Recovery after surgically treated distal radius fracture

ASPECTS OF EVALUATION AND REHABILITATION

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To my family

CONTENTS

ABSTRACT

BACKGROUND A distal radius fracture (DRF) is a common injury, occurring in both genders and during the entire life span, although it is most common in elderly women. An uncomplicated fracture is treated with a cast, but more complicated ones are treated surgically, most commonly with a volar plate, and the majority result in good clinical and radiological outcomes. Most patients normally regain the majority of their function and ability to perform activities within three to six months, but some experience pain and disability during a longer period of time. Even today, there is no consensus on treatment and rehabilitation.

AIM The overall aim of the thesis was to investigate various factors related to outcomes and rehabilitation after surgically treated distal radius fractures.

METHODS In Study I, patients' outcomes in terms of pain, function, activity performance and apprehensiveness to use the injured hand in daily activities were evaluated in a cross-sectional study up to three months after surgery. In Study II, translation and cultural adaptation of the Michigan Hand Outcomes Questionnaire (MHQ) were performed and the questionnaire's psychometric properties in terms of validity and reliability were evaluated. In Study III, a randomised controlled study (RCT), the outcomes of patients randomly allocated to a cast or a brace after surgery were compared in terms of activity performance, pain and grip strength up to two years after surgery. In Study IV, also an RCT, the relationship between sense of coherence and impact of anaesthesia method on patient-reported outcomes were investigated.

RESULTS In Study I, measurements of pain, oedema, range of motion (ROM) in the wrist, grip strength and activity performance revealed significant improvements over time. At 12 weeks, the study participants had regained almost 70% of their grip strength and 74-96% of the ROM in the non-injured hand and patients reported minimal severity of pain and disability. The apprehensiveness about using the injured hand in activity increased at the time of the cast removal, where the proportion of patients estimating a high degree of apprehensiveness was significantly higher compared with three days postoperatively. Apprehensiveness was moderately correlated with activity performance on all visits. The study also revealed that, in over 70% of participants, the plaster cast had to be adjusted, replaced with a new cast or with a brace, during immobilisation, due to a poorly fitting plaster cast. In Study II, the MHQ was successfully translated and culturally adapted according to guidelines. The process revealed no major issues and the Swedish version of the MHQ showed good validity and reliability. In Study III, patients' pain, activity performance and grip strength after using a plaster cast or a brace after surgery, were compared. All the outcomes improved significantly during the study period and, at six weeks, the outcomes indicated minimal pain and disability. The analysis of equivalence indicated that the outcomes in the groups could be regarded as equivalent, implying that a brace is as good as a plaster cast in the respects mentioned above. In Study IV, sense of coherence correlated with pain and activity performance and there were no significant differences between the groups in terms of outcomes for pain or activity performance at any time point in the study, indicating that anaesthesia method has limited impact on these aspects.

CONCLUSION In terms of activity performance, patients improve over time during the first three months (Studies I, II, IV), but they continue to improve also after three months after surgery (Studies III and IV). The translated and culturally adapted MHQ-Swe is an appropriate and relevant patient-reported outcome measurement (PROM) questionnaire, with good validity and reliability, which can be used for patients with a surgically treated DRF (Study II). A prefabricated brace instead of a cast is a feasible method of immobilisation after a surgically treated DRF, in terms of the outcomes for pain, activity performance and grip strength (Study III). Personal factors, both apprehensiveness (Study I) and sense of coherence (Study IV), correlates with patient-reported outcome measurements, which supports the importance of considering personal factors in the recovery process after a fracture. The anaesthesia method seems to have limited influence on outcomes in terms of pain and activity performance both after three days and in a longer perspective in the rehabilitation (Study IV).

KEYWORDS: occupational therapy, hand rehabilitation, distal radius fracture, ADL, activity performance, apprehensiveness, sense of coherence, patient-reported outcome measurement, function

SAMMANFATTNING PÅ SVENSKA

BAKGRUND En distal radiusfraktur (DRF) är en vanlig skada som förekommer hos båda könen och genom hela livsspannet, även om den är vanligast hos äldre kvinnor. En okomplicerad fraktur behandlas med gips, men mer komplicerade frakturer behandlas kirurgiskt, oftast med volar platta, och majoriteten av patienterna uppnår goda kliniska och radiologiska resultat. De flesta patienter återfår normalt merparten av sin funktion och aktivitetsförmåga inom tre till sex månader, men vissa upplever smärta och funktionsnedsättning under en längre tid. Det finns än idag ingen konsensus gällande behandling och rehabilitering.

SYFTE Det övergripande syftet var att undersöka olika faktorer relaterade till utfall och rehabilitering efter kirurgiskt behandlad distal radiusfraktur.

METOD I studie I utvärderades patienternas smärta, funktion, aktivitetsförmåga och oro för att använda den skadade handen i dagliga aktiviteter i en tvärsnittsstudie upp till tre månader efter operation. I studie II genomfördes översättning och kulturanpassning av Michigan Hand Outcomes Questionnaire (MHQ) och dess psykometriska egenskaper i form av validitet och reliabilitet utvärderades. I studie III, en randomiserad kontrollerad studie (RCT), jämfördes aktivitetsförmåga, smärta och greppstyrka upp till två år efter operationen hos patienter som randomiserats till ett gips eller ett handledsstöd efter operationen. I studie IV, också en RCT, undersöktes sambanden mellan känsla av sammanhang och inverkan av anestesimetod gällande patientrapporterade utfall.

RESULTAT Studie I visade signifikanta förbättringar över tid gällande smärta, ödem, rörelseomfång (ROM), greppstyrka och aktivitetsförmåga. Vid 12 veckor hade patienterna återfått nästan 70% av sin greppstyrka och 74-96% av ROM i den icke-skadade handen, och patienterna angav minimal smärta och funktionsnedsättning. Oro för att använda den skadade handen i aktivitet ökade vid tidpunkten för borttagningen av gipset, då andelen patienter som angav en hög grad av oro var signifikant högre jämfört med tre dagar efter operationen. Oro var måttligt korrelerat med aktivitetsförmåga vid alla besök. Studien visade också att hos över 70% av patienterna behövde gipset justeras, bytas ut till ett nytt gips eller till ett handledsstöd under immobiliseringstiden, på grund av att gipsets passform var dålig. I studie II översattes och kulturanpassades MHQ enligt riktlinjer.

Processen påvisade inte några större problem och den svenska versionen av MHQ visade god validitet och reliabilitet. I studie III jämfördes patienternas smärta, aktivitetsförmåga och greppstyrka efter att ha använt ett gips eller ett handledsstöd efter operation. Alla utvärderingsvariabler förbättrades signifikant under studieperioden och vid sex veckor uppgav patienterna minimal smärta och funktionsnedsättning. Ekvivalensanalysen visade att gruppernas utfall kunde betraktas som likvärdiga, vilket innebär att ett handledsstöd kan anses lika bra som ett gips i ovan nämnda avseenden. I studie IV korrelerade känsla av sammanhang med smärta och aktivitetsförmåga och det fanns inga signifikanta skillnader mellan grupperna gällande varken smärta eller aktivitetsförmåga vid någon tidpunkt i studien, vilket indikerar att anestesimetoden har begränsad inverkan på dessa aspekter.

KONKLUSION När det gäller aktivitetsförmåga förbättras patienterna över tid under de första tre månaderna efter operationen (Studie I, II och IV), men de fortsätter också att förbättras efter tre månader efter operationen (Studie III och IV). Det översatta och kulturanpassade MHQ-Swe är ett lämpligt och relevant bedömningsinstrument, med god validitet och reliabilitet, som kan användas för patienter med en kirurgiskt behandlad DRF (Studie II). Ett prefabricerat handledsstöd istället för ett gips är ett möjligt alternativ för immobilisering efter en kirurgiskt behandlad DRF vad gäller utfall av smärta, aktivitetsförmåga och greppstyrka (Studie III). Personliga faktorer, både oro (Studie I) och känsla av sammanhang (Studie IV), korrelerar med patientrapporterade utfall, vilket stöder vikten av att beakta personfaktorer i återhämtningsprocessen efter en fraktur. Anestesimetoden verkar ha ett begränsat inflytande på utfall vad gäller smärta och aktivitetsförmåga både efter tre dagar och i ett längre perspektiv i rehabiliteringen (Studie IV).

LIST OF PAPERS

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

I. Blomstrand J, Kjellby Wendt G, Karlsson J, Wangdell J, Fagevik Olsén M. (2022) Pain, hand function, activity performance and apprehensiveness, in patients with surgically treated distal radius fractures. Journal of Plastic Surgery and Hand surgery, *doi: 10.1080/2000656x.2022.2060992*

II. Blomstrand J, Karlsson J, Fagevik Olsén M, Kjellby Wendt G. (2021) The Michigan Hand Outcomes Questionnaire (MHQ-Swe) in patients with distal radius fractures—cross-cultural adaptation to Swedish, validation and reliability. Journal of Orthopaedic Surgery and Research, *doi: 10.1186/s13018-021-02571-7*

III. Blomstrand J, Sellbrant I, Nellgård B, Karlsson J, Fagevik Olsén M, Kjellby Wendt G. Evaluation of a plaster cast or a removable brace as immobilisation following surgically treated distal radius fracture – a randomised controlled trial. *In manuscript*

IV. Blomstrand J, Sellbrant I, Nellgård B, Karlsson J, Fagevik Olsén M, Kjellby Wendt G. Sense of coherence and its relationship to outcomes in patients with surgically treated distal radius fractures. *In manuscript*

ABBREVIATIONS

ADL	Activities of Daily Living
CRPS	Complex Regional Pain Syndrome
DASH	Disability of the Arm, Shoulder and Hand questionnaire
DRF	Distal Radius Fracture
MHQ	Michigan Hand Outcomes Questionnaire
NRS	Numeric Rating Scale
OT	Occupational Therapist
PROM	Patient-Reported Outcome Measurement
PRWE	Patient-Rated Wrist Evaluation
PT	Physiotherapist
ROM	Range Of Motion
SOC	Sense Of Coherence
VAS	Visual Analogue Scale

DEFINITIONS

ACTIVITY	“The execution of a task or action by an individual” (1)
ACTIVITY PERFORMANCE	“Choosing, organising and carrying out activities in interaction with the environment” (2)
EMPOWERMENT	“The aspiration to enrich the abilities and opportunities of people to engage and participate in the valued occupations of their everyday lives” (3)
FUNCTION	“The physiological functions of body systems” (1)
OCCUPATIONAL DISRUPTION	“A temporary state, characterised by a significant disruption of identity associated with changes in the quantity and/or quality of one’s occupations subsequent to a significant life event, transition, or illness or injury. It has the potential to affect multiple areas of functioning, including social and emotional functioning” (4, 5)
PARTICIPATION	“Involvement in a life situation” (1)
RELIABILITY	The extent to which an instrument is able to measure in a consistent manner, including its stability over time and between examiners (6)
SENSE OF COHERENCE	“A global orientation that expresses the extent to which one has a pervasive, enduring though dynamic feeling of confidence that 1) the stimuli deriving from one’s internal and external environments in the course of living are structured, predictable, and explicable (comprehensibility); 2) the resources are available to one to meet the demands posed by these stimuli (manageability); and 3) these demands are challenges, worthy of investment and engagement (meaningfulness)” (7, 8)
VALIDITY	The degree to which a measurement instrument measures the construct(s) it purports to measure (9)

1

”When you sustain a wrist fracture, life changes in a second. You are completely unprepared for what awaits you. At first, it is difficult to accept that it has actually happened. Gradually, you acquire information about the surgery and so on. Then you are surprised by the strong pain that follows surgery and the accompanying helplessness in combination with depression and anger. Then the exercise that takes time and effort. It feels like it’s going so slowly. You start to despair about whether you are ever going to get well again. This type of injury and rehabilitation dominates your everyday life completely. Your life is suddenly just about the hand, even other perhaps more serious ailments end up in the shadow of this. It sounds strange, but it’s true.”

Quote from a participant in one of the studies,
written spontaneously on the back of a questionnaire

1 INTRODUCTION

Our hands are not only important work tools but also important sensory organs that helps us to collect information from the outside world, thereby helping us to interact [10]. The function of the hands is complex and, in daily activity, they act as a means of grasping, a means of sensing and a means of communication. The representation of the hands in the brain is disproportionately large and a hand injury affects more than just the grasping ability and the mechanical tasks the hands perform [11, 12]. Our hands are a large part of what makes us human, by affecting our ability to perform work, leisure activities, self-care and social interaction, and they play a large role in communication and expression [13]. Being active is the foundation of all human beings and participation in activities is a necessary component of our physical and mental well-being [14]. Through the importance of hands in all parts of life, a person affected by a hand injury can experience severe physical, mental and social consequences [13, 15].

