Wrist osteoarthritis - Impact on daily life, self-management and outcome

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TRANSLATIONAL MEDICINE | FACULTY OF MEDICINE | LUND UNIVERSITY

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This thesis focuses on increasing the knowledge of wrist osteoarthritis from various viewpoints, with the patient's ability to function in focus, from acquiring a deeper understanding of patients' experiences of living with a painful wrist to evaluating a novel self-managed neuromuscular joint-protective exercise therapy program. Greater attention and increasing knowledge of wrist osteoarthritis – about its effects on the individual, motion-preserving contra motion-sacrificing surgery, the possible benefit of a self-management program, and the use of psychometrically valid outcome measures – could lead to improved future treatment strategies that can benefit both the patient and the healthcare system.

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DOCTORAL DISSERTATION

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Wrist osteoarthritis
Impact on daily life, self-management and outcome

Abstract

For individuals with symptomatic wrist osteoarthritis (OA), pain is the central problem negatively affecting all aspects of life. Despite the recommendations that all OA patients should be offered self-management treatment options, this approach is often lacking for patients with wrist OA. In addition, there has been surprisingly little interest shown in investigating wrist OA patients' wishes and thoughts regarding their care.

This thesis comprises four studies with the overall aim of investigating and increasing knowledge of wrist OA from various perspectives, with patients' functionality in focus. In Paper I, 13 individuals with advanced wrist OA, surgically treated with either total wrist fusion (TWF) or total wrist arthroplasty (TWA), were interviewed about their experiences of living with advanced wrist OA before and after surgery. Data were analyzed by qualitative content analysis. In Paper II, the Numerical Pain Rating Scale (NPRS/NRS), the Disabilities of the Arm, Shoulder and Hand (DASH) and the Patient-Rated Wrist Evaluation (PRWE) questionnaires were evaluated in 50 participants with wrist OA regarding test-retest reliability and construct validity. In Papers III and IV, 48 patients with wrist OA were randomized to a 12-week self-management program with either a neuromuscular joint-protective exercise therapy program (intervention group) or a placebo training program with range of motion (ROM) exercises only (control group). Primary outcome was pain and function assessed at 12 weeks with PRWE.

The results showed that the painful osteoarthritic wrist had a negative impact on the participants whole lives. Pain relief was the main expectation and successful coping strategies were developed enabling the participants to adapt to challenges in daily life (Paper I). The NRS, DASH and PRWE demonstrated excellent test–retest reliability and moderate to high construct validity in patients with wrist OA (Paper II). After a 12-week self-management program including education and exercises, there was no significant between-group difference for the primary outcome PRWE. Overall, at 12 weeks, the neuromuscular joint-protective exercise therapy program was no better at reducing pain and improving function than the placebo ROM training program (Papers III and IV).

In conclusion, this thesis provides an enhanced understanding of how patients' reason regarding their surgical choices between a motion-preserving (TWA) as opposed to a motion-sacrificing procedure (TWF) and how they cope with life after TWF or TWA. In addition, this thesis shows that pain and function in wrist OA can be measured reliably using NRS, DASH and PRWE. The thesis also acknowledges the lack of research within the area of exercise therapy in wrist OA and makes, to my knowledge, a first attempt to incorporate wrist OA in a first-line exercise therapy treatment approach.

Key words Wrist osteoarthritis, impact on daily life, total wrist fusion, total wrist arthroplasty, patient-reported outcome measures, self-management, exercise therapy, neuromuscular control

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To my family, patients and colleagues

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List of Papers

Paper I

Larsson S, Carlsson IK, Rosberg HE, Björkman A, Brogren E. Patients' experiences before and after total wrist fusion or total wrist arthroplasty: A qualitative study of patients with wrist osteoarthritis. Journal of Hand Therapy. 2022;35(1):41-50. Epub 2020 Oct 24. doi: 10.1016/j.jht.2020.10.004.

Paper II

Larsson SL, Brogren E, Dahlin LB, Bjorkman A, Ekstrand E. Psychometric properties of patient-reported outcomes (PROMs) in wrist osteoarthritis. Test-retest reliability and construct validity. BMC Musculoskeletal Disorders. 2022; 23(1):558. doi: 10.1186/s12891-022-05511-6.

