASH [62] and the scores from the PRWE [66] were com- pared with reference values to evaluate self-perceived ability to perform activities. For an evaluation of pain, the pain score of the PRWE was used.

A question constructed for this study was used to measure overall satisfaction with the result of the surgical procedure: "How would you describe the way your wrist functions today?". The answer was marked on a Likert scale with the following alter- natives; very bad, bad, quite good, good and excellent. The patients were also given the opportunity to comment on their wrist function in their own words.

4.5.3.4 HEALTH-RELATED QUALITY OF LIFE

To evaluate health-related quality of life, the Swedish version of the RAND-36 was used [220]. The mean and median scores were presented for each domain.

4.5.3.5 SELF-EFFICACY

To evaluate self-efficacy, the Swedish version of the general self-efficacy scale (S-GSE) was used. The S-GSE consists of 10 questions that are graded on a Likert scale with four steps, each step given 1-4 points. The score is the sum of the points and thus ranges from 10-40 points. The score can be presented as a total score or as a mean for the 10 items. There is no cut-off value, but higher scores indicate better self-efficacy. The reference value is a mean score of 2.9 (SD 4.6) [78]. The mean S-GSE score for the study group was compared with the reference value.

4.6 STATISTICAL ANALYSIS

The statistical methods that were used in this thesis are presented in Table 3.

Table 3. Statistical methods used in Studies I to IV

Statistical method	Study I	Study II	Study III	Study IV
Descriptive statistics	X	X	X	X
Chi-square		X		
T-test		X		X paired
Mann Whitney U-test		X		X
Friedmann's test		X		
Wilcoxon signed rank test		X		X
Saphiro-Wilks test				X
Spearman's rho				X

All significance tests were two tailed and conducted at the 0.05 significance level.

For Spearman's rho, the following categories were used: 0-0.19 (very weak), 0.20- 0.39 (weak), 0.40-0.59 (moderate), 0.60-0.79 (strong) and 0.80-1.0 (very strong) to describe the strength of the correlations [221].

(Analyses were performed with SPSS for Windows (Version 20, SPSS, Inc., Chicago, IL).

5 RESULTS

5.1 STUDY I

The study group comprised twenty participants, thirteen women and seven men, median age 59 years (16-85).

The participants described their experiences of the way a malunion of a distal radius fracture influenced their daily life. Activity performance was sometimes affected in a few yet highly valued activities, such as sports and work, or whenever the hand was used, and sometimes the wrist also caused problems at rest. Stiffness, pain, weakness and numbness prevented the participants from doing what they wanted or needed. The wrist was also an obstruction when moving around. The reduced functionality of the wrist caused secondary problems in other parts of the body. Sleep disturbances were common. The situation caused anxiety and feelings of vulnerability; participants expressed feelings of not recognising themselves any more and said that their social life was affected by the situation in different ways. The participants all felt that they had to struggle to deal with both the symptoms and the difficulties caused by them.

Three categories were identified during the data analysis:

- Obstacles in everyday life
- Secondary problems; body, mind and social aspects
- A struggle dealing with the situation

In all, the categories contained ten subcategories. Experiences of the impact of the injury on everyday life are expressed in the overall theme, i.e. “Life has become troublesome – my wrist bothers me around the clock”, which was derived from the categories. See Table 4.

Table 4. The main theme with categories and subcategories

Life has become troublesome – my wrist bothers me around the clock		
Obstacles in everyday life	Secondary problems, body, mind and social aspects	A struggle dealing with the situation
Everyday tasks have become awkward *Experiencing problems moving around*	*Other parts of the body are affected* *Disturbed sleep affects the day Anxiety and uncertainty* *Being like another person* *Relationships with spouse, family and friends*	*Managing pain* *Finding practical solutions* *Finding approaches to demands*

5.1.1 OBSTACLES IN EVERYDAY LIFE

The participants' descriptions of their activity performance in daily life gave a rich picture of obstacles caused by the wrist. The whole spectrum of activities, from basic ADL, such as personal care, and other everyday tasks, for example, handling charge cards or electronic equipment, to work-related activities, had become troublesome. Even the ability to manage moving around was affected.

5.1.1.1 EVERYDAY TASKS HAVE BECOME AWKWARD

Tasks that were difficult to perform in the household included preparing a meal, handling hot baking sheets, cleaning windows and wiping surfaces. Physically de- manding activities of all kinds, such as gardening or carrying children/grandchildren or grocery bags, were troublesome. It was also difficult to maintain a normal working rate, while working both in the household or in the garden and at work. The respon- dents missed the ease with which they used to do things both in ordinary daily tasks, like having a shower or handling a cell phone, and in work-related activities, such as computing or handling tools or heavy objects. The need for both hands was experi- enced in many situations.

5.1.1.2 EXPERIENCING PROBLEMS MOVING AROUND

The participants described limitations when sitting on the ground or on the floor because they could not lean on their hand. For the same reason, it was difficult to get up from the ground, the floor or from a chair. There were problems getting in and out of home because of difficulty handling keys and opening doors. Climbing stairs was difficult when carrying something or if the banister was on the wrong side. Travelling by public transportation was troublesome because of problems climbing the stairs and supporting oneself if there was no seat. Driving a car or going by bike was difficult and the ability to move from one place to another was thereby restricted.

5.1.2 SECONDARY PROBLEMS, BODY, MIND AND SOCIAL ASPECTS

An injury to the wrist was shown to create secondary problems in other parts of the body, such as the shoulder. The night-time was described as troublesome and that in turn affected the daytime. The lack of progress made the participants feel anxious and the unreliable wrist made them feel uncertain. In different ways, they did not recognise themselves and their psychological well-being and their social life, as well as their relationships with others, were affected.

5.1.2.1 OTHER PARTS OF THE BODY ARE AFFECTED

The whole arm and shoulder was used in a different way because of the stiff wrist, resulting in pain in the shoulder or in the whole arm. The stiffness also caused

difficulties wiping oneself after toilet visits, which for some resulted in small wounds and pruritus around the anal opening. Some had to use the shower to get clean after toilet visits and in periods when there was no shower on hand, constipation occurred, because of avoiding toilet visits. Constipation also occurred as an adverse reaction to pain-relief medication that was necessary because of the wrist.

5.1.2.2 DISTURBED SLEEP AFFECTS THE DAY

It was difficult to go to sleep because of pain and difficulties finding a resting position. Some participants also woke regularly during the night because of pain and de- scribed the night-time as a difficult period. The ability to concentrate and feel rested throughout the day was affected by the lack of sleep. However, not all participants experienced disturbed sleep because of the wrist.

5.1.2.3 ANXIETY AND UNCERTAINTY

Throughout the time from the injury, during the rehabilitation process to the time point of the interview, the respondents sometimes experienced feelings of anxiety and uncertainty. At different time points, the reasons for these feelings varied. The first months after the injury were characterised by disproportionate pain and no progress in range of motion despite every effort that was made. They experienced anxiety because they felt that their complaints were not always taken seriously by the healthcare professionals and they lacked explanations about what was wrong and how a malunion could occur. Thoughts of having done something wrong and thereby causing the malunion themselves worried the participants. They also lacked information on how much the hand should be used and which activities to avoid.