FIGURE 1. Our hands are important in many different situations in daily life, including both work and leisure activities

1.1 THE WRIST

The functionality of our hands is the basis of activity performance and involves a combination of sensation, proprioception, anatomy, neurological control and co-ordination, muscle strength and mobility (16). The wrist is one of the most complicated joints in the human body (17). Due to its complexity, an injury easily leads to dysfunction, which affects not only the function of the wrist but also the function of the hand, the entire upper extremity and also the entire person (18). The bones of the wrist region include the radius, the ulna, the carpal bones and the bases of the metacarpals (18), see Figure 2. The carpal bones have a complex surface geometry and are dependent on associated ligamentous support to work together with their neighbouring bones (19, 20).

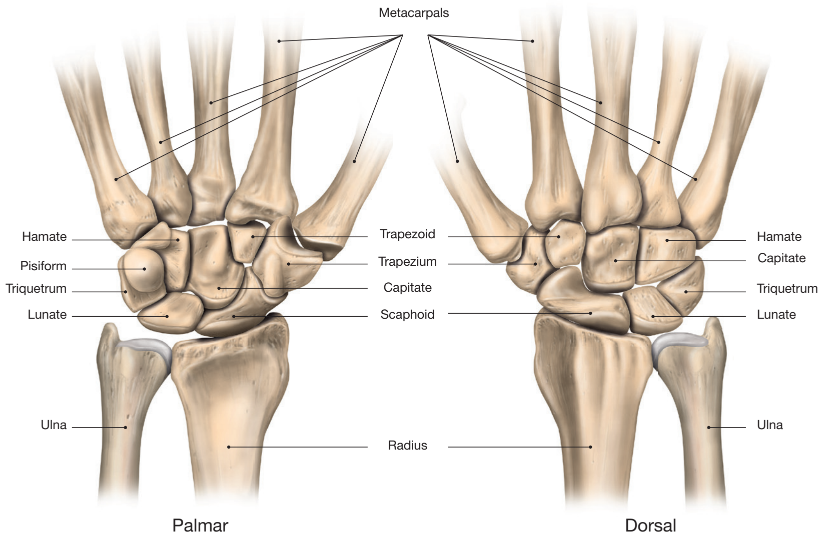

FIGURE 2. Anatomy of the wrist

1.2 DISTAL RADIUS FRACTURES

1.2.1 EPIDEMIOLOGY

A distal radius fracture (DRF) is one of the most common fractures and the incidence is increasing [21-24]. It is reported to account for approximately 25% of fractures in the paediatric population and up to 18% of all fractures in the elderly age group [25]. Even though the fracture is most common in young men and elderly women, DRFs occur in both genders and in all age groups [26-28]. In younger patients, they are mostly due to high-energy trauma [29]. In contrast, in the older population, the most common mechanism of injury is a low-energy trauma due to a fall from a standing height [30]. The most common patient is described as an elderly woman who sustains a DRF through a fall in her own home, whose fracture is extra-articular and treated non-surgically [31]. Osteoporosis is an important risk factor, which increases the incidence in women from the age of 50 [32]. The incidence of affected people in Sweden has been described as approximately 25,000 persons a year [22, 33]. The incidence of DRFs is expected to increase with a growing population, increasing life expectancy and, with it, an increased incidence of osteoporosis [34-36].

A DRF can be non-articular, partial articular or totally articular and varies in comminution and displacement [17]. Different fracture patterns are described as Colles, Smith, Barton and Hutchinson (chauffeur) fractures [37] and the diagnosis is confirmed clinically and radiographically. The most common of the above is the Colles fracture which generally results from a fall on an outstretched arm and involves a dorsally displaced fragment of the distal radius [36], see Figure 3.

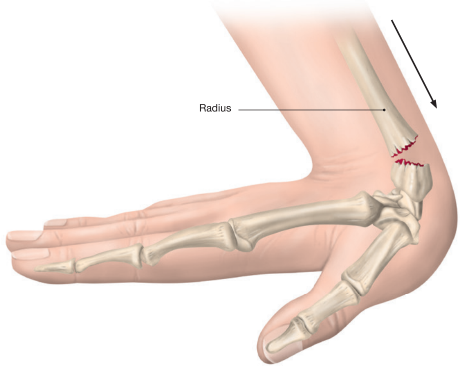

FIGURE 3. The most common mechanism of a Colles fracture

There are different systems of fracture classification, such as the Frykman [38], Fernández [39] and the Müller Arbeitsgemeinschaft für Osteosynthesefragen (AO) classification [40]. The latter describes fracture patterns in order of increasing severity and divides the fractures into extra-articular (Type A), partially articular (Type B) and completely articular (Type C) and the presence of comminution [40]. This classification is considered to provide the most comprehensive system for the distal radius, facilitating communication and diagnosis [41].

1.2.2 TREATMENT ALTERNATIVES

Treatment is based on the radiological appearance and stability of the fracture, the patient´s age and health situation, functional requirements and also the prevalence of osteoporosis [42]. Giving the patient the opportunity to participate in the decision on treatment options is regarded as extremely important. Fractures that are intra-articular or comminute are complex, and frequently require surgical treatment [43]. The main goal of the surgical treatment is to restore radial length, volar tilt, radial inclination and articular reduction at the radiocarpal and radial-ulnar joints [17]. A DRF is not an isolated injury, as it is often associated with median nerve compression, carpal/ulnar fractures and ligament injuries [44]. The associated injuries can affect both the surgical methods and the rehabilitation.

Uncomplicated fractures are mostly treated with a cast, but, for fractures regarded as unstable, surgery is recommended [45]. Fixation with a volar plate is one of the most common methods [46]. The plates are designed, among other things, to allow reliable fixation and early mobilisation [47] and they offer superior results compared with other surgical methods in terms of functional outcomes and the reduction of complications related to fracture healing [48, 49]. After the surgical treatment, the patient´s wrist is usually immobilised in a plaster cast for about two weeks before mobilisation begins. The question of both the type (cast, splint or brace) and length of immobilisation is, however, still the subject of debate [50, 51]. Figure 4 shows a DRF before and after surgery.

According to the Swedish Fracture Register [52], in 2021, Sahlgrenska University Hospital treated approximately 1,500 distal radius fractures, while in Sweden the number was approximately 24,000. The proportion of patients who were treated surgically was

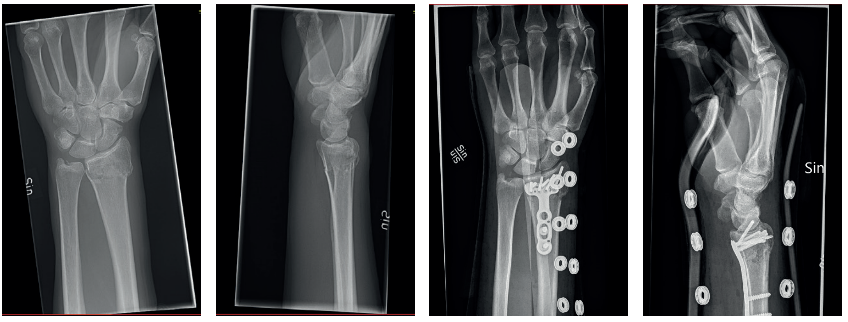

FIGURE 4. Distal radius fracture, before and after volar plating

about 1/3, both at Sahlgrenska University hospital and also in the whole of Sweden. Of the surgical treatments, 92% were performed with volar plating at Sahlgrenska University Hospital, and approximately 75% in the country in general (52).

The surgery is performed using different anaesthesia methods, regional anaesthesia (RA), such as a supraclavicular blockade (SCB), or general anaesthesia (GA) (53). There is limited evidence relating to which anaesthetic technique is superior in wrist surgery and there is a need for more long-term studies of anaesthesia methods related to the quality of recovery and patient satisfaction in patients with a DRF (53). A previous study showed that, at three and six months, patients who received RA had significantly less pain and better ROM and Disability of the Arm, Shoulder and Hand (DASH) scores compared with GA, but no differences were seen after 12 months (54). Recent studies indicate no differences in long-term functional scores between RA and GA but reduced early pain levels in RA groups (55, 56).

1.2.3 REHABILITATION

Postoperative rehabilitation starts immediately after surgery and is an essential part of the treatment, in order to enhance recovery and reduce and prevent complications and long-term disability (51, 57-59). The main strategy and goals of the postoperative rehabilitation are to manage pain, prevent and treat oedema, regain range of motion (ROM) and grip strength, enable the patient to regain function and activity performance to enable a return to activities and to prevent and reduce complications (58, 60, 61). In order to regain normal hand function, an early return to performing daily activities is essential (10).

Rehabilitation is reported to have a major impact on final outcomes (62, 63). Early rehabilitation interventions, such as home exercise programmes or supervised interventions, during the immobilisation period, lead to faster recovery and a positive effect on functional outcomes, improvements in pain and a return to daily activity (43, 59). Early involvement in rehabilitation as well as early interventions, such as advice on activity, how to manage daily life with a cast and coping strategies after a hand injury, are described as valuable contents of treatment (61, 64). Occupational therapy during immobilisation has been shown to lead to better short-term improvements in ROM and functional scores (65). If the patient is lacking information or knowledge, this can lead to fear of using the hand, which can in turn result in stiffness and pain (66).

During the rehabilitation, the treating occupational therapist (OT) or physiotherapist (PT) acts as a coach by empowering patients. Empowerment can be described as “the aspiration to enrich the abilities and opportunities of people to engage and participate in the valued occupations of their everyday lives” (3) and it is an essential part of hand rehabilitation. During the rehabilitation, the OT/PT empowers the patient, by using a coach-like role to motivate home exercises and to provide support and encouragement (61, 62). The relationship between the therapist and the patient is described as “not a one-way flow from therapist to patient but a mutual exchange between equals”, where the therapist is the one responsible for creating a suitable environment for this to be achieved [67]. Patient-centred care is correlated with reduced pain and disability, which highlights the importance of communication and the establishment of a relationship with the patient [68]. During the rehabilitation, patient compliance and the rehabilitation partnership are the most important factors to include [69].

The rehabilitation after a surgically treated DRF can be described in three phases:

- The immobilisation phase
- The mobilisation phase
- The strengthening phase [61, 69].

Immobilisation phase

During the immobilisation phase, the patient is commonly immobilised in a plaster cast. The fitting of the plaster cast is crucial to enhance ROM exercises in the non-immobilised joints, such as fingers, elbow and shoulder, and to prevent complications [60, 61]. A non-optimal plaster cast can cause both stiffness and swelling of the fingers, nerve entrapments, Complex Regional Pain Syndrome (CRPS) and pressure ulcers [70, 71]. It is recommended that an appropriate plaster cast for a DRF should be in a functional position, with the wrist in neutral or slight dorsal extension [72-74], facilitating ROM exercises in the fingers [74]. The plaster cast should always allow full movement of the fingers, metacarpophalangeal joints, as well as the abduction and opposition of the thumb, see Figure 5.

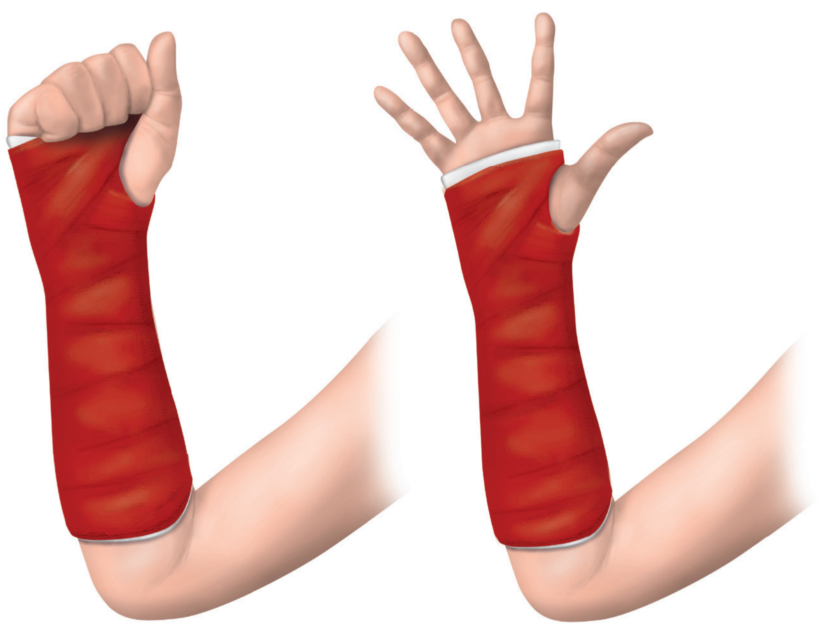

FIGURE 5. A well-fitting cast

Patient-reported outcomes are closely related to the maintenance of digit mobilisation [75,76]. Early therapy to improve digit motion already during the immobilisation phase is therefore of great importance. During the immobilisation phase, the interventions focus on preventing stiffness in the fingers, elbow and shoulder, in combination with reducing and counteracting oedema [17, 61, 77]. Prolonged oedema has an impact on both joint range of motion, soft tissue mobility, scar tissue formation and the function, strength and aesthetics of the hand, factors that may delay recovery, return to work and the resumption of activities of daily living [78]. When treating oedema, the most important factors are elevation of the extremity (above the heart), compression and active exercises of the fingers, elbow and shoulder [69, 79]. Treatment also includes encouraging the patient to use the hand in everyday activities to prevent reduced range of motion and oedema [77]. The performance of light, non-forceful daily activities can be safely initiated within two weeks of surgery [80].