Paper III

Larsson SL, Ekstrand E, Dahlin LB, Bjorkman A, Brogren E. A self-managed exercise therapy program for wrist osteoarthritis: study protocol for a randomized controlled trial. Trials. 2023; 24(1):628. doi: 10.1186/s13063-023-07668-4.

Paper IV

Larsson SL, Ekstrand E, Dahlin LB, Bjorkman A, Brogren E. Effects of a neuromuscular joint-protective exercise therapy program for treatment of wrist osteoarthritis: a randomized controlled trial. In manuscript.

Thesis at a glance

Paper I. Patients' experiences before and after total wrist fusion or total wrist arthroplasty: A qualitative study of patients with wrist osteoarthritis.

Introduction: Total wrist fusion (TWF) is the standard surgical treatment for patients with advanced wrist osteoarthritis (OA). Total wrist arthroplasty (TWA) is a plausible motion-preserving alternative but carries a higher risk of late complications. This study aimed to explore patients' experiences of living with advanced wrist OA before and after surgery with either TWF or TWA, as well as their expectations of surgery, appraisal of results and coping strategies.

Methods: Thirteen participants with advanced wrist OA who had been surgically treated with TWF or TWA participated in this study. Semi-structured interviews were conducted and analysed using qualitative content analysis.

Results: The results were presented in four categories: 1) the problematic wrist; 2) the breakpoint; 3) appraisal of the results; and 4) adaptation to challenges in everyday life. Pain relief was the main expectation and involvement in the discussion regarding different surgical options had a positive effect on the appraisal of the results. Successful coping strategies were developed enabling the participants to become more independent and adapt to challenges in daily life.

Conclusion: The participants' individual expectations, previous surgical experiences, preoperative range of wrist motion, readiness to accept the risk of additional surgery, personality, life situation and occupation, influenced the surgical choice of either TWF or TWA. The participants' ability to perform common tasks appeared to relate more to their level of pain than the range of wrist motion.

Overview of the categories and sub-categories

Categories	Sub-categories
The problematic wrist	Living with pain. Impact on activity and participation. Dependency on others.
The breakpoint	Decision to undergo surgery. Involvement in the decision to undergo surgery. Expectations of surgery.
Appraisal of the results	Pain. Stiffness versus motion. Impact on activity and participation.
Adaptation to challenges in everyday life	Compensatory movement patterns. Adjustments to everyday domestic life. Seeking assistance. Change of occupation and work tasks. Positive thinking and acceptance.

Paper II. Psychometric properties of patient-reported outcome measures (PROMs) in wrist osteoarthritis: test-retest reliability and construct validity.

Introduction: Patient-reported outcome measures (PROMs) are frequently used to assess the effects of treatments in patients with wrist osteoarthritis (OA), but their psychometric properties have not been evaluated in this group of patients. This study aimed to evaluate the psychometric properties of the Numeric Rating Scale (NRS pain at rest, pain on motion without load and pain on load), the Disabilities of the Arm, Shoulder and Hand (DASH) and the Patient Rated Wrist Evaluation (PRWE) questionnaires in patients with wrist OA regarding test-retest reliability and construct validity.

Methods: The NRS, DASH and PRWE were self-administered by 50 patients in a postal survey on two occasions, two weeks apart. Test-retest reliability was evaluated by Kappa statistics and the Spearman rank correlation coefficients (rho) were calculated to evaluate construct validity.

Results: The Kappa coefficients for DASH, PRWE, NRS pain on motion without load and NRS pain on load were >0.90, while NRS pain at rest was 0.83. A strong correlation was found between PRWE and DASH (rho 0.86). There was a closer correlation between PRWE and NRS (rho 0.80-0.91) than between DASH and NRS (rho 0.68-0.80). The NRS pain on motion and NRS pain on load correlated more strongly to both PRWE and DASH (rho 0.71-0.91) compared to NRS pain at rest (rho 0.68-0.80).

Conclusion: The NRS, DASH and PRWE demonstrate excellent test-retest reliability and moderate to high construct validity in patients with wrist OA. PRWE showed the highest test-retest reliability and the strongest relation to the other PROMs. Thus, the use of PRWE alone can be recommended in clinical practice.