The time waiting for an examination by a specialist was described as anxious and troublesome. The participants often had to wait first to get an appointment with a physician, either in primary care or at the hospital, and, after that, a specialist. Being dependent on the decisions of others was difficult. There appeared to be a lack of routines at different levels in the healthcare system when a malunion had occurred and time passed and nothing happened. With respect to this, the experiences varied and there were also examples of routines that worked well. In some cases, however, the lack of communication between healthcare levels led to major problems in terms of sick leave. Because of the sick-leave issue and thinking about their ability to earn their living in the future, participants also worried about their economic situation.

Feelings of vulnerability made the participants protect their hand unconsciously in crowded areas. Thoughts about accidentally doing something that would exacerbate the symptoms made the participants afraid to use their hand. Climbing stairs, being

outdoors or among people caused feelings of uncertainty and, even in the bathroom, participants were afraid of falling. In particular, participants who had some other health problems, such as back pain, knee or hip problems or difficulties with balance, experienced vulnerability caused by the interaction between the different functional impairments. They also feared that something might happen to the uninjured wrist.

5.1.2.4 BEING LIKE ANOTHER PERSON

Not recognising one's performance in different ways, such as the experience of hav- ing become clumsy and breaking things, not being able to use cutlery in the proper way and having lost one's style of handwriting, was described as very emotional. The appearance of the disfigured wrist was emotional, too, because it was difficult to recognise the wrist as one's own. Not being able to shake hands when greeting people created the feeling of being impolite and the tedious everyday life reduced the desire to socialise with family or friends. The whole situation caused frustration, anger, sadness and depression and participants were not in the mood to do things as usual. The participants felt they were different from before and the change was visible to others.

5.1.2.5 RELATIONSHIPS WITH SPOUSE, FAMILY AND FRIENDS

Pain made the desire for proximity and intimacy decrease. Intimacy was also affected by practical issues because it was problematic lying on the injured arm to caress one's partner and lying on the uninjured side to use the injured hand was no alternative. In intimate situations, the hand is also sometimes needed for support, which was difficult.

Other relationships that were affected were relationships with children and grand-children due to difficulties helping them with clothing, lifting and carrying them or pushing the stroller or taking part in play. Lack of sleep and being in pain made the participants tired and less patient with their partners and children. Not being able to do one's share of the housework produced a bad conscience and having to ask someone to do things for them made the participants frustrated. Irritation between spouses arose as a result of the situation.

Difficulties preparing a meal and washing the dishes made participants avoid inviting friends for dinner. Not being able to help friends and neighbours with practical issues like before had a negative impact on relationships. Others had found that friends, neighbours and partners were very understanding.

The participants' ability to take part in activities and social life was also affected by the economic shortcomings caused by being on sick leave for a long time. Relationships

with friends were missed when participation in certain activities, usually undertaken with certain friends, was restricted by the economic situation.

5.1.3 A STRUGGLE DEALING WITH THE SITUATION

The participants described how the need to deal with the difficulties involved in every-day tasks led to various strategies for managing pain, as well as the practicalities of everyday life. They also explained how they tried to find ways to approach the demands and duties of everyday life.

5.1.3.1 MANAGING PAIN

To reduce or avoid pain the participants used various strategies, such as using both hands instead of one hand, or the uninjured hand only. Different aids like splints or sports tape and painkillers were used. A strategy that was also described to manage pain was to distract oneself with creative activities.

5.1.3.2 FINDING PRACTICAL SOULUTIONS

Electric toothbrushes and food processors and equipment of that kind were fre- quently used to simplify different tasks. A washing-machine of one's own was the solution when it was too difficult to use the shared laundry room. Some participants had to re-arrange their kitchen so that the china, pots and other equipment stood where they could reach them. When getting dressed, the participants had to choose manageable clothes, which sometimes meant the clothes were easy to put on and take off but were not appropriate for the situation.

5.1.3.3 FINDING APPROACHES TO DEMANDS

One approach to managing the duties of everyday life was to try to continue as usual until the pain was too intense and then stop. Another strategy was the opposite, to try to reduce the need to have a clean home and a neat garden, for example, and thereby avoid performing certain activities. One common alternative was also to ask relatives or neighbours for help or to pay for services. Managing to work, having a flexible work situation, where one could lower the working rate and work part-time, was a prerequisite.

5.2 STUDY II

When comparing the patients completing the study with the drop-outs, there were no significant differences in terms of age, gender or injury to the dominant hand.

The treatment group and the control group each comprised 15 women and four men. The mean age was 59 (SD 13) years in the treatment group and 55 (SD 16) years in

the control group. There was no significant difference between the groups in terms of age. In the treatment group, one patient, who was injured during childhood, vol- untarily postponed surgery to 336 months (28 years) after the injury. For the other patients, the range was four to 65 months from injury to surgery. In the control group, the range was six to 65 months.

5.2.1 COMPARISON BETWEEN GROUPS

5.2.1.1 PROMS

With respect to pain, measured with the PRWE pain score, and self-perceived ability to perform activities, measured with the PRWE and the COPM, there were no signif- icant differences between the groups at any time point. Further, there were no sig- nificant differences between the groups preoperatively or 12 months postoperatively in terms of self-perceived ability to perform activities, measured with the Q-DASH, or health-related quality of life, measured with the RAND-36.

5.2.1.2 RANGE OF MOTION AND GRIP STRENGTH

There were no significant differences between the treatment group and the control group with respect to range of motion or grip strength at any follow-up appointment.

5.2.2 COMPARISON WITHIN GROUPS

5.2.2.1 PROMS

The ability to perform activities improved significantly for both groups from pre-operatively, when the PRWE scores indicated moderate disability, to the 12-month follow-up, when the scores indicated minimal disability. Within the treatment group, the score decreased from a median score preoperatively of 58 points (95% CI 33- 76) to 14 points (95% CI 7-31) ($p<0.05$), while, in the control group, the median score decreased from 58 points (95% CI 32-75) to 20 points (95% CI 9-44) ($p<0.05$), With respect to pain there was also a significant improvement: the median PRWE pain score decreased from 28 points (95% CI 21-41) to 9 points (95% CI 6-20) ($p<0.01$),
in the treatment group and from 29 points (95% CI 21-33) to 17 points (95% CI 6-24) ($p<0.01$), in the control group. The COPM showed a significant increase for both groups with regard to satisfaction ($p<0.05$), but in terms of activity performance, there was an increase only for the control group ($p<0.05$). The Q-DASH score was significantly lower 12 months postoperatively compared with preoperatively for both groups, also indicating increase in the ability to perform activities ($p<0.05$).

With respect to health-related quality of life, measured with the RAND-36, there was a significant improvement in the treatment group for the domain of “role physical” and the domain of “bodily pain” ($p<0.05$), 12 months postoperatively compared with

preoperatively. In the control group, there were no significant differences in any of the domains.

5.2.2.2 RANGE OF MOTION AND GRIP STRENGTH

ROM was significantly less on the injured side compared with the uninjured side pre-operatively for all movement directions in both groups ($p<0.05$), with the exception of dorsal extension.

There was a significant increase in both groups for pronation, supination, volar flexion, radial and ulnar deviation at twelve months postoperatively compared with preoperatively ($p<0.05$). There was no significant difference in either group regarding dorsal extension.