In terms of pain, the treatment includes support in dealing with the pain, in combination with elevation and active exercises. It is also important to investigate where the pain begins, for example, due to a poorly fitting plaster cast, a median nerve compression (carpal tunnel syndrome) or joint tightness [69].

Mobilisation phase

Stable internal fixation is beneficial as it makes it possible to initiate early range of motion (ROM) exercises of the forearm, fingers and wrist and thereby a return to activities of daily living as soon as possible [81]. The mobilisation phase usually starts approximately two weeks after surgery [61, 81]. Patients who start therapy at a later stage after volar plating tend to require both more frequent follow-ups and a longer rehabilitation period, as well as risking greater stiffness and poorer outcomes [81, 82].

The goals of managing pain and oedema control, movement of fingers and activity/two-handedness continue during the mobilisation phase, with the addition of improving wrist motion [61]. Depending on stiffness and the level of pain, the exercise protocol is adjusted to every patient's need. The most common active wrist mobilisation protocol includes exercises (dorsal extension, volar flexion, supination, pronation and deviation/dart-throwing motion) three to four times a day, with 10 repetitions. Between exercises, a removable brace should be used during the first weeks [69, 79]; for example, a brace as shown in Figure 6.

Wrist mobilisation exercises consist mainly of active ROM exercises. However, the performance of daily activities could also promote ROM, and may also be beneficial in increasing and restoring movement patterns, improving self-efficacy, for pain relief and facilitating engagement in therapy [83-85].

Strengthening phase

During the last phase, when the fracture healing progresses, the interventions described in the previous phases (everyday activities, ROM exercises, combined with continued oedema treatment if necessary) continue, with strengthening exercises and increased load in everyday activities in addition. In terms of time, the strengthening phase is usually started around six to eight weeks after surgery [69, 77, 79].

FIGURE 6. Prefabricated, stable brace with volar and dorsal aluminium rails (Wrist lacer, CAMP, Sweden)

Strength and load can be achieved with manual stabilisation exercises and exercise dough, followed by elastic bands and, later, dumbbells.

1.2.4 COMPLICATIONS

Surgery with volar plating is regarded as a safe and effective method, but complications nonetheless occur [86, 87]. The total complication rate has been reported as between 7% and 32% [86-89]. Approximately 70% of all complications occur in AO type C fractures [86, 87].

Complications after a DRF can be classified into tendon, nerve, or hardwarerelated and other complications [90], but they can also be described as early (within 6 months) and late (> 6 months) [91]. Early complications include complex regional pain syndrome (CRPS), tendon ruptures (mostly extensor pollicis longus – EPL), nerve injuries, loss of reduction and infection. Late complications include non-, or malunion, joint contractures and stiffness [91]. Complications are extremely important, but they will not be further discussed in this thesis.

1.2.5 OUTCOMES

The majority of patients treated surgically with a volar plate after a DRF experience good clinical and radiological outcomes with no complications [92]. Numerous of factors influence the outcomes of DRF management, such as the fracture pattern, associated injuries, the treatment chosen and the patient's characteristics [17].

With regard to the fracture, increased fracture severity and high-energy trauma have been shown to be associated with inferior functional outcomes up to six months after surgery [93]. The degree to which the articular step-off, the gap between fragments, and radial shortening are improved by surgery has been shown to be strongly correlated to improved outcome [94].

In terms of patient characteristics, higher age and lower bone mineral density are important risk factors that influence delayed functional recovery up to 12 months after DRF surgery [93]. Studies have also shown that there are significant associations between higher age and pain intensity and disability [95]. Although higher age is described as a risk factor in some studies, more recent studies imply the opposite [87, 92].

At baseline, initially after the patient sustains an injury, it is common to experience pain, oedema, reduced range of motion, reduced hand strength and finger dexterity, which may also affect the performance of daily activities [96, 97]. The range of motion in the wrist, grip strength, pain and activity performance are described as being significantly impaired compared with the healthy hand six weeks after surgery [98]. Initially after the fracture (both surgically treated and non-surgically treated patients), patients report high levels of pain and disability which improve for the most part during the first three months [99]. Most patients normally regain the majority of their range of motion, strength and function within three to six months [99-101]. However, a small proportion of patients experience disability for even longer [102].

During the first year after fracture, pain and disability are present, but they gradually improve. Eleven per cent of the patients have been described as estimating their pain from moderate to very severe and 16% experience moderate to very severe disability even one year after fracture [95]. Likewise, another study showed that, at three months, only 39% of the patients reported minimal or no pain, 33% reported mild pain, 16% moderate pain and a full 12% estimated their pain as severe to very severe. At one year, 69% reported minimal or no pain, 19% mild pain, 5% moderate pain and 6% severe to very severe pain [99]. In the same study, 45% of the patients reported minimal or no disability at three months, but at 12 months, this percentage increased to 79%. At the same time, 28% reported moderate, severe or very severe disability at three months, but only 8% at 12 months, indicating continuous improvement during the first year [99]. Some variables, such as pain and grip strength, for example, have been described to improve continuously up to two years after the fracture [100].

In terms of ROM, average outcomes after one year after fracture are reported as wrist flexion 59°, extension 63°, pronation 80° and supination 81° [101] or the wrist flexion-extension arc 118° and forearm rotation arc 168° at final follow-up (12-52 months after surgery) [89]. In terms of grip strength, research has shown that, at three and six months, there are clinically important differences in grip strength between the injured and non-injured hands, but that the differences are small and of uncertain clinical importance at 12 and 24 months [103]. A systematic review described the outcome of grip strength in the injured hand as 76% of that in the non-injured hand at the last follow-up (12-52 months after surgery) [89].

The rehabilitation after a hand injury often takes time, includes several coping strategies and may also lead to psychological distress [104]. Personal, psychological and psychosocial factors are important factors, in particular coping ability and its relevance to outcomes [105]. It has been shown that fear and catastrophic thinking are important determinants of recovery after an acute, painful, fracture (106). Sense of coherence (SOC) is one personal factor that reflects a person's view of life and thereby their capacity to deal with situations that can be stressful, such as the trauma involved in sustaining a DRF. The concept is strongly related to perceived health; the stronger the SOC, the better the perceived health in general (107). Low SOC is associated with an increased risk of having a less good clinical and functional outcome one year after an orthopaedic injury (105). It has a significant influence on patients with a severe or major traumatic hand injury and it has been shown that patients with lower SOC scores benefit from the extra support and help to master their daily life (108). This supports the belief that it is important to consider personal factors in the recovery process after a fracture and indicates that this is an important factor in rehabilitation. SOC is discussed further in the "Theoretical framework and aspects of health" section.

1.3 HOW TO MEASURE OUTCOMES

During the rehabilitation process, different outcome measurements are used, to evaluate the progress over time, to motivate the patients and to evaluate different interventions. Consistency in the measurements is important and the measurements should be performed in a standardised manner. The outcome measurements are more thoroughly discussed in the "Methods" section.

Range of Motion (ROM)
When measuring the range of motion of the wrist, a goniometer is used and the results are reported in degrees, see Figure 7. The ROM is measured in terms of volar flexion, dorsal extension, radial deviation, ulnar deviation, supination and pronation (109).

Grip strength
A measurement of grip strength is seen as a good measurement of "overall hand health" (11), and is an important aspect of performing daily activities (100, 110). Grip strength is often measured with a Jamar dynamometer (111), see Figure 8.

Oedema
Oedema in the wrist, around the MCP joints and in the fingers can be measured in millimetres with a non-stretch tape measure (112), see Figure 9.

Pain
The patients' experienced pain intensity is an important aspect of assessments of function. Since the pain is affected by emotional factors, it is a subjective experience (11). The pain intensity can be assessed with rating scales. The numeric pain rating scale (NRS) is one method for measuring pain, where the patient estimates the degree of pain on an 11-step scale from 0 to 10, where 0 stands for "no pain" and 10 "worst imaginable pain" (113). Another way of measuring pain is related to localisation, quality and time (11).

Activity performance
The outcomes after an injury are often assessed primarily by means of objective measurements such as radiographic outcomes and physical capabilities in terms of grip strength and range of motion, but nowadays the use of patient-reported outcome

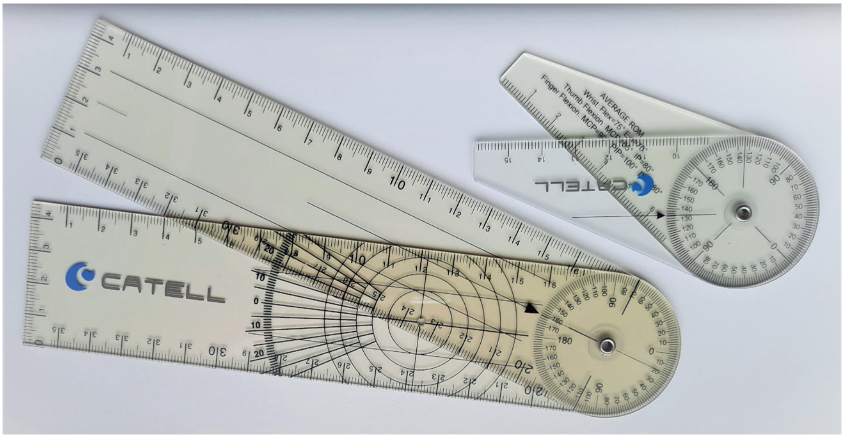

FIGURE 7. Goniometers for measuring wrist and fingers

FIGURE 8. Jamar dynamometer

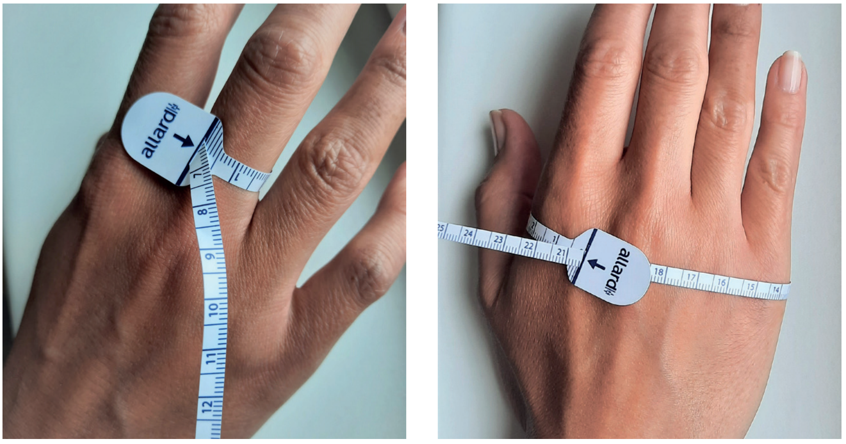

FIGURE 9. Measurement of oedema

measurements (PROMs) is equally important [114, 115]. In order to assess and evaluate activity performance, for example, the functional assessments should be combined with patient-reported outcome measurements, since the objective clinical outcomes do not always correlate with functional assessments [101, 116-119].

The definition of a PROM, is "A report on the status of the patient's health condition that comes directly from the patient, without interpretation of the patient's response by a clinician or anyone else" and can be used, for example, to evaluate change over time [120]. PROMs refer to subjective assessments of activity limitations and the severity of symptoms or quality of life, for example, and they are also an important part of understanding how patients perceive their care and the outcome of it. PROMs contribute to a value, in addition to measurements of functional outcomes in terms of treatment efficiency, for example [91]. PROMs can be used for many different purposes. They can be used, for example, when evaluating rehabilitation/interventions, and to improve or change the communication between patient and therapist.

Two common questionnaires for evaluating patient-reported outcomes after DRFs are the Patient-Rated Wrist Evaluation (PRWE) [121] and the Michigan Hand Outcomes Questionnaire (MHQ) [122]. Both questionnaires evaluate pain, function and activity after hand injuries, but the PRWE lacks the aspect of patient satisfaction.

Personal factors
The outcomes after injury are also dependent on personal factors, such as sense of coherence, SOC. The impact of SOC, the person's view of life and their capacity to deal with situations such as the trauma when sustaining an injury, can be assessed using Antonovsky's Sense of Coherence questionnaire [123], which is also a patient-reported outcome measurement.

1.4 RELIABILITY AND VALIDITY OF OUTCOME MEASUREMENTS

To minimise the risk of inaccurate or biased results, it is crucial that the measurements used are reliable and valid [124].

Reliability describes the extent to which an instrument is able to measure in a consistent manner, including its stability over time and between examiners [6]. It can be described as the extent to which scores for patients who have not changed are the same for repeated measurement under different conditions [9]. Depending on circumstances, the type of instrument and study aims, there are different types of reliability. In this thesis, the reliability of a patient-reported outcome measurement questionnaire in terms of test-retest reliability and internal consistency reliability will be discussed in further detail.