Paper III: A self-managed exercise therapy program for wrist osteoarthritis: study protocol for a randomized controlled trial.

Introduction: Although there is strong evidence that all patients with OA should be offered adequate education and exercises as a first-line treatment, an effective self-management program, including structured education and therapeutic exercises, has not yet been introduced for individuals with wrist OA. The aim of this study protocol was to describe a randomized controlled trial (RCT) that will evaluate the effectiveness of a neuromuscular exercise therapy program with joint-protective strategies (intervention group) compared to a placebo training program with range of motion (ROM) exercises (control group).

Methods: The study protocol describes a single-blinded superiority RCT with two treatment arms. The two different treatments, that 48 individuals with radiographically confirmed and symptomatic wrist OA were randomised to, were either a neuromuscular joint-protective exercise therapy program (intervention group) or a training program with ROM exercises only (control group). The Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT) checklist was used when the study protocol was conducted.

Conclusion: The upcoming results from this trial may add new knowledge concerning the effectiveness of a self-managed exercise therapy program on pain and function for individuals with wrist OA. If this self-management program proves to be effective, it can redefine current treatment strategies and may be implemented in wrist OA treatment protocols.

Paper IV: Effects of a neuromuscular joint-protective exercise therapy program for treatment of wrist osteoarthritis: a randomized controlled trial.

Introduction: No previous studies have evaluated the effect of a self-managed exercise therapy program on patients with wrist OA. Therefore, this trial aimed to investigate the effectiveness of a self-managed neuromuscular joint-protective exercise therapy program compared to a placebo training program with range of motion (ROM) exercises in patients with wrist OA.

Methods: In a randomized controlled single-blinded superiority trial, 48 patients with wrist OA were randomly allocated to a 12-week self-management program using either a neuromuscular joint-protective exercise therapy program (intervention group) or a training program with ROM exercises only (control group). The primary outcome was the Patient Rated Wrist Evaluation (PRWE). Secondary outcome measures were grip strength, range of wrist motion, the Numerical Pain Rating Scale (NPRS), the Disabilities of the Arm, Shoulder and Hand (DASH) and the Generalized Self-Efficacy Scale (GSES). The outcome measures were assessed at baseline and 12 weeks. Between-group differences were analyzed using the Mann-Whitney U test.

Results: A total of 41 participants were analyzed at 12 weeks, revealing no significant differences in PRWE between the groups. For the intervention group, there was a significant between-group difference for DASH (p=0.02) and a significant and clinically meaningful within-group difference for NPRS on load (p=0.006). The difference in DASH should be interpreted with caution since it could be due to a non-significant increase (worsening) from baseline in the control group in combination with a non-significant decrease (improvement) in the intervention group.

Conclusion: A novel neuromuscular joint-protective exercise therapy program was no better at reducing pain and improving function, at 12 weeks, than a placebo training program with ROM exercises.

Between group comparison of the primary outcome PRWE at 12 weeks

Outcome measure	Intervention group (n=21)	Control group (n=20)	p-value
PRWE			
Pain	27 [13–34]	28 [21–36]	0.82
Function	16 [5–28]	25 [19–33]	0.13
Total	46 [16–63]	52 [41–68]	0.27

Definitions

Exercise therapy describes a regimen of physical activities designed and prescribed for specific therapeutic goals. Its purpose is to correct impairments, improve or restore musculoskeletal function, or reduce pain caused by diseases or injuries (1).

Joint protection comprises a set of strategies and techniques, such as the use of proper joint and body mechanics, using assistive devices and modifying activities and routines, designed to reduce stress and strain on joints affected by conditions, such as osteoarthritis, injury, or chronic pain (2).

Neuromuscular exercises are based on biomechanical principles and target the sensorimotor system with the aim of obtaining functional joint stabilization. The objectives for improvement are postural control, proprioception, muscle activation, muscle strength and coordination (3).

Patient education signifies the process of providing individuals with information and resources to help them understand and manage their health conditions effectively. It is also a crucial aspect of healthcare that empowers patients to make informed decisions about their health and to actively participate in their own care (4).

Psychometric properties refer to the evaluation of the methodological quality of an outcome measure. This involves assessing whether the outcome actually measures what it is intended to measure (validity) and that it is stable over time (reliability) (5).