The two groups differed with respect to range of motion on the operated side com- pared with the uninjured side, at the 12-months follow-up. In the treatment group, the ROM was not restored with respect to pronation, supination, volar flexion and ulnar deviation, as there was still a significant difference between the uninjured side and the injured side at the 12-month follow-up ($p<0.05$). The control group experienced the restoration of ROM compared with the uninjured side in all directions apart from volar flexion, where there was still a significant difference compared with the un- injured side ($p<0.01$).

At 12 months, there was a significant increase in grip strength for both groups, com-pared with the preoperative status ($p<0.05$). In the treatment group, there was no longer a significant difference between the injured side and the uninjured side at 12 months, which means that the patients experienced the restoration of strength compared with the uninjured side. Nonetheless, grip strength was still significantly reduced compared with the uninjured side at the 12-month follow-up in the control group ($p<0.05$).

5.3 STUDY III

Twenty-four patients fulfilled the inclusion criteria. Two patients declined to partici- pate and two interviews were not analysed because co-morbidities were revealed. Sixteen women and four men, median age 65 years (22-82), made up the study group. Seven patients in the study group had also taken part in Study I.

One year after surgery, the participants experienced the relief of different types of in-convenience and symptom. Some had experienced complications following surgery.

The ability to perform activities had improved, but some participants were still restricted by their wrist at times. Their social relationships were more like normal again, for example, because the participants had regained their independence from others. The participants were feeling better. They felt they were more like themselves again and were pleased when thinking of the things they were able to do. The participants were also confident of further improvements in the future.

During the analysis, five categories were identified:

- Relief of inconveniences and symptoms
- Managing new symptoms and complications
- Regaining abilities
- Normalised social relationships
- Increased well-being.

From the categories, one main theme was derived: Daily life works again. The results are presented as one theme with five categories. See Table 5.

Table 5. The main theme with categories

Daily life works again				
Relief of inconveniences and symptoms	Managing new symptoms and complications	Regaining abilities	Normalised social relationships	Increased wellbeing

Each category is described below. To illustrate the findings, quotations, with identify- ing numbers, are given.

5.3.1 RELIEF OF INCONVENIENCES AND SYMPTOMS

The participants had noted that the way they were able to move their wrist was more normal and, when they compared it with the uninjured wrist, they noticed the improvements. They were able to take a top off in a normal manner and fold their arms in front of them again. Moreover, their arm was no longer a troublesome object, which had to be placed carefully when going to the cinema, for example. The participants were also able to put their arm as they pleased even when lying in bed.

A few participants still experienced some residual stiffness in the wrist and had to move their arm differently to compensate for this in certain activities. They also complained of pain in the elbow or shoulder. Pain in the wrist, varying from a little

pain after extensive use of the hand to greater problems, was still present for some participants. The pain was sometimes described in terms of exercise pain, which has a positive meaning. Further, pain in the arm during the night was no longer a problem. The participants said that they were stronger in their wrist and hand than before surgery, but a few of them still experienced some weakness. When the recovery that participants had expected did not occur, they were disappointed.

The participants appreciated the great difference in the appearance of the wrist compared with before surgery. The wrist looked more like it used to, which was mentioned with gratitude and gave a sense of normality. Some said that the functionality of the wrist was more important than the appearance, but they were still pleased that their wrist looked better.

5.3.2 MANAGING NEW SYMPTOMS AND COMPLICATIONS

The participants sometimes had to face and handle new symptoms, like numbness in the hand, tingling sensations on the dorsal side of the hand and tenderness around the scars.

Some participants used bracelets to conceal the scars because they found the appearance of the scars disturbing. Others accepted their scars and mentioned that they were fine and not so noticeable. One participant even thought the scars looked “cool”. Scarring between tendons and the soft tissues in the healed wound led to restricted mobility of a finger or thumb for some participants. A few experienced discomfort from the plate when placing their wrist on a surface such as a laptop or desktop.

Some participants had experienced complications, for example ruptures of extensor tendons that were surgically treated, and struggled to regain function. The reduced mobility in the thumb or index finger affected the participants’ ability to perform different activities.

A few participants were waiting for additional surgery (plate removal and, for one individual, ulna shortening).

5.3.3 REGAINING ABILITIES

The participants no longer needed to think of different strategies when using their injured hand in daily life. They were using both hands like before, such as the dominant hand being dominant. Some participants said they used the hand in an unconscious way and did not even think about the wrist any more. They also used it for making gestures, which gave a feeling of ease and normality.

The participants had regained the ease of performing, or the ability to perform different everyday activities relating to personal care. This meant a lot to them. For example, they were able to reach to wash both armpits and used both hands when washing their face. Further, they were able to get dressed without difficulty and they were even able to manage small buttons. They were once again able to use curlers and a hair dryer, cut their nails and wipe themselves after toilet visits.

Kitchen work, like putting the china back in the cupboards from the dishwasher, pouring sauces from frying pans, baking bread and cutting vegetables, went more smoothly than before surgery. The participants found that household work, like vacu- um cleaning, wiping floors or cleaning the porcelain in the bathroom, went well again, even if it was recognised as requiring both the ability to move the wrist and strength. Further, physically demanding tasks like moving heavy pieces of furniture and open- ing stiff locks caused no problems for most participants. Moreover, work-related activities, like painting and carpentry, were manageable, as were activities performed in leisure time, like mowing the lawn, pruning bushes or digging in the garden. Par- ticipants had resumed different activities such as sailing and the performance of various sports.

Transportation had been recovered. The participants were able to hold the banister and support themselves and as they climbed the stairs, even when carrying some- thing. This also meant they were able to travel by public transportation. They were able to ride a bike and drive a car again, which they found practical and satisfying.

In spite of the improved ability to perform activities, some participants still had difficulty performing certain tasks and activities following restricted functionality of the wrist. Examples of tasks that were difficult were to open heavy doors, take out a hot baking sheet from the oven and wipe the kitchen table. For some participants, it was also difficult to use their hand in heavy activities, such as renovation work. Different strategies, like careful planning and using a different grip from normal, were used to manage these issues.

5.3.4 NORMALISED SOCIAL RELATIONSHIPS

The participants found that their social relationships had normalised during the year after surgery, as they had regained their independence in various activities. The independence from other people was appreciated and was mentioned with relief and gratitude. For example, the participants no longer needed help to get up from the floor, pour hot water from saucepans or open jars and bottles. One participant appreciated not needing help like a child to cut a pizza into slices in the restaurant.

Another used the example of managing to go to the grocery store independently, not needing the reluctant spouse for assistance.

The participants experienced less irritation in relation to their spouses due to their increased ability to do their share again. Moreover, the wrist and hand functioned better in intimate situations, when caressing their partner, for example, but it was still troublesome for some if their partner lay on the injured arm.

Due to their increased ability to use their hand, social life roles, such as looking after grandchildren regularly, were resumed. The participants also found that the will and energy to socialise had returned. Further, small things, like being able to shake hands with people, mingle with a glass of wine in their hand, or have a cup of coffee in a café without fear of spilling, meant the participants were able to socialise more like normal again.

5.3.5 INCREASED WELLBEING

The participants were grateful and they felt better because they had been given the opportunity to undergo surgery. Some participants said that the surgery had been necessary. They had gained new insights with respect to what the hands mean for the ability to work, as well as for the ability to do things just for the pleasure of it, and how being able to do things in turn affects well-being. The functionality of the wrist was of great importance, in particular for participants who suffered from back pain or had a hip prosthesis, because they had to rely so much on their hands for support. For many, the difference compared with before surgery was large. Although some had worried before undergoing surgery, they did not regret the decision. It was worth the effort.