Test-retest reliability measures response stability over time [125], when the same patient performs the same questionnaire on at least two occasions [124]. The correlation between the different measurements is then calculated as the intraclass correlation, ICC.

Internal consistency reliability refers to the degree of the interrelatedness among the items of an instrument [9], measuring the similarity of an individual's responses across several items [125]. It measures how well different questions measure the same thing, i.e. correlation between the questions. One measure of internal consistency is Cronbach's alpha [122].

Validity refers to the degree to which an instrument measures the construct(s) it purports to measure [9]. Validity is basically the relevance of the extent to which a test really measures what it is intended to measure [124]. For example, if an assessment instrument is designed to assess hand function, there will be a correlation between the score in the questionnaire and the difficulty performing hand-related tasks. There are several types of validity, such as content, criterion and construct validity [122]. In this thesis, only construct validity is discussed.

Construct validity reflects the ability of a questionnaire to measure the underlying concept of interest [124]. It is described as the degree to which the scores of an instrument are consistent with hypotheses (for instance with regard to internal relationships, relationships to scores of other instruments, or differences between relevant groups) [9]. One type of construct validity is convergent validity, which is related to a comparison with a different instrument that is assumed to be measuring the same thing [124].

1.5 THEORETICAL FRAMEWORK AND ASPECTS OF HEALTH

To explain, understand and explore the consequences and context after a DRF, frameworks and explanatory models are needed.

The International Classification of Functioning, Disability and Health (ICF) [1] is a classification developed by the World Health Organisation (WHO), intended for measuring health and disability at both individual and population levels. The ICF provides a common terminology and structure for the description of health and health conditions. The ICF classifies body function/structure, activity, participation and environmental and personal factors [1], and is regarded as a model that is applicable to describe the consequences of hand injuries [126]. In the ICF, the term "function" is defined as "the physiological functions of body systems", such as range of motion, pain and grip strength, while "structure" is defined as "anatomical parts of the body". The term "activity" is explained as "the execution of a task or action by an individual" and "participation" as "involvement in a life situation" [1]. The ICF definitions of function and activity are used in this thesis. The term "activity performance", which is also used in this thesis, is described in occupational therapy literature as "choosing, organising and carrying out activities in interaction with the environment" [2]. In this thesis, the term "activity performance" is used synonymously with the ability to perform activities.

A DRF can lead to consequences in every domain of the ICF, since the influence on body function and body structure, may result in difficulties in the other domains [127]. Different evaluation tools are associated with different parts of the ICF; for example, measurements of ROM and grip strength are related to body function/structure, while the PROMs, such as the PRWE and MHQ, are related to body function, performance of activities and participation [128].

As seen in the ICF, both internal and external aspects are necessary to explain activity, see Figure 10.

In relation to the explanatory model of the ICF, the biopsychosocial model of health contains a wide perspective of general health, by recognising the impact of personal and social factors. For example, the model views the interpretation of pain as an interaction between biological, psychological and social factors [129] and highlights the necessity to consider the three aspects in relation to each other. The model was introduced by George Engel in 1977 [129] with the purpose of complementing the traditional biological model of disease.

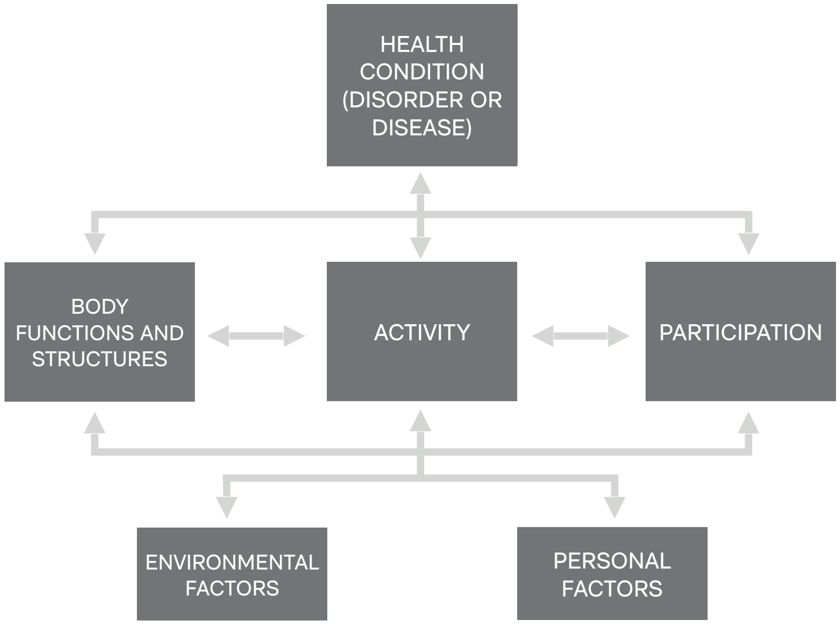

FIGURE 10. The ICF components and their interaction

Personal factors are highlighted in the concept of Sense of Coherence (SOC). The salutogenic theory of sense of coherence was introduced by Antonovsky [7, 123], focusing on factors influencing health rather than risk factors for disability. A high SOC could indicate that a person is able to maintain personal balance and health in spite of threats, stressful events or high environmental demands [7]. The SOC consists of three dimensions: comprehension, manageability and meaningfulness, reflecting the interaction between the individual and the environment [130]. Comprehensibility (cognitive dimension) refers to the extent the internal and external stimuli are perceived as understandable, coherent and clear. Manageability (behavioural dimension) is defined as the extent to which one feels that one's resources are sufficient to meet requirements. Meaningfulness (motivational dimension) refers to the extent of feeling emotional meaning in life [131]. It has been suggested that SOC can be used as an indicator of need for support, motivation and information and also in selecting treatment [132].

Hand in hand with both the biopsychosocial model and the sense of coherence theory, occupational therapy theory focuses on a holistic approach. In occupational therapy theory, the understanding of a person is achieved by understanding the dynamic interaction between the person, the activity and the environment [133]. To enhance the understanding of the physical aspects of human functioning, the biomechanical perspective is highly relevant when treating patients with hand injuries [134, 135]. The occupational therapy biomechanical model assumes that movements form the basis of human activity and that all meaningful activities are based on the ability to move the body [136, 137]. This model can be applied in the rehabilitation of patients whose activity limitations are due to problems in the musculoskeletal system and experience limitations in ROM, strength or endurance [136] and it fits well as a theoretical framework in the treatment of a DRF, complementing the definitions of function in the ICF. The goal is to focus the assessment and treatment on the possibility of motion in specific activities, by preventing deterioration, maintaining existing motion, regaining ROM and compensating for the loss of it [136, 137].

Motion-related principles, different types of interventions and meaningful activities should be used together to resolve the problems that each unique individual experiences. This is achieved by enabling the improvement or compensation of an individual's physical performance in terms of mobility, strength and endurance, with the goal of being able to perform activities in relation to self-care, work and leisure [137], but this must be preceded by a person-centred approach, where the patient is involved in goal formulation and the choice of intervention. The biomechanical model is intended to be used together with other models to see the patient in a wider context, complement the overall picture and thereby improve the end result [137-139]. The biomechanical model must be combined with a holistic, client-centred, activity-based approach [140].

A distal radius fracture is expected to affect a person's involvement in daily activities for a limited time and can therefore be described as an "occupational disruption", due to its characteristics of being temporary and hopefully transient. An occupational disruption is described as "a temporary state, characterised by a significant disruption of identity associated with changes in the quantity and/or quality of one's occupations subsequent to a significant life event, transition, or illness or injury. It has the potential to affect multiple areas of functioning, including social and emotional functioning" (4, 5). The patient and the therapist can together identify the affected activities, set goals to facilitate participation in activities and ensure that the environment facilitates everyday life for the patient and counteracts negative consequences in life.

The fear-avoidance model was introduced by Vlaeyen et al. in 1995 (141, 142) and it focuses on the way in which pain is interpreted by the person that experiences it (141). Depending on how the patient perceives pain, the interpretation leads to two different trails. If the pain is experienced as non-threatening, the patient is likely to confront the injury and the pain and maintain engagement in daily activities, which in turn leads to recovery. However, if the patient experiences the pain as threatening, it can lead to avoidance and pain-related fear, which may lead to a vicious circle (143). This vicious circle can lead to exacerbated fear, avoidance of movements and activities, disuse, distress and disability (141). The model can be used to understand the complexity of pain and also the important role of OT/PT in helping the patient to recovery and avoiding the vicious circle.

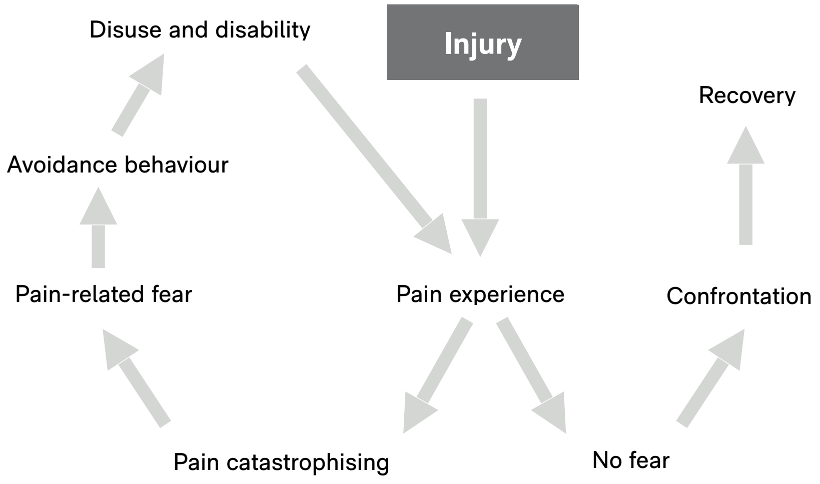

FIGURE 11. The fear-avoidance model by Vlaeyen et al. 1995. The pain experience leads to either no fear and recovery or pain catastrophising, disuse and disability

1.6 RATIONALE OF THE THESIS

There are previous studies that have investigated the outcome after a surgically treated DRF, but there are few studies describing patients' outcomes related to early intervention with a structured rehabilitation model.

Existing questionnaires translated to Swedish lack the aspect of patient satisfaction. As a result, there is a need for a PROM that not only measures and investigates a patient's perception and description of the function of their hand, the level of pain and activity performance but also takes patient satisfaction into consideration.

Most previous studies comparing a cast and a splint focus on thermoplastic splints, but studies investigating a prefabricated brace as an alternative to a cast are lacking. For this reason, there is a need for further research on using a prefabricated brace instead of a plaster cast after surgery related to patients' function and activity performance.

Research has shown that personal factors, such as sense of coherence, are important in the recovery after orthopaedic injuries, and further research is needed.

2

2 AIMS

The overall aim of the thesis was to investigate various factors related to outcomes and rehabilitation after surgically treated distal radius fractures.

The specific aims of the studies were as follows.

I. Assess pain, hand function, activity performance and apprehensiveness and their association, during the first three months after a surgically treated DRF

II. Translate and culturally adapt the MHQ to Swedish and to test the validity and reliability in patients with surgically treated DRFs

III. Evaluate and compare the outcomes in terms of patients' activity performance, pain and grip strength, between conventional immobilisation in a plaster cast compared with a prefabricated, stable wrist brace

IV. Evaluate patients' sense of coherence and its relationship to pain and activity performance in the early rehabilitation phase and ≥ 1 year after surgically treated DRF using three different anaesthesia methods.

3

3 METHODS

In Table 1, an overview of the study designs, participants and methods of the studies is presented.

TABLE 1. Overview of study design, participants and methods of data collection

	Study I	Study II	Study III	Study IV
Study design	Prospective cross-sectional study	Methodological study	Prospective, randomised, controlled study	Prospective, randomised, controlled study
Study population	n=88	n=40+78 (phase 1 + 2)	n=60 (30/30)	n=90 (30/30/30)
Gender, female	72%	81%	82%	87%
Age, years mean ± SD	55±16	61±14	60±10/52±16	57±15/62±13/60±10

3.1 ETHICS

All the studies were approved by the Regional Ethical Review Board in Gothenburg, Sweden (891-14 for Study I, 1157-16 for Study II and 214-18 for Study III-IV). All the studies were conducted in accordance with the Declaration of Helsinki. Ethical considerations are discussed in more detail in "Ethical considerations" section.

3.2 CONTEXT OF THE STUDIES

All the studies (I-IV) were conducted at the occupational therapy unit, where occupational therapists (OT) and physiotherapists (PT) both work on the rehabilitation of patients following DRF. Three days after surgery, the patients have their first appointment at the occupational therapy unit. The cast is usually removed at two weeks after surgery and, depending on status, the patient continues their rehabilitation on site or in primary care. An overview of the structured rehabilitation model used is presented in Figure 12.