Self-efficacy is described as an individual's belief in their capacity to act in ways necessary to achieve specific goals (6).

Self-management is defined as “the intrinsically controlled ability of an active, responsible, informed and autonomous individual to live with the medical, role and emotional consequences of their chronic condition(s) in partnership with their social network and the healthcare provider(s)” (7).

The sensorimotor system refers to the complex network of sensory and motor neurons, as well as the processes and structures in the brain and spinal cord, that are responsible for processing sensory information, coordinating motor responses and maintaining functional joint stability (8).

Abbreviations

ADL	Activities of Daily Living
CI	Confidence Interval
CMC	Carpometacarpal
CONSORT	Consolidated Standards of Reporting Trials
COSMIN	COnsensus-based Standards for the selection of health Measurement INstruments
CT	Computerized Tomography
DASH	Disabilities of the Arm, Shoulder and Hand
DRUJ	Distal Radioulnar Joint
ECRB	Extensor Carpi Radialis Brevis
ECRL	Extensor Carpi Radialis Longus
ECU	Extensor Carpi Ulnaris
EULAR	European League Against Rheumatism
FCR	Flexor Carpi Radialis
FCU	Flexor Carpi Ulnaris
GROC	Global Rating of Change
GSES	Generalized Self-Efficacy Scale
ICF	International Classification of Functioning, Disability, and Health
IQR	Interquartile Range
JPS	Joint Position Sense
NPRS/NRS	Numeric Pain Rating Scale/Numerical Rating Scale
OA	Osteoarthritis
OARSI	Osteoarthritis Research Society International
PRC	Proximal Row Carpectomy
PROM	Patient-Reported Outcome Measure
PRWE	Patient-Rated Wrist Evaluation
PT	Physiotherapist

RCT	Randomized Controlled Trial
ROM	Range of Motion
SD	Standard Deviation
SL	Scapholunate
SLAC	Scapholunate Advanced Collapse
SNAC	Scaphoid Non-union Advanced Collapse
SPIRIT	Standard Protocol Items: Recommendations for Interventional Trials
T1	Test occasion 1
T2	Test occasion 2
VAS	Visual Analogue Scale
TWA	Total Wrist Arthroplasty
TWF	Total Wrist Fusion

Preface

Thinking back, the first step towards becoming a doctoral student was taken in 2015 when my colleague, and then head of the rehab department, Freyja Kristjansdottir, asked if I wanted to be part of a research project that, my present main supervisor, Elisabeth Brogren, was about to conduct. Since my goal, even at the start of my physiotherapy studies, has always been to extend my clinical knowledge in the direction of research, I gladly accepted. Little did I know, at the time, that this was the start of a great research journey that would culminate in this thesis. The study I was about to collect data for, was a prospective cohort study investigating the clinical and patient-reported outcomes after total wrist fusion (TWF) and total wrist arthroplasty (TWA), due to symptomatic end-stage wrist osteoarthritis (OA). This meant that I became deeply involved in the functional challenges that these patients faced before surgery, and how they improved, or sometimes failed to do so, after surgery. At the same time, I started my master's studies at Lund University, and again, Elisabeth Brogren had a great idea for a research project; How do the patients themselves experience living with advanced wrist OA leading to either a motion-sacrificing surgery such as TWF, or a motion-preserving surgery, such as TWA? This time, it was my colleague and the supervisor of my master's thesis, Ingela Carlsson, who asked if I wanted this qualitative research project to be my master's project. Which I did. By now, wrist OA had become the focus of my interest. Time went by, and it became clear to me that I really enjoyed digging deep into research questions. So, when I was asked if I wanted to continue with PhD studies, I didn't have to think twice. Of course I did! That is when we started making plans for future research projects and topics that have grown into this thesis. This doctoral research project started with the surgical experience of patients with wrist OA. But as a physiotherapist, I wanted to develop and explore a conservative treatment program for these patients. Could we help patients with wrist OA to improve their function and reduce their pain with an exercise therapy treatment program? Are there reliable and valid patient-reported outcome measures for patients with wrist OA? A research program gradually evolved, and an ethical application was sent to the Swedish Ethical Review Authority. By 2018, I was accepted as a doctoral student at Lund University.