The participants noticed the difference from before surgery and reflected on what it meant for their well-being. They felt pleased that they were able to manage ordinary things again, like peeling a carrot or handling a credit card. Further, the ability to do things “my way” again, like making the bed, was a source of satisfaction. Their well-being had also increased because they were confident that the wrist had healed and would not break. They no longer protected their hand when playing with children or grandchildren or in crowded places. It was no longer frightening to experience some pain, during activity or after using the hand.

The participants reported feelings of pride and self-esteem because of being phys- ically strong again and being a person who could help others. Fear of falling when being physically active was no longer a source of distress, which made them feel

better. For example, they climbed ladders to change light bulbs and walked the dog without fear. Moreover, when walking in the mountains or going into the sea for a swim, the participants used their hand for support without fear.

Participants mentioned with satisfaction that they were fearless when going skating or cross-country skiing, as well as downhill skiing. In winter, however, some participants were still cautious because they were afraid of falling and sustaining a new fracture.

It was satisfying for the participants once again to be able to regard themselves as an active person, managing being busy and not having to rest for the whole evening after the working day. The participants were in a better mood, more like they used to be, and were also able to concentrate again, because the pain was gone. Moreover, they were pleased because they heard from family members that the change was also noticeable to them. The participants thought about how their well-being and quality of life as a whole had increased because of less pain and because they were once again able to do things that meant a lot to them. They had a feeling of having come back to themselves. They got satisfaction from cooking, being in the stable taking care of the horses or sitting on the dock, being able to lean on their hands, among other things.

The participants still noted progress one year after surgery and were confident that the progress would continue. They made plans to start biking again and training like before. Even if their wrist might never be fully restored, they would be content with the gains they had made. They were satisfied because everything that could be done had been done.

5.4 STUDY IV

The study group comprised 37 patients, 20 women and 17 men.

Twenty-eight of the patients were of working age at the time they were injured. In 18 patients the dominant arm was injured and in 19 patients the non-dominant arm was injured. Twenty-five fractures were due to low-energy trauma, 12 to high-energy trauma, 16 fractures were extra-articular and 17 intra-articular, while data were missing in four cases. The primary treatment was a plaster cast following closed reduction in 16 cases, no reduction in 10 cases and 11 fractures underwent surgery with volar plates with or without Euloc pins (Euloc-pin ®, Swemac AB, Linköping, Sweden). The corrective surgery was performed by five different surgeons, of which one performed 27 of the osteotomies. None of the surgeons was engaged in the analysis of the results.

5.4.1 SURGICAL PROCEDURE

The osteotomy was carried out through a dorsal approach. The osteotomy was temporarily fixed with two Kirschner wires. A modified volar approach according to Henry was then used and the osteotomy was fixed with a conventional volar titanium plate (DVR® Medica, Stryker Variax®) or a polyetheretherketon plate (PEEK-plate, DiphosR®, Lima Corporation, Udine, Italy). The osteotomy gap was filled with an autologous or synthetic graft (HydroSet®, Stryker Corp, Freiburg, Germany) or left empty. A plaster cast was then applied for two to four weeks based on the surgeons' discretion.

One patient had undergone a tendon transfer due to an EPL rupture two years after the osteotomy. One patient had undergone a median-nerve decompression and eight patients had had the plate removed, due to local discomfort, one to four years after the osteotomy.

5.4.2 RADIOLOGICAL FINDINGS

After surgery compared with before, there was an improvement with respect to anatomical parameters, with an increase in radial height ($p<0.01$), and volar tilt ($p<0.05$), and significantly less ulnar variance ($p<0.001$). With respect to radial incli- nation, however, no significant difference was found postoperatively compared with preoperatively. The degree of osteoarthritis had increased significantly ($p<0.001$). At follow-up, there was a weak correlation between osteoarthritis and age ($rs= 0.37$, $p<0.05$), but there was no significant difference between women and men and no significant correlation between the degree of osteoarthritis and time from surgery to follow-up. From post-surgery to follow-up, the corrections were maintained, as no significant differences were found in terms of radial height, radial inclination, ulnar variance and volar tilt. None of the patients had an implant failure at follow-up.

5.4.3 FUNCTION, GRIP STRENGTH, RANGE OF MOTION

The mean grip strength of the injured hand was 31 kg (SD 13) for the study group, which was 89% compared with the uninjured hand. For the men, the mean grip strength was 38 kg (SD 14), 86% compared with the uninjured hand, for the women it was 25 kg (SD 7), 94% compared with the uninjured hand.

The range of motion in different movement directions was 80-95% on average in the injured wrist compared with the uninjured side. Pronation and dorsal extension followed by supination were the movement directions where the greatest restoration was observed, while the least was seen in radial deviation. At follow-up, there was still a significant difference in all movement directions between the injured and uninjured hands ($p<0.05$). No correlation was found between radiological findings and range of motion.

5.4.4 ACTIVITY PERFORMANCE AND PAIN

At follow-up, the median total score for the PRWE was 12 points (IQR 23), (women 19.5 (IQR 50), men 5 (IQR 17)). The mean value for the whole group, calculated in relation to individual age- and gender-specific reference values, was 21.3 points (SD 26.3), which was significantly higher ($p<0.01$), than the reference mean value of 7.7 points (SD 15.0), [217]. When dividing the group according to gender, it was found that the women scored significantly higher, 27.9 (SD 26.0), than the reference values, vs. 8.6 (SD 15.9), ($p<0.01$), which was not seen among the men, 13.7 (SD 23.7) vs. 6.5 (SD 13.6), (ns).

The median pain score was 9 points (IQR 23), women 14 (IQR 30) and men 4 (IQR 14). This value is significantly higher than the reference values (women 4.7 (SD 9.0) and men 3.8 (SD 8.1)) for the whole group ($p<0.01$), and among the women ($p<0.01$), [217].

A lower PRWE total score correlated moderately to better grip strength ($rs=0.40$, $p<0.05$). There was also a moderate correlation between a lower PRWE total score and more volar tilt ($rs=0.453$, $p<0.01$) and a very weak, albeit non-significant, correla- tion between a higher PRWE pain score and increased osteoarthritis ($rs=0.108$, ns).

For the Q-DASH, the median score was 11.4 points (IQR 19.8). The reported reference values are 10-15 points (SD 14.7), [65].

5.4.5 HEALTH-RELATED QUALITY OF LIFE AND SELF-EFFICACY

The domains of the RAND-36 with the highest median scores were “role physical”, “social functioning” and “role emotional”, while the lowest median scores were seen in the domains of “bodily pain”, “vitality/fatigue” and “general health”.

With respect to self-efficacy, the S-GSE showed a mean score of 3.2 points (SD 0.6), which was significantly higher ($p<0.01$), than the reference value; mean 2.9 (SD 4.6) [78].

A self-constructed question about overall satisfaction with the wrist was rated as follows: excellent (n=8), good (n=14), quite good (n=8), bad (n=5) and very bad (n=1). One patient did not answer this question.

When asked whether they would have chosen surgery, if they had known the results, 33 patients answered yes and three no. One patient did not answer this question.