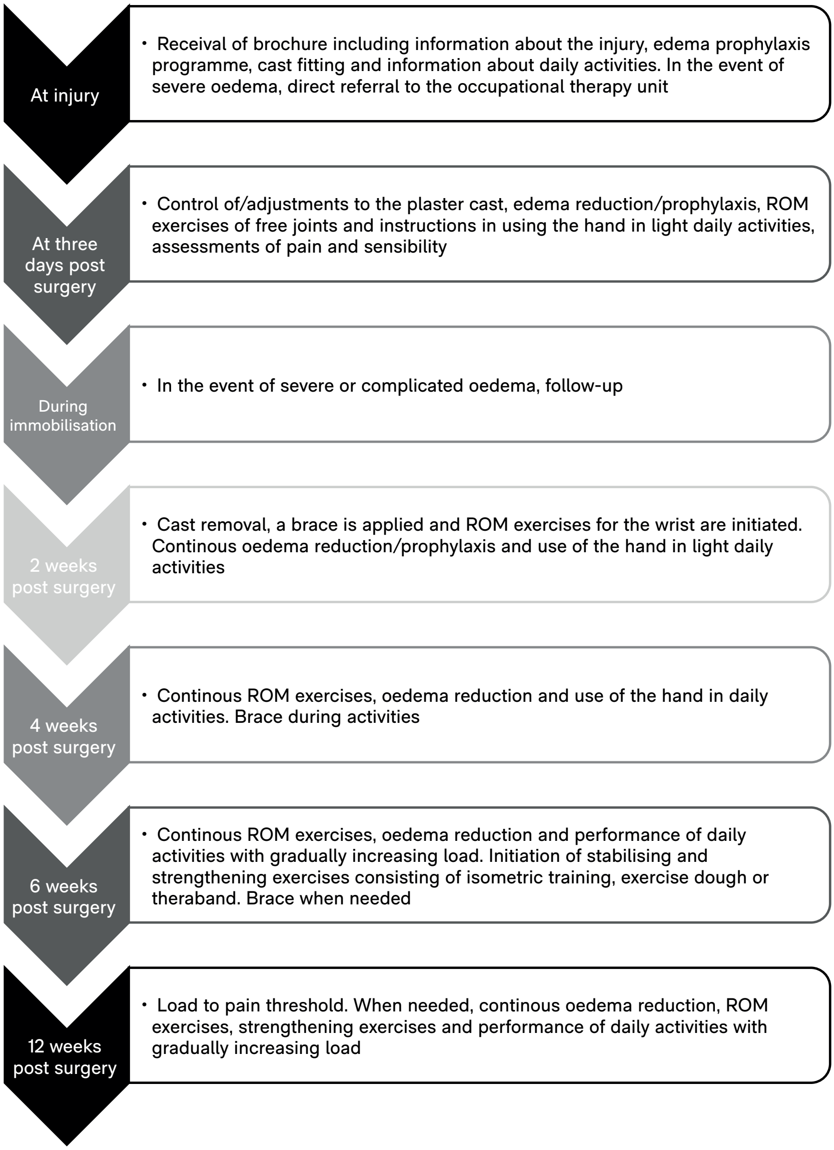

FIGURE 12. The structured rehabilitation model for patients with surgically treated distal radius fracture

3.3 OVERVIEW OF OUTCOME MEASUREMENTS

Table 2 gives an overview of the measurement methods in the four studies.

TABLE 2. Overview of measurement methods

	Study I	Study II	Study III	Study IV
Pain	X	X	X	X
Apprehensiveness	X			
Oedema	X			
Range of motion (ROM)	X			
PRWE	X	X	X	X
MHQ		X		X
Grip strength	X		X	
Sense of coherence (SOC)				X

Pain

Pain was measured using a numeric rating scale (NRS) [144], from 0 (no pain) to 10 (worst imaginable pain). The NRS is considered to be a reliable and valid tool for pain assessment in patients with musculoskeletal conditions [145]. The MCID of the NRS is 1.65 points [146]. Pain was also assessed using the pain subscale in the Patient Rated Wrist Evaluation (PRWE) [121, 147] and MHQ [122, 148].

Apprehensiveness

Apprehensiveness was assessed with a study-specific question (Study I) used in clinical practice "How apprehensive are you about using your injured hand in everyday activities?". Answers were given on a numeric scale from 0 (no apprehensiveness) to 10 (worst imaginable apprehensiveness). The question is not validated.

Oedema

Oedema (defined here as postoperative swelling) was assessed by measuring the circumference of the wrist, MCP and proximal phalanx of digit III bilaterally, with a tape measure, measured in millimetres [112]. The inter-rater reliability and intra-rater reliability of tape measurements of the MCP joints has proven to be excellent (ICC=0.98 and 0.99, respectively), while finger circumference is good to excellent (inter-rater: ICC=0.88–0.95; intra-rater: ICC=0.98–0.99) [112].

Range of motion (ROM)

ROM (dorsal extension, volar flexion, supination, pronation, radial and ulnar deviation) was measured bilaterally using a goniometer [149] according to Handkirurgiskt Kvalitetsregister (HAKIR) [150], except for wrist flexion and extension that were measured with the elbow on a stable surface and the goniometer on the radial aspect of the wrist, aligned with the third metacarpal [151]. Both the inter-rater and intra-rater reliability in goniometry measurements of the wrist are high and the accuracy has proven to be within 8° [152].

The Patient-Rated Wrist Evaluation (PRWE)

The Patient-Rated Wrist Evaluation (PRWE) is a 15-item questionnaire designed to measure wrist pain and disability in activities of daily living. The PRWE was developed in 1996 by Joy MacDermid [121, 153] and is a self-reported instrument including issues of pain and function, where function is divided into specific activities and general activities. The pain subscale consists of five questions about when and how often the patient experiences pain and the subscale on function consists of 10 questions about activities (six specific questions, and four general questions) about how to handle various everyday activities. Each question is answered on an 11-level scale, from 0 (no pain/no symptoms) to 10 (worst pain imaginable/impossible to do), where patients estimate their status. The scores from the five pain-related questions are added up to produce a maximum of 50 points. The scores from the 10 questions of function are also added, but they are divided by two, also adding up to a maximum of 50 points. In total, the score ranges from 0 to 100, where 0 is interpreted as no disability/pain and 100 as maximum disability/pain. A loss of response is replaced by the average of the patient's other answers in the current subscale [147]. Descriptors of severity for scores in the PRWE has been suggested for the total score as 0 = none, 1-20 = minimal, 21-40 = mild, 41-60 = moderate, 61-80 = severe and 81-100 = very severe disability, and for the pain subscale as 0 = none, 1-10 = minimal, 11-20 = mild, 21-30 moderate, 31-40 severe and 41-50 = very severe pain [99]. The Swedish version of the PRWE has shown good reliability and validity [147] and is regarded as one of the most suitable instruments for assessing outcome following a DRF [119, 154].

Michigan Hand Outcomes Questionnaire (MHQ)

The Michigan Hand Outcomes Questionnaire (MHQ) [122, 148] was developed in 1998 by Kevin C Chung, with the goal of creating an instrument which could be used to measure outcomes for patients with hand injuries [122]. The MHQ is a self-reported questionnaire consisting of 37 questions in six domains:

1. Overall hand function
2. Activities of daily living
3. Pain
4. Work performance
5. Aesthetics/appearance
6. Patient satisfaction with
hand function [122].

The item responses range from 1-5 and, apart from the "work performance" subscale, the subscales are administered separately for the right and left hand. The raw score for each subscale is the sum of the responses for each scale item, which is converted to a score ranging from 0 to 100. The total scores in the subscales range from 0 to 100, with a higher score indicating a better result, apart from pain, where high scores indicate more pain. Depending on which hand is affected, the right- or left-hand score on each subscale is selected to calculate the total score on the subscale. If both hands are affected, the right- and left-hand scores are averaged. A total score is calculated by adding up the total scores on the subscales after reversing the pain scale score and then dividing by six [(122)]. The questionnaire has shown good reliability, validity and responsiveness for clinical changes in patients with DRFs and other hand injuries [(122, 127, 148, 155)].

Grip strength
Grip strength was measured with a Jamar dynamometer according to HAKIR [(111, 150)]. The measurements were performed with the patient seated, with the shoulder adducted and neutrally rotated, the elbow flexed at 90° and the forearm and wrist in a neutral position [(111)]. Both hands were assessed three times each and the mean for each hand was calculated [(156)].

When grip strength is assessed using a standardised procedure, it has shown to be reliable and valid in both healthy subjects as well as in populations with musculoskeletal conditions [(157)]. Because of its reliability, validity and accuracy, the Jamar dynamometer is considered to be one of the best instruments for assessing grip strength [(158)]. The minimal clinically important difference (MCID) for grip strength with regard to DRFs treated surgically with a volar plate is 6.5 kg [(159)].

The measurements can be compared with the non-injured hand, or with normative values, correlated to age and gender [(111)]. Grip strength is often not symmetrical in right-handed people, as the right hand is approximately 10% stronger, although the differences diminish with age [(156, 160)]. However, this assertion is questioned and there is no consensus with regard to the difference. The hands are usually equally strong in left-handed people [(160)].

Sense of Coherence
Sense of coherence (SOC) was assessed using the Swedish version of Antonovsky's Sense of Coherence questionnaire, KASAM-13 [(107, 123, 161)]. The questionnaire is a 13-item scale, which measures the three aspects of SOC, i.e., the patients' comprehensibility, manageability and meaningfulness. Scores on each item range from 1 to 7, and the total score ranges between 13 and 91. A total score is calculated by adding the raw scores, after reversing some of the scores. A high score indicates a strong SOC [(123, 161)]. The questionnaire is considered to be valid and reliable in a general Swedish population [(162, 163)].

3.4 PARTICIPANTS

Study I
Patients with a DRF, treated surgically using a volar plate, participating in the visit on day three postoperatively to an occupational therapist (OT) or physiotherapist (PT) at the occupational therapy unit, a minimum age of 18 years and understanding Swedish in speech and writing were included. The exclusion criterion were other injuries/illnesses to the hand/arm/shoulder, which could affect the potential

for normal activity performance, and cognitive impairment.

During the study, one participant was excluded due to an EPL rupture and one due to a humeral fracture. Two participants declined further participation after the follow-up on day three and an additional 11 were lost between follow-ups for unknown reasons.

Study II

Phase 1: Patients with a DRF, surgically treated using a volar plate, age 18 years and over, who speak and understand Swedish in speech and writing were included. The exclusion criterion was any other injury/disease in hand/arm/shoulder that could affect activity performance or a cognitive impairment that affected the opportunity to participate. The patients were included anywhere in the rehabilitation process.

Phase 2: Patients with a DRF, surgically treated using a volar plate, age 18 years and over, who speak and understand Swedish in speech and writing, and participated in rehabilitation at the occupational therapy unit six weeks post-surgery were included. The exclusion criterion was any other injury/disease in the hand/arm/shoulder that could affect activity performance or a cognitive impairment that affected the opportunity to participate.

Studies III and IV

Patients ≥ 18 years, with a closed DRF assessed on radiographs and classified as AO 23 A-C1 (Orthopaedic Trauma Association), scheduled for surgical fixation with a volar plate, ≤17 days from trauma and and maximum length of surgery <90 minutes were included. The exclusion criterion were multiple fractures, inflammatory diseases, dementia, severe psychiatric disorder or other cognitive dysfunction, ongoing drug and alcohol abuse, known local anaesthetic allergy, pregnancy and no fluency in the Swedish language. Fracture classification was performed by an experienced orthopaedic surgeon.

The participants were included by a research nurse or anaesthesiologist at the Department of Anaesthesia and Intensive Care. The 120 participants were randomised, using a closed envelope system, to one of three groups of commonly accepted anaesthesia methods (groups 1, 2 and 3). The participants in group 3 were also randomised to one of two subgroups for a cast or a brace as postoperative immobilisation. In each group, 30 participants were included, except for group 3, where 60 participants were included, due to cast/brace randomisation, see the flow chart in Figure 13. Patients in groups 1 and 2 received a plaster cast postoperatively according to current routines. Studies III and IV share 30 patients, group 3a.

The patients received general anaesthesia or a supraclavicular blockade with a long-acting or short-acting local anaesthetic according to group affiliation.

1) **General anaesthesia.**

2) **Supraclavicular blockade with a long-acting local anaesthetic.**

3) **Supraclavicular blockade with a short-acting local anaesthetic.**
   a) Received a plaster cast postoperatively.
   b) Received a brace postoperatively.