This has truly been an enriching experience and I hope that the studies in this thesis will serve as a stepping stone towards improved care for patients with wrist OA. In the future, I also hope we will be able to offer more conservative self-managing treatment options to these patients. In fact, I will make this the quest for my continuing journey.

Sammanfattning på svenska

Artros, även kallat ledsvikt, är en kronisk ledsjukdom som påverkar miljontals människor i hela världen. I Sverige drabbas cirka var fjärde person över 45 år av artros, vilket motsvarar cirka en miljon människor. Orsaker till artros kan bero på en tidigare ledskada, övervikt och arbete med höga nivåer av ledbelastning, men även ålder, kön, ärftlighet och kroppsliga metabola faktorer kan påverka. När man får artros bryts ledbrosket, den stötdämpande glidytan i en led, ner mer än det byggs upp vilket gör att brosket blir tunnare och kan till och med försvinna helt. En irritation och inflammation kan uppstå i leden och även påverka andra delar som ledhinnor, ledband och muskler. Den artrosdrabbade leden kan så småningom bli smärtsam, stel och svullen. Många leder i kroppen består oftast av två ledytor mot varandra. Här skiljer sig handleden åt då den består av ett 20-tal leder som hålls samman av ett komplicerat system av ledband. Den vanligaste leden som drabbas av artros är knäleden, men det är även vanligt att höftleden och finger/tumlederna drabbas.

Att drabbas av handledsartros är mindre vanligt och orsakas oftast av en tidigare ledskada. Handledsartros utvecklas långsamt. Det kan gå många år från det att man skadade handleden tills det att man känner av symtom. Den som drabbas lider främst av smärta men även stelhet, svullnad och svaghet kan skapa besvär och funktionsnedsättningar med en negativ påverkan på vardagen och yrkeslivet.

Enligt nationella och internationella behandlingsriktlinjer ska artros i första hand behandlas med grundläggande fysioterapeuthandledd utbildning, träning och vid behov hjälp med viktkontroll. I Sverige finns det så kallade Artrosskolor i primärvården på de flesta orter som erbjuder den här typen av behandling. Behandling av artros kan liknas vid en trappa som börjar med utbildning och träning och slutar med eventuell operation. Forskning om effekten av utbildning och träning har främst utförts på personer med knä-, höft-, och finger/tumledsartros. Det finns ingen tidigare forskning som har undersökt om utbildning och träning kan ha en positiv effekt även hos personer med handledsartros.

Den här avhandlingen består av fyra studier som först och främst är gjorda för att uppmärksamma, undersöka, och tillföra ny kunskap om handledsartros ur olika synvinklar – före och efter kirurgi – med patientens funktionella förmåga i fokus. Hur är det att leva med handledsartros? På vilket sätt kan det påverka en persons liv? Hur resonerar och vad förväntar sig en person med svår smärtsam handledsartros som ställs inför val av kirurgisk behandling? Kan utbildning och träning minska smärta och förbättra funktionen vid handledsartros? Hur kan vi utvärdera effekten av olika behandlingar på bästa sätt?

I den första studien intervjuades personer som hade opererat handleden på grund av svår handledsartros. Total 13 personer intervjuades varav sju personer hade opererats med en steloperation av handleden och sex personer med en konstgjord

led, så kallad handledsprotes. Under intervjun fick deltagarna beskriva sina upplevelser och erfarenheter av att leva med en smärtsam handledsartros, beslutet som ledde fram till kirurgi, deras delaktighet vid val av kirurgi, vilka förväntningar de hade på effekterna av kirurgin, hur de upplevde resultatet samt eventuella funktionella konsekvenser i det dagliga livet. Studien visade att smärtsam handledsartros påverkade alla aspekter av deltagarnas liv negativt och att den konstanta smärtan fick deltagarna att nå en brytpunkt där de kände ett behov av att genomgå omfattande handledsoperation för att bli av med smärtan. Sammanfattningsvis gav den här studien en ökad förståelse för hur det är att leva med handledsartros, betydelsen av att inkludera patienter i resonemanget kring val av kirurgi samt hur rimliga förväntningar på kirurgi kan påverka resultatet i en positiv riktning. Att leva med en smärtsam handled upplevdes som mer begränsande än att leva med en stel handled.