Patients were given the opportunity to comment in their own words and 16 patients (n=16) did. One posted a question about the implant and one commented on being

free from pain since plate removal. Five commented on being satisfied with the result of surgery, one commented on being satisfied with the communication with caregivers, while five had complaints related to communication, five were dissatisfied with the waiting time for surgery and one was dissatisfied with the result of surgery because of restraints in fine dexterity.

Due to pain and/or crepitations, six patients were referred to a specialist in orthopaedics at follow-up.

6 DISCUSSION

The overall aim of this thesis was to explore patients' experiences of how a mal- united, symptomatic, distal radius fracture affects the ability to perform activities in daily life, and patients' experiences of the functionality of their wrists in daily life one year after corrective osteotomy. The aim was also to evaluate functional outcome after corrective osteotomy during the first postoperative year and in the long term.

The experiences of the patients were reported in two qualitative interview studies, preoperatively and 12 months postoperatively (Studies I and III). Functional outcome during the first postoperative year was studied in a randomised, double-blind trial (Study II) and, in the long-term, in a cohort study (Study IV).

6.1 A MALUNION HAS CONSEQUENCES FOR THE DAILY LIFE

As found in Study I, a malunited distal radius fracture was shown to have an impact on broad areas of life. Activities and participation, as well as environmental factors and personal factors, were affected, in addition to body function/structures, accord- ing to the terminology of the ICF [103]. This means that all domains of functioning were influenced. A malunited distal radius fracture should therefore be seen as a multidimensional problem with emotional, social and physical dimensions.

The patients suffering from a malunion after distal radius fractures constitute a chal- lenging patient group for the rehabilitation staff, due to the severity and the diversity of their problems. During the rehabilitation following a distal radius fracture, it is therefore suitable to apply a model that has an holistic stance, such as, for example, the Canadian Model of Occupational Performance and Engagement (CMOP-E). The client-centred approach of the CMOP-E is an advantage [110], as the rehabilitation process must be individualised because patients are individuals, with their own personal characteristics, who live their lives in their own social and environmental contexts. As shown in Study I, there might be a need for the individual to reflect on how to overcome difficulties related to hampered ability to perform different activities and the goals that are most important when it is not possible to regain the functional ability from before the injury.

The term "activity", as used in the occupational therapy framework, is broad and entails all kinds of human activity, from getting dressed to working in the garden. Moreover, moving around and transportation are "activities" [113, 114]. Despite the amount of research with respect to functional outcome after distal radius fracture, it has not previously been reported that patients have difficulties moving around, following malunion. In Study I, it was shown that patients experience difficulty, for example, getting up from the floor and with transportation, not only cycling and driving a car but also travelling by public transportation. The difficulties were more pronounced for individuals who had some other physical limitation, such as knee pain, because they had to rely more on their hands for support. A study of health-related quality of life after a distal radius fracture [91] revealed that older pa- tients report poorer general health and vitality during the first six months after the fracture. The authors concluded that this could be caused by age itself or by the fracture aggravating pre-existing health conditions. Both explanations seem plau- sible and the findings in Study I illustrate that a fracture to the wrist can aggravate the impact of other physical impairments. Difficulties in the area of transportation are easily neglected, because they are not automatically expected following an injury to the wrist. The same applies to the secondary problems in other parts of the body that patients spoke about, such as pain in the shoulder, or pruritus around the anal opening due to difficulty using toilet paper, and constipation, due to the use of painkillers. The number of different strategies for solving everyday problems showed that the patients had to struggle a great deal to manage their everyday lives. Rehabilitation staff need to have a broad perspective in relation to the different areas that might be troublesome for the patients. The findings in Study I stress the importance of letting patients talk about their daily life and their difficulties, to identify areas in which and professions from which they need intervention. Patients might need an examination of their compensatory movements and guidance to restore functional movements, as far as possible. They might also need ergonomic advice, assistive devices and splints. In the event of secondary problems in other parts of the body, such as pruritus and constipation, they might also need advice from other professionals in the team.

Since the functionality of the wrist is essential for the ability to use the hand [1, 2, 54], it is not surprising that an injury to the wrist can have major consequences. However, the consequences were at times larger than could be foreseen. Important social life roles, such as being a parent or grandparent or a worker, were negatively affected by the injury. This has been shown earlier following different injuries to the hand [222, 223] and also in relation to different wrist disorders [68]. For example, an elderly woman, who was very vivacious and full of energy, was no longer able to collect

her grandchildren from kindergarten or school two or three days a week, as she normally did. She would take care of her grandchildren the whole afternoon and take them back by car to their parents in the evening. This was both a pleasure and an opportunity to offload the parents, who worked hard, and, for the children, the arrangement meant shorter days at kindergarten. The injured wrist made it impossible to drive a car, to lift the small children into the car and to help the chil- dren with their clothes. Cooking and washing the dishes, not to mention playing with the children, had also become too strenuous. In this way, the injury also had consequences for the young family.

Anxiety, related to different issues, was common. Some patients said that they be- lieved they had caused the malunion themselves by using their hand too much during immobilisation. This shows that patients need information on fracture healing and how a malunion can occur in order to stop blaming themselves and avoid being overly cautious. Some had experiences of not being listened to by physicians and other healthcare professionals and had had to struggle for a referral to a specialist. In the light of the extent to which a malunion of a distal radius fracture may influence daily life, this is inappropriate. Patients need guidance when it comes to the time point at which to seek a renewed examination by a physician. A generous approach to re-referral to the physician should be applied. One suggestion, based on clinical experience, would be to re-refer the patient if he/she still has a high level of pain after three months, or even earlier, if the radiographic appearance of the fracture indicates a possible malunion and if, for example, the patient is unable to maintain social life roles or to work. Not all patients with a malunion need surgery, but any patient who, after appropriate rehabilitation efforts, complains of a poor outcome after a distal radius fracture should be taken seriously and a careful assessment should be made without delay.

Another source of distress, which was not uncommon for the patients in Study I, was problems with sick-leave issues. This was an extra burden for the patients in combination with their other difficulties and worries, about the prognosis, for exam- ple. In clinical practice, my colleagues and I often notice that unresolved sick-leave issues can have a major impact on the rehabilitation process. It seems the patients are simply too mentally occupied to move forward. There is a need for a renewed clarification in the sick-leave system that the time frames of healing and rehabilitation after a distal radius fracture can vary to a large extent. Moreover, some patients even have to go through corrective surgery, followed by rehabilitation, before they are able to work again.

6.2 DAILY LIFE AFTER CORRECTIVE SURGERY

In Study III, patients were interviewed one year after corrective surgery. In a sense, the patients' experiences were distributed along a continuum, from being dissatisfied with how the wrist functioned in daily activities, to being much more content and regarding oneself as almost fully restored. Different complications sometimes influenced their ability to perform activities and were of course unwelcome to the individual. Nevertheless, corrective osteotomy for malunion of the distal radius is a challenging procedure and complications do occur [174, 183, 184]. Because complica- tions often interfere negatively with the ability to use the hand effectively in activi- ties, and are disturbing for patients, efforts should be made to avoid complications. Previous research indicates that low surgeon volume contributes to plate-related complications after volar plating and after corrective osteotomies of the distal radius [184, 224]. To minimise the complication rate, it is important to concentrate this kind of complicated surgery at large care facilities where a few, specialised surgeons perform the surgery.