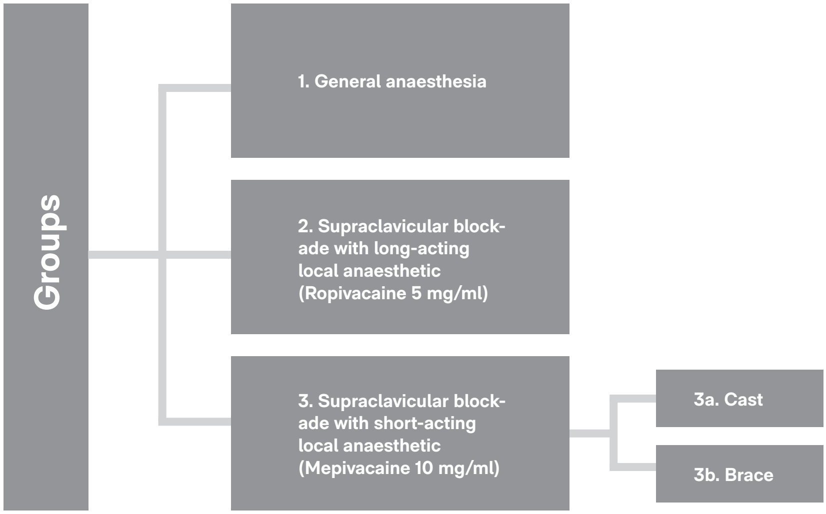

FIGURE 13. Schematic overview of the study groups in Studies III and IV

In Study III, one participant in the brace group was excluded, due to reoperation. At the last follow-up, two participants in the cast group and six in the brace group were lost for unknown reasons. Five participants (three in the cast group and two in the brace group) received additional GA due to failed supraclavicular block, but were still included in the study and in the analysis.

In Study IV, five participants (two in group 2 and three in group 3) were excluded due to failed blockade and therefore receiving GA. One patient in group 1 was excluded due to surgery time of > 90 min. An additional three participants were lost during the study period due to personal reasons (one in group 1 and two in group 2) and an additional six (one in group 1, three in group 2 and two in group 3) due to unknown reasons at the last follow-up.

3.5 STUDY DESIGN & PROCEDURE

Study I

Patients' pain, function and activity performance were evaluated by an occupational therapist or physiotherapist on four occasions (three days and two, six and 12 weeks after surgery). The patients were recruited consecutively, initially by a research nurse at the operating unit, but for practical reasons, after patient 67, all patients were asked about participation on their first visit to the occupational therapy unit.

TABLE 3. Overview of assessments in Study I

	Three days	Two weeks (cast removal)	Six weeks	12 weeks
Pain (NRS)	X			
Pain (PRWE)		X	X	X
Apprehensiveness	X	X	X	X
Oedema	X	X	X	X
ROM		X	X	X
Activity performance		X	X	X
Grip strength			X	X

Study II

The study was divided into two parts; firstly, the translation and the cross-cultural adaptation were performed and, secondly, the reliability and validity testing. A total of 118 patients (40 in phase 1 and 78 in phase 2) participated in the study.

Prior to study start, permission to use and translate the MHQ [122] was obtained from the developers (Academic licence #3372).

The translation and cross-cultural adaptation followed the guidelines published by Beaton et al. [164]. Two native Swedish-speaking, professional translators independently translated the instrument from English into Swedish. After that, the two translators together with two of the authors then synthesised the results of the two translations, which were then independently translated back to English by two other, native English-speaking, professional translators. To ensure intelligibility and consistency with the original version, the back translations were reviewed by two of the authors. A committee of experts then met to review all the versions to develop the preliminary version of the instrument.

The preliminary version of the instrument, MHQ-Swe, was tested in a clinical setting in 40 patients (Phase 1). The final version was completed and the process was presented to the developers of the questionnaire. The final version of the instrument was then tested for psychometric properties (Phase 2), see Figure 14.

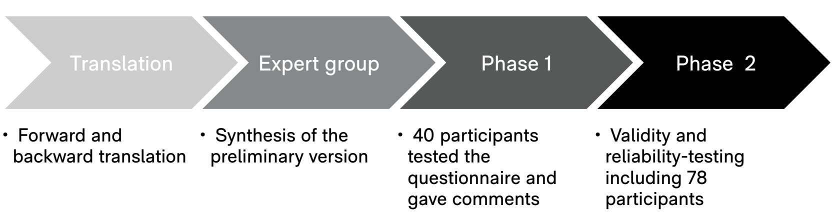

FIGURE 14. An overview of the translation process

The process of testing the psychometric properties of the MHQ

The test of reliability was performed through a test-retest, where 78 patients completed the MHQ-Swe twice, once at their six-week postoperative visit and once at home five to seven days after the visit. The last questionnaire was then sent back by mail. During the six-week postoperative visit, the patients also completed the PRWE and estimated their pain (NRS) in order to test the validity of the questionnaire.

Studies III and IV

The study is part of the "RADAR study", a collaborative project between the Department of Anaesthesia, the Department of Orthopaedics and the Department of Occupational Therapy and Physiotherapy at Sahlgrenska University Hospital/Mölndal.

Study III included patients from group 3 (supraclavicular blockade with short-acting local anaesthetic, receiving a cast (3a) or a brace (3b) as postoperative immobilisation). The brace used in the study was a stable, prefabricated brace with volar and dorsal aluminium rails (Wrist lacer, Camp Scandinavia AB).

The patients' pain (NRS), grip strength (Jamar) and activity performance (PRWE) were evaluated by an occupational therapist on five occasions (three days and two, six and 12 weeks and ≥ 1 year after surgery).

The assessment of grip strength measured at ≥ 1 year postoperatively had to be excluded due to the Corona pandemic.

Study IV included patients from groups 1, 2 and 3a (all patients received a plaster cast as postoperative immobilisation).

The patients' pain (NRS) and activity performance (PRWE and MHQ) were evaluated by an occupational therapist on five occasions (three days and two, six and 12 weeks and ≥ 1 year after surgery). Sense of coherence was assessed at two weeks after surgery.

TABLE 4. Overview of assessments in Study III

	Three days	Two weeks	Six weeks	12 weeks	≥ One year
Pain (NRS)	X	X	X	X	X
Grip strength (Jamar)			X	X	
Activity performance (PRWE)			X	X	X

TABLE 5. Overview of assessments in Study IV

	Three days	Two weeks	Six weeks	12 weeks	≥ One year
Pain (NRS)	X	X	X	X	X
Activity performance (PRWE and MHQ)			X	X	X
Sense of Coherence questionnaire		X			

3.6 STATISTICAL ANALYSIS

An overview of the statistical methods used in the different studies in the thesis is presented in Table 6.

TABLE 6. Overview of statistical methods used in the thesis.

Statistical methods	I	II	III	IV
Descriptive statistics	X	X	X	X
Paired T-test	X			
Intraclass correlation		X		
Cronbach's alpha		X		
ANOVA	X			
Wilcoxon's signed rank test	X		X	X
Kruskal-Wallis				X
Chi-2			X	X
Mann-Whitney U-test			X	
Spearman's rank correlation	X	X		X
Multivariate analysis/linear regression	X			X
Equivalence test (TOST)			X	

The analyses were performed with SPSS software (version 27 and 28).

When interpreting correlation strength, the limits r = 0 for no correlation, r = 0.1-0.3 for weak correlation, r = 0.4-0.6 for moderate correlation, r = 0.7-0.9 for strong correlation and r = 1 for perfect correlation were assumed [165].

In terms of Cronbach's alpha, a higher coefficient (range 0-1) indicates a more consistent scale. A threshold value of 0.80 was considered acceptable [166].

Test-retest was assessed using an intraclass correlation coefficient (ICC). The classification suggested by Cicchetti et al. [167] as poor (<0.40), fair (0.40-0.59), good (0.60-0.74), and excellent (0.75-1.00) was used [167].

4

4 RESULTS

In this section, the main results of the studies are highlighted. The results are reported in full, in the respective papers in the appendix.

4.1 STUDY I

In terms of pain measured with the PRWE, the patients estimated a significant decrease between two, six and 12 weeks ($p=0.001$). At six weeks, the mean score for pain was 15 points, indicating mild severity of pain, while at 12 weeks it was 10 points, indicating a minimal severity of pain.

Measurements of oedema, ROM and grip strength revealed significant improvements over time ($p=0.001$). There was also a significant reduction in ROM and grip strength in the injured compared with the non-injured hand during the entire study period. At 12 weeks, the study participants had regained almost 70% of their grip strength and 74-96% of the ROM of the non-injured hand. At the same time point, there was still a difference at the proximal phalanges and around the wrist between the injured and non-injured hands in terms of oedema.

Self-reported apprehensiveness was measured on a numeric rating scale (0-10) with a self-constructed question on apprehensiveness about using the hand in daily activities. During the study period, significant changes over time ($p<0.001$-<0.01) were seen. At day three after the surgery, 25% of the participants estimated their apprehensiveness at five or higher, a percentage that increased to 36% at cast removal. This decreased to 11% at six weeks and 3% at 12 weeks. Although, at 12 weeks, only 52% of the participants reported having no apprehensiveness about using their injured hand, indicating that this is still an issue three months after surgery.

Activity performance, as evaluated with PRWE, indicated a gradual improvement over time ($p<0.001$). At 12 weeks, the mean total score on the PRWE was 17 points, indicating a minimal severity of pain and disability.

In terms of correlations, the study revealed that apprehensiveness correlated moderately with activity performance on all visits ($r=0.40$-0.47, $p<0.01$), which indicates a covariation between the variables. In terms of regression analysis, the results showed, however, that the variances in the PRWE at 12 weeks cannot solely be explained by the differences in apprehensiveness or range of motion at cast removal.

The study also revealed that, in over 70% of participants, the plaster cast had to be adjusted, replaced with a new cast or to a brace, during immobilisation, due to a poorly fitting plaster cast.

4.2 STUDY II

The translation and cultural adaptation were conducted based on guidelines with translation by two professional, native Swedish-speaking translators summarised to produce a synthesis, and then back-translated by two other, professional native English-speaking translators. The back-translated version was carefully reviewed to ensure consistency with the original version. A group of experts (both clinicians and research experts) then met, discussed the different versions and created a preliminary version.

In phase 1, 40 participants were given the opportunity to complete the questionnaire and then give feedback on both content and wording. This led to small changes in the wording of some questions. The greatest difficulty in the cultural adaptation was encountered in the activities of "turn a doorknob" and "carry a grocery bag", as these activities are performed differently in the USA compared with Sweden. Moreover, the wording relating to work/everyday activity felt irrelevant for elderly patients and was adjusted. A final version of the questionnaire, MHQ-Swe, was developed.

The questionnaire was then tested in terms of psychometric properties. The reliability of the questionnaire was tested with internal consistency and test-retest. The internal consistency in the subscales of the MHQ-Swe was proven to be good, ranging from 0.77 to 0.94 at test 1 and from 0.81 to 0.96 at test 2 for all subscales. The lowest internal consistency was found in the hand function subscale and the highest in work performance. In terms of test-retest reliability, the ICCs ranged from 0.77 to 0.90 on all MHQ subscales, which is considered to be excellent. The highest results for the ICC were noted in the satisfaction subscale (ICC=0.90), while the lowest were noted in the aesthetic subscale (ICC=0.77). In terms of correlation, the study showed a moderate to high correlation for all the subscales between the MHQ-Swe, PRWE and VAS ($p<0.01$), indicating good validity of the questionnaire.

Taken together, in terms of the cross-cultural adaptation and translation process, no major linguistic or cultural issues were revealed, and the MHQ-Swe showed good validity and reliability in patients with a surgically treated DRF.

4.3 STUDY III

In both the cast group and the brace group, activity performance improved significantly during the study period ($p<0.05$), for the most part between six and 12 weeks. At six weeks, the total PRWE score in both groups was a median of 11 points, indicating minimal pain and disability, and, at the last follow-up, the median value was 3 in both groups, indicating a good overall outcome.

Pain measured with the NRS was 0 (median value) at six weeks in both groups and significant improvements were seen between two and six weeks in the brace group ($p<0.01$), and between six and 12 weeks in the cast group ($p<0.01$). In terms of grip strength, significant improvements were noted between six and 12 weeks in both groups ($p<0.001$). Grip strength in the injured hand was a median of 20 kg in both groups at 12 weeks.

In terms of comparisons between the groups, they were considered alike at baseline. There was a difference in age between the groups, where the brace group was younger, albeit not statistically significantly. The only observed difference between the groups, was that the time point for the last follow-up differed ($p<0.05$).

In terms of the differences in outcomes of pain, activity performance and grip strength, an analysis of equivalence between the cast group and the brace group indicated that the groups could be regarded as equivalent. The minimal clinically important difference (MCID) limits were outside the confidence range of differences ($p=0.04$-<0.001), which indicates that there were no significant differences in patients' activity performance, pain or grip strength in terms of using a cast or brace.

4.4 STUDY IV

The mean values for sense of coherence measured with the total score on the sense of coherence questionnaire revealed relatively high values compared with normal values which has been described as a mean of 61 in a Swedish population [163]. The three groups ranged between 75-78 points (mean values) (±10-13), and no differences were observed between the groups ($p=0.49$).

In terms of activity performance (PRWE and MHQ), a significant gradual improvement over time was seen in all the groups ($p<0.05$), even at the last follow-up ≥ 1 year postoperatively, indicating that outcomes continue to improve after 12 weeks. With regard to estimated pain (NRS), the study already indicated low levels of pain at six weeks, which also explains why there were no significant improvements in pain after 12 weeks.

There were no significant differences between the groups in terms of outcomes for pain (NRS) or activity performance (PRWE and MHQ) at any time point.