The patients' experiences, reported in Study III, were divided into five categories, where the contents were related to symptoms, complications, ability to perform tasks and activities, social relationships and well-being. The majority of the patients expe- rienced the relief of symptoms and a great improvement in their ability to perform activities. The improvement was seen both in personal care and in heavier activities, like gardening. Moreover, the patients' social relationships were positively affected and the patients' well-being improved. The red thread in the interviews in Study III was that the patients felt that their daily life worked again. This finding was presented in the main theme.

The patients' description of the improvement in their ability to perform activities, as a result of a decrease in symptoms and an increase in function, is expected. In a previous trial by Mulders et al. [193], the majority (93%) of the patients reported that they experienced the relief of symptoms following corrective osteotomy. The experience of functional recovery that patients mentioned in Study III is in line with the results of previous research that show that functional outcome is improved by osteotomy [187, 191, 192]. In any case, Study III bridges a gap in research, as no other qualitative study has been conducted on this specific patient group and, in this sense, Study III allows the voice of the patients to be heard. The message that ev- eryday life works again one year after osteotomy is important to patients suffering from a symptomatic malunion.

6.3 FUNCTIONAL OUTCOME RELATED TO GRAFT OR NO GRAFT

Study II focused on the effects on patient-related outcome related to whether or not a graft was used in corrective osteotomies for malunion of the distal radius. The main finding in Study II is that there were neither significant nor clinically relevant differences in terms of grip strength, ROM and patient-reported outcome between the groups at any time point during the follow-up period of 12 months. This is important because it means that, during the rehabilitation process, the patients' course is similar and the use of a graft or no graft does not need to be taken into consideration. Further, both groups improved and reached a similar functional outcome. The result of Study II therefore suggests that grafts do not need to be used when osteotomies of the distal radius are performed with preservation of the cortical contact.

Considering that graft might be needed to create structural stability in larger gaps [225-227] and that there are known risks of complications when a graft from the crista iliaca is used [177], the finding that the use of bone substitute does not appear to imply any disadvantages with respect to the functional outcome is positive. Study II contributes a piece of evidence that bone substitute is an alternative to auto grafts. The result of Study II is consistent with the findings of a previous retrospective trial by Mulders et al. [193] that reported no difference in functional and patient-reported outcome due to the use of a graft or no graft after six months.

In terms of self-perceived ability to perform activities, both groups improved significantly from preoperatively to 12 months postoperatively. Further, the improvement also largely exceeded the minimal clinically important difference for the PRWE, which is 11.5 points for patients with distal radius fractures [216]. Moreover, both groups had scores corresponding to the moderate perceived disability preoperatively and, 12 months postoperatively, the scores instead corresponded to the minimal perceived disability. These changes indicate that the improvement was also clinically meaningful. A previ- ous trial by Ozer et al. [180] also showed a clinically meaningful improvement with a mean 28-point reduction in the DASH score at follow-up and no differences in functional outcome related to the use or non-use of a graft were observed. Additionally, in Study II, the reduction in pain was large enough in both groups to be clinically important, as the change in the PRWE pain scores also largely exceeded the MCID, which has been shown to be 1.5 points [216]. The reduction in pain was probably reflected in the results of the PROMs used for evaluating the ability to perform activities, as pain has been shown to be of great importance for the ability to perform activities [55].

For HRQL, there was a significant difference in the domains of physical function and bodily pain 12 months postoperatively compared with preoperatively, in the group

that received bone substitute. These changes were large enough to be clinically meaningful, but, as there were no significant differences in terms of grip strength, ROM or PRWE scores between the groups at any time point during follow-up, the improvement in HRQL could presumably not be due to the wrist. For the other do- mains of HRQL, there were no significant differences preoperatively compared with 12 months postoperatively in either group. A stable state of HRQL was an expected result in this patient group in which the patients did not suffer from any progressive diseases. From an occupational perspective on health, however, participating in ac- tivities that are meaningful for the individual is perceived to contribute substantially to the experience of well-being and meaning in life [108, 109, 111]. In the light of the find- ings of Studies I and III, which showed a large impact by the injury on activity and participation preoperatively and improvements in these factors 12 months after surgery, it is possible to argue that another PROM, perhaps focusing on quality of life instead, would have revealed the change.

6.4 FUNCTIONAL OUTCOME IN THE LONG-TERM

In Study IV, the study group comprised patients who had undergone corrective os- teotomy for malunion of a distal radius fracture three to 10 years prior to the study. The postoperative gains in alignment at the fracture site were maintained at the long- term follow-up. The degree of osteoarthritis had increased significantly, which has also been shown in previous research [228, 229] after both non-surgically and surgically treated distal radius fractures, and was evenly distributed between men and women.

Wrist stability and movability are required to use the hand successfully [2, 54, 230]. At the long-term follow-up, the ROM varied between 80% and 95% of the ROM in the uninjured wrist, for the different movement directions. Similar long-term results have previously been reported with respect to ROM after osteotomies for extra-articular fractures [189]. Considering the cohort of patients in Study IV, with both extra- and in- tra-articular injuries, the result with respect to ROM can be regarded as excellent. An earlier trial, on the relationship between patient satisfaction and functional outcome three months after surgical intervention for distal radius fractures [231], shows that ROM is of great importance. The cut-off point of 95% of ROM on the uninjured side was established for patient satisfaction. The corresponding number for grip strength was 65%. The patients in Study IV did not fully reach this level with respect to ROM, but they improved to a greater extent when it came to grip strength. After corrective osteotomy, which is often undertaken a few years after the fracture, during which time the patients have been in pain and are physically limited, the patients are most definitely satisfied, even when they do not attain this level of outcome. Other studies

have confirmed that ROM is not fully restored by corrective surgery [156, 186, 190], but, when it reaches 80% or more of the uninjured side, this probably does not matter that much to most patients. It has been shown that, in the normal use of the wrist in activities of daily life, only 70% of ROM is used [54].

With respect to grip strength, the result of Study IV was excellent. The grip strength was a mean of 31 kg, which is 89% of the grip strength on the uninjured side. Mulders et al. [193] reported a similar result with slightly less grip strength of 85% compared with the uninjured side. This may be due to the shorter time from surgery to follow-up, which varied from six months to 82 months [193]. The restoration of grip strength has been shown to be important for the ability to perform activities of daily life [55, 56]. In Study IV, grip strength correlated moderately to the PRWE scores. The mean score for the PRWE was 12 points, while the median score for the QuickDASH was 11.4 points. This result is comparable to the result of a median PRWE score of
18.5 and a median DASH score of 10 presented by Mulders et al. [193]. In spite of the excellent grip strength, the mean PRWE score was poorer than the reference value, which is approximately eight points [217], which indicates some residual difficulties when activities are carried out. The women had a mean PRWE score corresponding to a mild perceived disability [82], approximately 14 points higher than the men, whose score corresponded to a minimal perceived disability [82]. The difference between genders is probably explained by the higher median pain scores in the women (14 points), compared with the men (4 points). Since there was no difference between the genders with respect to the grade of osteoarthritis, there are probably other causes of the pain among the women. Greater pain in women after distal radius fracture, or subsequent surgery, has been reported earlier, without finding any explanation [91]. The pain score for the women was significantly higher than the reference values (mean approximately 5 points), which was also the case for the whole group. This finding indicates that patients may experience some residual pain in the long term following corrective osteotomy. It is important for occupational therapists and physiotherapists who encounter these patients to keep this in mind. It may be wise to provide patients with orthoses to relieve the pain during strenuous activity as a means of being able to maintain an active lifestyle. In order for patients to have realistic expectations when deciding to undergo surgery, it is very valuable to inform them that some residual pain may be present even in the long term after surgery.