In terms of correlations of the group as a whole, weak, yet significant correlations were seen between sense of coherence and both pain (NRS) and activity performance (PRWE and MHQ) up to 12 weeks postoperatively ($p<0.05$). When analysing the groups separately, moderate, significant correlations were seen in groups 2 and 3 up to 12 weeks postoperatively but not in group 1. The strongest correlations between sense of coherence and pain were seen at three days and, in terms of activity performance, at six weeks.

The regression analysis indicated that variances in activity performance in terms of the PRWE and MHQ at 12 weeks can be explained to some extent by sense of coherence in combination with pain, at two weeks (22% and 13%, respectively, $p<0.01$). In terms of the potential to predict outcomes according to group affiliation with respect to anaesthesia method, the regression model indicated that this was not possible.

5

5 DISCUSSION

The overall aim of the thesis was to investigate various aspects related to outcomes and rehabilitation after a surgically treated DRF.

The specific aims were to assess patients' pain, hand function, activity performance and apprehensiveness over time (Study I), to expand the range of options of patient-reported outcome measurement questionnaires by translating and culturally adapting the MHQ to Swedish and to test the validity and reliability (Study II), to investigate and compare patient-reported outcomes between a plaster cast and a brace (Study III) and finally to evaluate patients' sense of coherence and its relationship to pain and activity performance in the early rehabilitation phase and ≥ 1 year using three different anaesthesia methods (Study IV).

5.1 DISCUSSION OF THE RESULTS

Improvements over time

Not surprisingly, the outcomes for pain, activity performance, ROM, grip strength and oedema improve gradually over time after surgery. Both Studies I, III and IV shows statistically significant changes over time in all outcome variables.

Perceived pain is an important aspect of outcomes, and pain early in the rehabilitation process is described as a predictor of chronic pain [(168)]. In the current studies, the estimated pain levels were relatively low. Measured with the PRWE, pain levels were already estimated as mild at cast removal, just like the NRS, where patients estimated their pain (0-10) as a median of between 1-2 points. At three months, the pain scores in Study I were estimated as mild, with a few exceptions, and, in Studies III and IV, the results were alike, with a median NRS score of 0 from the six-week follow-up and onwards, with a few outliers. Pain levels in the studies can be regarded as comparable or somewhat low compared with previous research [(50)].

The ideal range of motion in the wrist required to perform activities of daily living is described as 60° of dorsal extension and 54° of volar flexion. Moreover, 30° of ulnar deviation and 10° of radial deviation is satisfactory for most daily activities. Most activities can be performed with 70% of the maximum range of wrist motion, which can be converted to 40 degrees each of volar flexion and dorsal extension and 40 degrees of combined radial-ulnar deviation [(169)]. The results in Study I indicated that the ROM was reduced compared with the non-injured hand during the first three months after surgery. At 12 weeks, the patients had regained 74° (89%) in supination, 77° (96%) in pronation, 60° (88%) in dorsal extension, 52° (73%) in volar flexion, 18° (86%) in radial deviation and 26° (81%) in ulnar deviation. Previous research concluded that the ROM in the wrist 12 weeks after surgery was 74-79° in supination, 77-80° in pronation, 58-60° in dorsal extension, 52-59° in volar flexion, 18-19° in radial deviation and 30-32° in ulnar deviation (50, 101), remarkably like the results in Study I. With this in mind, the outcomes in Study I can be regarded as satisfactory and consistent with previous research.

Grip strength is important in terms of the ability to perform activities (100, 110). Already at 12 weeks, the participants in Study I had regained almost 70% of the strength in the non-injured hand. Grip strength in the injured hand in Study I was described as 15 kg at six weeks and 22 kg at 12 weeks (mean) and, in Study III, as 12/15 kg at six weeks and 20/20 kg at 12 weeks (median) in the cast and brace groups. This is consistent with previous research showing similar results at both six and 12 weeks, 15 and 22 kg respectively (50). Another study reported similar results for grip strength at six weeks and six months (13 kg and 23 kg respectively) (170). Grip strength at 12 weeks was still significantly lower than in the non-injured hand, indicating that grip strength in most patients is not restored at three months after surgery. The fact that grip strength is an important aspect, which has been shown not to be fully restored at 12 weeks, indicates that patients should continue stability and strengthening exercises even after three months of rehabilitation.

The results of both Study I, III and IV all indicate an improvement in activity performance in the first three months after surgery, but also that it continues to improve even after this. The results of the current studies correspond well with previous research which highlights the fact that outcome in the PRWE can improve even a long time after surgery (99, 100). The total score on the PRWE in the studies indicated mild disability at six weeks and minimal disability at 12 weeks and ≥ 1 year, with lower total scores than previous research at these timepoints (92, 99, 100, 171). The median and mean PRWE scores in a normal population are 0 (IQR 0-8.5) and 7.7 (±15) respectively (172). With this in mind, the results in the studies can be regarded as satisfying.

The MHQ in a Swedish setting

The hands and their function are complex and important for human beings, which makes a multifaceted evaluation questionnaire important. The MHQ is a well-known, widely used questionnaire, successfully translated and culturally adapted to many different languages, including Turkish, Korean, Portuguese, Farsi, German, Japanese, Korean and French (173-179). The purpose of the questionnaire is to measure outcomes in both research and clinical practice in patients with different hand disorders and it has been used in patient groups such as carpal tunnel syndrome, distal radius fracture, Dupuytrens contracture and rheumatoid arthritis (127, 155, 180-182).

In study II, the Swedish version of the MHQ was proven to be a relevant questionnaire with good validity and reliability in patients with surgically treated DRF. It has been shown to contain relevant and appropriate questions and the translation and cultural adaptation process revealed no major linguistic or cultural differences. The MHQ adds another dimension to the patient-reported outcome measurements used in rehabilitation, since it contains a subscale on patient satisfaction, which is missing in other common questionnaires, such as the PRWE (121). In clinical settings, the aspect of patient participation in rehabilitation as well as patient satisfaction with the outcomes is very important, and must be the ultimate goal of rehabilitation, and not whether the patient achieves 60 or 65° of volar flexion. In clinical experience, this perspective of paying attention to the patient being satisfied with outcomes is probably the most interesting aspect. Two patients with the same injury and exactly the same outcomes in ROM, for example, may experience completely different outcomes. The reason for this is unknown, but it is important to highlight and consider it. It perhaps depends on personal factors, on expectations, or on previous experiences. Regardless of which, it is important to evaluate, and the Swedish version of the MHQ provides an ample opportunity to do so.

The MHQ is a comprehensive questionnaire which, in addition to including aesthetics and patient satisfaction, also takes both hands into account. This is most often not necessary in DRF rehabilitation, making the questionnaire perhaps unnecessarily extensive for this patient group. As mentioned previously, the questionnaire is used in many different patient groups and it is perhaps even more suitable for chronic, bilateral diseases and conditions in which two-handed assessments come into play to a greater degree. Since the questionnaire is extensive, it also takes time to complete. The presence of the aesthetic subscale is an advantage when assessing patients with hand deformities or scarring due to injuries or disease, for example, but it might not be as applicable in the DRF patient group. A DRF is a hopefully transient injury, which in most cases does not cause any aesthetic complications except for a volar scar.

In addition, the MHQ scoring algorithm can be perceived as complicated. A few of the questions on the subscales, as well as an entire subscale (IV), have to be reversed to obtain a total score. The reversed questions in the aesthetic subscale were also perceived to be confusing by some of the participants in Study II, resulting in some misunderstandings and contradictory answers. The user friendliness would increase with a digitalised scoring algorithm, perhaps one for unilateral injuries and one for bilateral. With this in mind, there is also a requirement for a costly licence for clinical use, which can make the questionnaire most useful in research, where the licence is free.

Taken together, the MHQ-Swe is an appropriate and relevant questionnaire, with good validity and reliability, which can be used for patients with surgically treated DRFs. It can be used in both research and clinical settings and provides a further dimension of patient satisfaction, as well as raising awareness of patient participation. In spite of this, there are some issues in terms of the scoring algorithm, the length of the questionnaire, the reversed questions and the bilateral perspective, which must be considered when the questionnaire is used.

The impact of immobilisation methods

In Study I, it was concluded that, in over 70% of the patients, the plaster cast had to be adjusted or replaced on the visit on day three or during the immobilisation period. Over 70% is a large number, considering the importance of the plaster cast fitting. A non-optimal plaster cast can cause severe complications such as stiffness and oedema in the fingers, lead to nerve entrapments, Complex Regional Pain Syndrome (CRPS) and cause pressure ulcers (70, 71). From clinical experience, these complications can delay rehabilitation and, first and foremost, cause suffering to the patient. It is therefore extremely important that the plaster cast is properly fitted during the immobilisation period, and interventions on the plaster cast fitting must otherwise be made. If the plaster cast rubs, or if it is too tight or hinders finger exercises, it should be adjusted immediately (183). This is time consuming for patients and resource demanding for the units performing the adjustments and plaster cast replacements.

In Study III, we evaluated if a removable, prefabricated brace could be an alternative to the conventional plaster cast which is currently the clinical standard at our clinic. Even before the study, the plaster cast was sometimes replaced with a brace after a few days when the plaster cast did not work well, but the outcomes have not been investigated in any detail. Some argue that a plaster cast after a surgically treated DRF is unnecessary (50, 51), while some claim that a thermoplastic splint is a feasible option after surgery, since the type of immobilisation (a plaster cast or thermoplastic splint) does not have an impact on either the complication rate or functional or radiological outcomes (92).

However, at our clinic and many others, immobilisation after a surgically treated DRF traditionally still consists of a plaster cast, which also corresponds to the recommendations in the “National care program for treatment of distal radius fractures” in Sweden (184). From clinical experience, these patients need the support and stabilisation of the wrist after surgery, even if the plate fixation per se is stable. The patients are in pain and they are often also quite apprehensive about using the hand in activity. Using some kind of immobilisation, stability of the wrist is achieved, the pain will presumably be less and the patient feels safer about using the hand during activities. With the wrist stabilised, it is easier to perform finger flexion exercises, as well as using the hand in activity. Further, wound healing and associated soft tissue injuries can benefit from support/stability, in the first weeks after surgery. However, even if patients need immobilisation in one way or another after surgery, it may not always have to be a plaster cast.

The results in Study III showed that, in terms of the outcomes for activity performance, pain and grip strength, the use of a prefabricated brace is an equally good choice compared with a plaster cast as immobilisation after surgery. By using a brace, adjustments and replacements of the plaster cast is avoided, which would logically save both time and money since the extra interventions and visits are avoided, and, according to current clinical practice, all the patients receive a brace at two weeks anyway. It is possible to speculate that the option of using a prefabricated brace directly after surgery could save time in the surgical unit, since the application of a brace is much faster than manufacturing a plaster cast. The benefits of a removable brace are that it is perceived as comfortable and that it is possible to remove the brace for wound care, or for adjusting it due to increasing/decreasing oedema when needed.

However, even if nothing in our study indicated this, it must be remembered that there is a need for further research on and knowledge of which patients are more suitable to use a brace after surgery and whether there are patients that should not. In other words, a removable brace instead of a cast is perhaps not appropriate for everyone, due to its obvious ability to be removed. A decision to use a brace instead of a cast must be based on an individual approach, with several aspects, such as patient compliance, associated soft tissue injuries, fracture pattern and stability and osteoporosis, in mind, where the decision relating to the immobilisation method is made by the orthopaedic specialist.

Taken together, the use of a brace instead of a cast is regarded as a good choice for immobilisation, with the activity performance, pain and grip strength in mind. The goal must be to use a plaster cast when needed, while not overtreating those patients who would do well with a brace.

The impact of anaesthesia methods

The primary aim in Study IV was to investigate the impact of sense of coherence in a patient population, without respect to anaesthesia methods. However, the study was made on a patient material where patients received three different anaesthesia approaches and we therefore also investigated the impact of anaesthesia methods on pain and activity performance.

The study indicated that there were no differences between the three groups in terms of pain, the PRWE or MHQ at any time point in the study, nor could the group affiliation predict outcomes in the PRWE or MHQ according to the regression analysis, indicating that the anaesthesia method has limited impact on these outcomes after three days after surgery. A previous study of the same group of patients indicated that the patients who received GA had the highest pain (NRS) levels directly after surgery and the patients who received the supraclavicular block (SCB) with long-lasting local anaesthetic had the highest pain (NRS) levels at 24 hours postoperatively. The patients who received a SCB with long-lasting local anaesthesia estimated a higher level of pain and consumed more opioids than patients with the SCB with short-acting local anaesthesia the first 72 hours after surgery [185]. Previous research also reports that patients receiving GA experienced higher levels of pain early after surgery compared with patients receiving RA, but, after that, the opposite was true up to 48 hours [55, 56, 186]. Nor were there any differences in functional scores such as ROM, grip strength, PRWE or DASH in a longer perspective [55, 56, 186], which is consistent with the results in Study IV. On the other hand, it has been suggested that patients that received RA had lower pain scores, better ROM and DASH scores six months after surgery, although this study was non-randomised and the data were collected retrospectively [54].

Sense of coherence and pain measured at two weeks appeared to be a stronger predictor of the level of disability than the anaesthesia method, when it came to patient-reported outcomes at 12 weeks. The fact that there were no differences in the outcomes for pain or activity performance between the groups indicates that the anaesthesia method has limited influence both after three days and in a longer perspective in the rehabilitation. With this in mind, it is important to acknowledge other aspects in terms of patient-reported outcomes, and that the choice of anaesthesia method can be based on aspects other than the outcomes of activity performance and pain after three days after surgery.

Considerations on impact of personal factors

Both Studies I and IV investigated the impact of personal factors on outcomes and, in both studies, correlations were seen. In Study I, self-perceived apprehensiveness about using the injured hand in daily activities was correlated to activity performance in terms of the PRWE, while, in Study IV, the sense of coherence scale was correlated to pain (NRS), the PRWE and MHQ. The correlations indicate that, the higher the sense of coherence, the higher the level of activity performance and, the lower the level of perceived pain. Although there was a correlation between both apprehensiveness and sense of coherence and the outcomes in terms of activity performance, they can only explain a small degree of the variations in activity performance. Sense of coherence and pain together were able to explain 22% of the variances in the PRWE at 12 weeks, indicating that the outcomes after DRF are multifaceted and is influenced by several different aspects.

During my clinical years, I have helped hundreds of patients to remove the cast and start rehabilitation and many of them have expressed doubts and hesitation about using their hand in daily activities. The fact that the patients in Study I experienced a higher degree of apprehensiveness at the time of the plaster cast removal than at the previous follow-up supports this and highlights the importance of support at this time point. In my clinical experience, the importance of information, feeling safe and receiving support and commitment from the therapist is huge. This is also confirmed in research where it has been concluded that early information on the injury and the rehabilitation is important for patients to feel safe and that they are participating and to motivate the patients to perform ROM exercises [64]. This is where the fear-avoidance model comes in. If the patient is provided with instructions on ADL, information and empowerment at an early stage, the interventions can help the patients avoid ending up in a vicious circle of avoidance of activities, disuse and disability and instead help the patient prevent the pain catastrophising and instead focus on recovery. The structured rehabilitation model used in the studies, where the patients receive their first post-surgery follow-up as early as three days after surgery is believed to work well. For many years, this model has focused on an early, patient-centred care. This follow-up, which in addition to being used to assess the cast and oedema and to implement exercise programmes, for example, also allows patients to ask questions and share thoughts and experiences. The patients already receive information on this early follow-up at the post-anaesthesia care unit, which hopefully contributes to them feeling that they are being well taken care of. In addition to this, the structured rehabilitation model is also built on a close team collaboration between many professional categories, such as occupational therapist, physiotherapist, orthopaedic surgeon, nurse and counsellor.

SOC is considered to be stable, but an occasional change in life might temporarily change it [187]. In terms of patients with fractures, it has been described that SOC-scores changed after the injury, highlighting the importance of therapists supporting the patients personal resources [188]. A recent study suggested that it can be strengthened with empowerment and reflection processes [189]. Due to the fact that SOC might be strengthened with empowerment, one can speculate that the structured rehabilitation model may have an impact on SOC, but this remains to be further investigated.

It has previously been suggested that SOC scores should be included in the assessment of patients with a DRF [171], and this statement is supported by the results in the current thesis. The results of the studies indicate that both a fast, easily performed evaluation of apprehensiveness and measurements of sense of coherence are important factors in understanding of a patient's recovery after surgery. The results emphasise the importance of considering personal factors and coping strategies in the recovery process after a fracture. It is possible to speculate that the introduction of an SOC questionnaire early in the rehabilitation phase could contribute to more patient-centred care and facilitate the identification of patients who need extra support. It has previously been stated that patients with a low sense of coherence are in need of more support in rehabilitation [108] and it is possible to speculate that identifying the patients who need extra support at an early stage could both facilitate the rehabilitation and possibly reduce long-term complications. The SOC questionnaire could perhaps be implemented at the follow-up three days after surgery. With such a questionnaire included in the clinical evaluations, the rehabilitation could become more patient centred and multifaceted, raising awareness of personal factors and coping strategies in relation to outcomes.

5.2 METHODOLOGICAL CONSIDERATIONS

When conducting research, several different methods of investigating and evaluating outcomes are used. In this thesis, measurements of pain, oedema, ROM, grip strength, sense of coherence, apprehensiveness and patient-reported outcome measurements are used. It is valuable that the instruments are valid and reliable and also that the measurements are made with accuracy and consistency.

Considering the chosen follow-up time points in the studies, it is possible to speculate that, in Study I, for example, it would have been of interest to follow the patients up to six months instead of three, to obtain a deeper understanding on how outcomes continue to improve over time. This would also have been of value in Studies III and IV, since the time between follow-ups 4 and 5 was long and it would have been interesting to investigate how patients' status changed even during this period of time. With another follow-up at six months, it would have been possible to increase our knowledge of when improvements occur. The last follow-up in the RADAR study (Studies III and IV) was planned to take place one year after injury, but it was unfortunately delayed due to the

Corona pandemic. The variation in time so long after surgery is, however, not thought to be clinically relevant or to affect the participants' perception of their outcomes at that time point.

Sense of coherence was investigated with a SOC questionnaire at one time point. It might have been interesting to measure it at one more time point, for example at the follow-up three days after surgery. It might also have been of value in carrying out in-depth interviews with the participants, in order to obtain a deeper and wider understanding of the concept and how it can affect the patient's outcomes.

In Study I, several OTs and PTs were involved in the data collection. In Studies II, III and IV, only OTs were involved, even if there were several different ones. In studies in general, it is mostly desirable to limit the number of therapists involved in the data collection, due to the fact that it is important that the measurements are made in the same way to ensure a high reliability. The fact that several occupational therapists were involved in the data collection in all the studies could be interpreted as both a limitation and a strength. In clinical work, different occupational therapists treat patients and this therefore reflects clinical settings. All the therapists followed the same protocol and were well informed about data collection before the projects started. The measurements of grip strength, oedema and ROM, for example, are standardised and all OTs perform them according to predefined guidelines. When using standardised guidelines, both inter-rater and intra-rater reliability in grip strength, oedema and ROM have been shown to be high [103, 112, 152, 190].

To capture the patients' perspective, PROMs are being increasingly used to measure outcomes. The PRWE is regarded as one of the most valid questionnaires when evaluating patient-reported outcomes after a DRF. However, the difficulty with the PRWE is calculating the total score – since measurements of pain and function (specific and general activities) are added up to produce a joint sum, two patients can have the same total score, but one experiences a high level of pain and the other high levels of disability in daily activities or the opposite. It may therefore also be an advantage to analyse and discuss the subscales in the questionnaire separately. As described previously, the MHQ raised a few issues on the user friendliness, which must be considered when using it. Also, in both questionnaires, the issue of calculating a mean score for ordinal data must be kept in mind. There are also some other issues in existing PROMs used in measuring outcomes after hand injury. The questions do not evaluate the patients' ability to perform daily activities before injury and the questions are predefined and some of them can be perceived as irrelevant to the patient. Also, patients tend to use compensatory strategies after an injury which the questionnaires do not evaluate. All of the above could potentially influence the outcome measurement.

When choosing a design for a study, one must be aware of the different characteristics of the designs, as well as their pros and cons. Study I was a cross-sectional study without a control group, with the aim of describing the normal course after surgery and describing the structured rehabilitation model in the patient group. The design chosen was a good fit given the aims of the study. The design of a cross-sectional study is observational and provides information about the particular patient group without adding any intervention. In relation to this, randomised controlled studies, like Studies III and IV, aim to compare groups and investigate different interventions. An RCT was therefore well suited in relation to the aims in Studies III and IV. An RCT limits the risk of confounding factors, as patients are randomly allocated to an intervention.

5.3 ETHICAL CONSIDERATIONS

In terms of internal ethics, the studies included in this thesis were prospectively registered at FoU i VGR and Studies III and IV were also registered at Clinical Trials. The registered information was followed in the execution of the studies.

Personal data were processed in accordance with the Personal Data Act [(1998: 204)]. All the results have been reported at group level so no individuals can be identified in the completed studies. Patients were covered by customary patient insurance and no compensation was paid for participation in the studies. The collected data have been stored according to regulations at Sahlgrenska University Hospital.

With respect to individual autonomy, participants in studies require sufficient information to make an informed decision on participating. Before inclusion, all the patients (Studies I-IV) were therefore informed both orally and in writing. The patient information contained information about the overall plan and purpose of the studies, the risks and benefits, data handling and privacy. The patients also received information on the fact that participation was voluntary and that they could end participation at any time without having to state why and without this affecting their continued treatment and rehabilitation. Participants were also informed about who was responsible for the research. All the participants signed an informed consent form when they chose to participate.

The studies were not considered to contain any major ethical considerations, except that it took a little extra time to complete the questionnaires for patients on the follow-ups.

The questions in the PRWE and MHQ questionnaires were not considered to be of a sensitive nature. The SOC questionnaire contained questions which could be interpreted as being of a sensitive nature. However, the questionnaire had been tested previously and the questionnaires were completed and submitted anonymously.

In Study III, the patients received a cast or a brace after surgery. Even before the study, some patients received a brace for postoperative immobilisation. All the patients received a brace after the plaster cast was removed at the visit two weeks postoperatively. This did not change during the study.

5.4 STRENGTHS AND LIMITATIONS

In Study I, a non-validated question on apprehensiveness was used and this can be regarded as a limitation, even though the question was self-constructed for the study, with the aim of investigating whether this simple question/aspect could be used to predict outcome. It is possible to argue that the question was not validated or tested, but on the other hand, the purpose was precisely to test this simple question and its correlation to outcomes.

In Study II, we asked patients to complete a questionnaire on their opinions of the contents and language in the translated questionnaire (MHQ). It is possible to speculate that we would have received more complete and detailed answers if we had conducted interviews instead. Moreover, we did not ask questions about time consumption and perceived relevance to the current injury, something that would also have given a deeper understanding of the patients' views of the questionnaire.

The data in Studies III and IV comes from an RCT study, which is a major strength and limits the risk of confounding factors. However, the immobilisation methods were not blinded to the occupational therapists who treated the patients, which may have affected the results. Even so, it is not possible for the occupational therapists to be blinded to the immobilisation method during the immobilisation.

In Study III, we unfortunately did not investigate patient satisfaction or discomfort with the different immobilisation methods. Further, we were unable to investigate patient compliance with the immobilisation method. Both would have been of great value and might have provided a deeper knowledge of patient participation in treatment choices. It is possible to speculate that a brace is more comfortable.

Studies III and IV are sub-studies of a larger study and the sample size calculation was made for the main study. The studies might be slightly underpowered, but there were no trends in the data to imply that the results would have been different if the groups had been larger.

Unfortunately, the RADAR study (Studies III and IV) was conducted during the Corona pandemic. The pandemic affected not only the time frame of the final follow-up, but also how it was conducted. The idea was that even the last follow-up in the RADAR study would take place at the occupational therapy unit, but, due to decisions by the hospital management to pause all research both because all the staff were needed in clinical work and because healthy people were not admitted to the hospital, the last follow-up was converted into a follow-up by mail. Taken together, we chose to continue with what we could, to be able to finish the study, out of respect for the participants.

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6 CONCLUSIONS

- In terms of activity performance, patients improve over time during the first three months (Studies I, II, IV), but they continue to improve also after three months after surgery (Studies III and IV).

- The translated and culturally adapted MHQ-Swe is an appropriate and relevant PROM questionnaire, with good validity and reliability, which can be used for patients with a surgically treated DRF (Study II).

- A prefabricated brace instead of a cast is a feasible method of immobilisation after a surgically treated DRF, in terms of the outcomes for pain, activity performance and grip strength (Study III).

- Personal factors, both apprehensiveness (Study I) and sense of coherence (Study IV), correlates with patient-reported outcome measurements, which supports the importance of considering personal factors in the recovery process after a fracture.

- The anaesthesia method seems to have limited influence on outcomes in terms of pain and activity performance both after three days and in a longer perspective in the rehabilitation (Study IV).

7

7 FUTURE PERSPECTIVES

When working in clinical settings and when conducting research, several new research questions become relevant.

It would be of interest to carry out in-depth interviews with patients on the concept of sense of coherence, in order to obtain a deeper and wider understanding of the concept and how it can affect the patient's outcomes. Related to personal factors such as sense of coherence, the patients' compliance/coherence with exercises is a also field where further knowledge and a deeper understanding are needed.

The question of early mobilisation and its relationship with associated soft tissue/ligament injuries is another aspect requiring further studies.

In terms of a brace or a cast, it would be of interest to conduct a qualitative study comparing patient experiences of different immobilisation methods. Moreover, further investigating the cost effectiveness of using a brace instead of a plaster cast would be of great value.

It would also be interesting to further explore the concept of more occupational- and activity-based interventions in rehabilitation, such as more research into the way activities of daily living can be further implemented as a natural part of the rehabilitation.

In terms of the MHQ, it would be interesting to investigate the applicability of the translated questionnaires in other patient groups, such as patients with rheumatic arthritis.

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