In terms of HRQL, the domains with the lowest (worst) scores were bodily pain and vitality/fatigue. Since the RAND-36 is a generic instrument for measuring HRQL [72], the questions refer to physical ability, such as the ability to walk shorter and longer

distances, the ability to kneel and to psychological aspects of well-being, such as experiences of fatigue and of being happy or sad [72]. In any case, the result according to the scores on the PRWE, which is sensitive to wrist problems [61], indicates that the wrist was not the source of trouble for the patients. The result, with respect to the RAND-36 for this cohort of patients, probably reflects that some patients in the study group had different comorbidities and pain in different sites of the body that influenced the RAND-36 scores.

Higher levels of self-efficacy have been shown to correspond to better ROM and greater grip strength in the short term after surgical treatment after distal radius frac- tures [77]. It has also been shown that self-efficacy and anxiety mediate pain intensity and wrist function after volar plating [76]. The cohort in Study IV had a very good outcome with respect to ROM and grip strength and had a slightly higher mean self- efficacy score than the reference values. However, self-efficacy was not measured preoperatively but was measured a few years post-surgery. It is therefore difficult to determine whether the individual patient's self-efficacy influenced the functional outcome or the other way round. In the clinical setting, a postoperative evaluation of self-efficacy, when the patient first attends the rehabilitation clinic, might be valuable as an indication of which patients need extra information on fracture healing, extra encouragement to use the injured hand to a suitable extent and a more detailed explanation of the training regimen. The use of evaluating self-efficacy in this manner is also suggested by Björk et al. [77] and Hiraga et al. [76].

The patients in Study IV were asked if they would choose surgery again, had they known the result, and thirty-three (89%) answered that they would. One possible ex- planation of this is that they experienced less pain and greater ROM and grip strength than before surgery and that, despite the wrist not being fully restored, patients felt that their ability to use their hand in everyday life had improved. Study IV contributes to the evidence base that corrective osteotomy for malunion of the distal radius has favourable results that are maintained in the long term.

6.5 METHODOLOGICAL CONSIDERATIONS

6.5.1 QUALITATIVE AND QUANTITATIVE FRAMES OF REFERENCES

Qualitative research aims to obtain an understanding of phenomena, such as experiences of an injury. Objectivity is not possible, but the researcher instead uses him- or herself as a tool and the research process is a co-operation between the researcher and the informant [232, 233]. Interviews are often used for data gathering. When using interviews, different steps are taken to ensure that it is the voice of the patient that

is heard in the report. One way is to clarify the understanding of what the patient has said, by referring back to the patient, "You said this, have I understood you cor- rectly?". Another way is to use member checking, which means that the transcribed interviews are read by the patients who give feedback if something has been wrongly interpreted [80]. There are several qualitative methods and different variants of them. Grounded theory, as described by Strauss and Corbin [232], aims to build a theory based on the research data. In this method, the analysis starts during the first inter- view and is continued throughout the data-gathering process. This means that data collection and analysis occur in alternating sequences. Data collection is continued until saturation is reached, which means that no new information is obtained through further interviews.

Since the aim of this thesis was not to build a theory, but rather to explore expe- riences, qualitative content analysis [201] was deemed a more appropriate method. Qualitative content analysis aims to describe similarities and differences in both the manifest and the latent content of a text. The analysis can be undertaken at different levels and the categories and themes can be more or less abstracted. For this thesis, an inductive method was used during the analysis and an attempt was made to reveal the latent content but also to describe the manifest content that is close to the data [202, 233]. To describe experiences of difficulties performing everyday life activities, this was appropriate.

In qualitative research, certain steps are taken to ensure rigour and trustworthiness. Fellow researchers perform the analysis in a co-operative manner and discuss the coding, the categories and the themes. To create dependability, it is important to give enough information on how the analysis was performed and it is common to give examples of the coding process. Citations are used to show that the interpretation is derived from data. In terms of transferability, the judgement lies with the reader. It is therefore important to report the patient group and the context in which the study was undertaken and to report on the different characteristics of the participants. This information is essential for the reader to have an opportunity to judge whether or not the result is transferable to another patient group or setting [80, 232, 233].

In quantitative research, the focus is the mathematical or statistical analysis of nu- merical data and the research aims at hypothesis testing. Quantitative research can be used to make predictions and to find patterns. It can also be used to generalise results to wider populations. Objectivity and transferability are ensured, by reducing bias [79, 234]. The randomised, controlled study (RCT) is a study design with a quanti- tative approach and this was used in Study II. RCTs are often conducted to evaluate

different kinds of intervention, such as in Study II that evaluated whether there were any differences with respect to whether the osteotomy void was filled with bone substitute or left open. The advantages of this kind of trial are that it is prospective and the results are compared with a control group, which has not received the treat- ment of interest. The participants are randomly selected and randomly allocated to either treatment or the control group. For the results to be transferable, a correct power calculation of the sample size is important and the participants in the control group should not differ from the treatment group, with respect to important charac- teristics such as age, smoking habits or lifestyle. One disadvantage is that the cost of conducting an RCT is often high. Another example of study design that has a quantitative approach is the cross-sectional study, exemplified in this thesis in Study
IV. A cross-sectional study is observational, no intervention is given and an evaluation is made on one occasion and not over time. The result thus provides information with respect to the assessed outcome at a certain time point.

In quantitative research, such as studies of functional outcome after a corrective osteotomy, different instruments are used for data collection. To ensure reliability, it is crucial to follow established routines when the measurements are taken and when PROMs are used. In this thesis, the researcher made the measurements with few exceptions. In these cases, two other pre-trained occupational therapists collected the data and agreement on procedures for the measurements was assured.

Since ROM and grip strength are essential aspects of the functionality of the wrist, these properties are measured. Goniometers are generally accepted as valid tools and both the inter-rater and the intra-rater reliability are high for measurements of upper extremity ROM [104, 204]. The accuracy using a manual goniometer has been shown to be within 8° [205]. The ROM of the injured wrist can be compared with that of the contralateral wrist or with normal values. In this thesis, the injured side was compared with the uninjured side. The result was calculated at group level and, as there were both men and women of different ages, this was feasible because the groups were small. Grip strength is dependent on the position of the elbow, forearm and wrist, as well as body posture (sitting/standing). Using a standardised procedure, the assessment of grip strength has been shown to be reliable and valid in healthy subjects, as well as in populations with various health conditions, including musculoskeletal conditions [208]. To ensure reliability when measuring grip strength, the patient is seated with the elbow flexed at 90° and the forearm and wrist in a neutral position. Both hands are assessed and the mean of three mea- surements is calculated [207].

The measurements of ROM and grip strength constitute ways of comparing the patient's functionality with normative values, or the contralateral side, thereby acquiring an understanding of the degree of functional limitation the patient has. It has, however, been shown that measurements of grip strength and ROM correspond at best moderately with self-perceived ability to perform activities [56, 235]. To capture the patients' opinions of their ability to perform activities and different aspects of their well-being and health, PROMs are being used increasingly [46]. The QuickDASH is used extensively in research because it is easy to fill in. It has been shown to be reliable in the evaluation following wrist disorders [62]. In spite of this, there are some disadvantages. It evaluates the functionality of the whole upper extremity and is therefore more generic than the PRWE. The PRWE was created to evaluate pain and disability in activities of daily living related to disorders of the wrist. It is easy to fill in, has been tested for reliability and validity and has been shown to be the most sensitive PROM for evaluating wrist disorders [59, 61, 66]. If a certain task or activity is only performed occasionally by the patient, he or she is instructed to appreciate the degree of difficulty he or she would experience when performing the task. This is perceived as more appropriate than leaving the item blank [236]. The issue of hand dominance is difficult to overcome, but the principle of approximating the difficulty is used, even in the case of a task that is normally performed with the dominant hand, but the functionality of the non-dominant wrist is evaluated. The subjectivity of the scores must be taken into consideration because of these issues and because the amount of pain and other subjective experiences influence the patient, when filling in the questionnaire.

Another disadvantage of PROMs is that it is difficult to create a PROM that captures certain tasks and specific activities that might be of value or that are troublesome for the individual to perform. Study I also revealed other aspects of importance, such as changes in social life roles and compensatory strategies. These aspects are not cap- tured by existing PROMs, according to an earlier trial [237]. In spite of this, the PROMs represent the patients' own ratings and provide a score that can be compared with normative values [46]. A score is also useful when evaluating the individual patient during the course of rehabilitation.

The COPM is a client-centred tool, developed to assess the patient's self-perceived ability to perform activities. The advantage of the tool is that the patient chooses activities of personal importance to evaluate, which is unique, as problematised above, and that satisfaction with the ability is also graded. The COPM complements the other PROMs that are used, as it aims to identify the tasks and activities that are troublesome for the specific individual. The scores represent ordinal data and

comparisons between patients are not recommended. In research, the magnitude of change is of interest [67], but this was not calculated in Study II. The mean scores were compared at group level. The use of the COPM provided an indication that the patients in Study II were more satisfied with their activity performance one year postoperatively, but the results should still be interpreted with caution.

6.6 LIMITATIONS

During the time that Study II was being conducted, a narrower plate was introduced because the original plate was deemed to be too wide to be suitable for patients with a thinner skeleton. The narrower plate was used in 10 patients. No calculations were made with respect to the kind of plate that was used, but the groups would nevertheless have been too small to detect any differences, creating the risk of a type-II statistical error.

When interviewing patients one year after surgery, it was sometimes difficult for the patients to understand what they were supposed to talk about because their daily lives now worked well. All the interviews were therefore not as rich in content as the preoperative interviews. In any case, as 20 interviews were conducted, the data were rich and covered a variety of experiences related to the aim of the study.

Only patients with volar plates were included in Study IV. This was because patients more frequently experience problems with tendons after dorsal plating and patients with dorsal plates were therefore regarded as not being comparable with patients with volar plates. The study group would have been larger if patients with dorsal plates had also been included.
No calculations were made to evaluate whether there were any differences related to the type of fracture, such as an association between increased osteoarthritis and intra-articular engagement of the fracture.

Twenty-six patients (23%) took part in two or more of the studies in this thesis. This may have biased the results, but this is due to corrective osteotomy being a fairly rare procedure. To be able to avoid this, the studies should have been multicentre based.

7 FUTURE PERSPECTIVS

- During my work on this thesis, I have met many patients who said that they experienced very high levels of pain during the immobilisation period. The question arises of whether the disproportionate pain at the fracture site during immobilisation is a sign of fracture complication, for instance, gliding, and whether this may lead to malunion. The treatment protocol for distal radius fractures, commonly followed in Sweden, entails a radiographic evaluation at approximately seven to 10 days after the injury. Studies of the possible benefit of an extra radiographic assessment for patients with disproportionate pain after this checkpoint are needed.

- A radiographic evaluation of distal radius fractures is essential to guide physicians in the choice of treatment. Studies are warranted to evaluate whether other radiographic modalities constitute a more informative alternative than the standard protocol and which patients would benefit from this.

- From a rehabilitation perspective, early osteotomy is presumably beneficial, as patients often develop compensatory movements over time. Moreover, a limb that has been painful for a long time is more difficult to mobilise. Studies are needed to further investigate the time point that is optimal for osteotomy, both from the perspective of fracture healing and with respect to how function is recovered.

- Studies are warranted to evaluate the advantages and disadvantages of early osteotomy from the patients' perspective.

- Oedema of the hand following a fracture of the wrist is a common phenomenon that is critical and sometimes difficult to overcome. There is no feasible, reliable and valid method to measure the amount of oedema in a hand. Studies are needed to evaluate whether it is possible to use a 3D scanner effectively and reliably to assess oedema after injuries to the hand or wrist.

- Studies are also needed to evaluate the optimal rehabilitation protocol following corrective osteotomy for malunion of the distal radius.

- Studies focusing on the influence of self-efficacy on functional outcome after distal radius fractures are needed, as well as studies of the impact of malunion of distal radius fractures on HRQL, or QoL.

- Research to develop a PROM that captures the variety of factors that are influenced by a malunion of a distal radius fracture and that influence health is warranted.

8 CONCLUSIONS

This thesis provides increased knowledge relating to the experiences of patients who have sustained a symptomatic malunion of a distal radius fracture. It also pro- vides knowledge about the functional outcome during the first postoperative year, patients' experiences of how their daily life functions one year after surgery and patient-related functional outcome in the long term.

One of the main findings was that malunion of a distal radius fracture might influence the patient's daily life to a great extent. For some patients, the injured wrist is in focus at all times, due to pain, stiffness and other types of inconvenience. The wrist not only hinders patients from working, it also obstructs their normal lifestyle, including social- ising with relatives and friends. Moreover, the arm is sometimes like a troublesome object at rest and during the night, difficult to place in a satisfactory resting position. The functionality of the wrist is of greater importance to patients suffering from other physical impairments such as back pain. This is due to their need to rely more on their hands for support and because they may have greater difficulty reaching when both the back and the wrist are stiff.

One year post-surgery, the majority of the patients found that pain and stiffness had decreased. Their well-being had increased because they were once again able to do things that meant a lot to them and they had the energy to socialise. Patients consider their lives to be more like before the injury. For a minority of patients, the experiences are coloured by complications.

The studies indicate that functional outcome one year after surgery is much improved and both the radiographic and the functional results are maintained in the long term.

- A symptomatic malunion of a distal radius fracture may have a negative impact on body function/structure, activity and participation, as well as environmental factors and personal factors. Patients might require interventions in all these areas.

- During the first year after corrective open-wedge distal radius osteotomy, where

cortical contact is maintained and volar plates are used, there are no significant or clinically relevant differences in pain, functional outcome or the ability to perform activities, regardless of whether or not a bone substitute is used to fill the void.

- A year after surgery, the majority of the patients experience an improvement in the ability to perform activities and relief of symptoms and they find the residual symptoms manageable.

- In the long term, function and the ability to perform activities are restored to a high degree. Patients may experience some residual pain, but the majority deem it worthwhile to have undergone surgery.

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