I den andra studien utvärderades tillförlitligheten och giltigheten hos tre vanliga frågeformulär som ofta används för att utvärdera effekter av olika behandlingar på patienter med handledsartros. Femtio patienter med handledsartros fick svara på de tre frågeformulären vid två olika tillfällen med cirka två veckors mellanrum. Studien visade att alla tre frågeformulären kan användas tillförlitligt vid utvärdering av patienter med handledsartros, vilket är en ny kunskap eftersom de frågeformulären inte har undersökts på just patienter med handledsartros tidigare.

I den tredje och fjärde studien undersöktes effekten av utbildning och ett specifikt utformat muskelstärkande träningsprogram för handledsartros. Fyrtioåtta patienter med handledsartros lottades till antingen behandling med utbildning och det specifika muskelstärkande träningsprogrammet (det programmet som undersöktes) eller till behandling med utbildning och ett träningsprogram med enbart rörelseträning (kontrollgrupp). Deltagarna i båda träningsgrupperna utförde övningarna två gånger om dagen i 12 veckors tid. Alla fick med sig ett häfte med information om handledsartros, principerna bakom träningsprogrammen, ergonomiska råd samt ett handledsstöd. Efter 12 veckors träning visade det sig att det muskelstärkande träningsprogrammet inte minskade smärtan eller förbättrade funktionen mer jämfört med träningsprogrammet med rörelseträning. Men de som utförde det muskelstärkande träningsprogrammet minskade sin smärta vid belastning betydligt mer jämfört med den smärtan de hade innan.

Sammanfattningsvis har min avhandling belyst och ökat kunskapen om hur det är att leva med smärtsam handledsartros och vilka konsekvenser det kan medföra i det dagliga livet. Studierna i avhandlingen har även visat på 1) vikten av ett gemensamt beslutsfattande mellan patient och vårdgivare gällande val av behandling samt betydelsen av att ha rimliga förväntningar på en behandling, 2) utvärderat en grundläggande behandling, innehållande utbildning och träning, som patienter med handledsartros tidigare inte har inkluderats till, samt 3) visat att smärta och funktion kan mätas tillförlitligt vid behandling av handledsartros. Fler studier behövs för att utvärdera effekten som utbildning och träning kan tänkas ha på handledsartros, men

min förhoppning är att studierna i den här avhandlingen är en början på ett förbättrat omhändertagande av den här patientgruppen. Jag hoppas att hälso- och sjukvården i framtiden kan erbjuda fler behandlingsalternativ samt individanpassa och patientcentrera vården för patienter med handledsartros, vilket kan vara till nytta främst för personen som drabbats, men även för hälso- och sjukvårdssystemet i stort.

Introduction

Individuals with wrist osteoarthritis (OA) can suffer from functional impairments, such as pain, joint stiffness and pain-related psychological distress, that can lead to a reduction in their quality of life (9, 10). The treatment of OA in general is acknowledged as a patient-centered incremental process that starts with self-management strategies – including patient education, exercises and weight loss (if needed) – and ends with surgery (11). It is accepted that surgical interventions should only be considered when non-surgical treatments have failed (12). However, compared to OA affecting the knee, hip and hand (i.e., the base of the thumb and finger joints), wrist OA is less common and has not received the same attention regarding conservative treatments involving self-management programs. Although wrist OA is a chronic disease with no cure, patients may benefit from self-management treatment options that enable them to manage symptoms and optimize their quality of life (13). Previous research into wrist OA treatment has mainly focused on exploring and evaluating various surgical treatment options. This does not seem particularly equitable since the first-line treatments for most patients with OA in other joints are patient education and exercises. In addition, the considerably longer waiting times for surgery faced by healthcare systems worldwide have enhanced the interest in pre-rehabilitation in maintaining and improving patients' functional status before surgery, or even eliminating the need for surgical interventions (14-16). If, however, non-surgical treatment fails, the patient will be faced with deciding whether or not major wrist surgery is needed. Although this is not an uncommon clinical situation, there is no research which explores how patients reason concerning their choices and what they subjectively wish for. Rather, most research has focused on objective measurements and patient-reported function to the exclusion of the perspectives, feelings, and behaviours in this group of patients. The conclusion to be drawn here is that greater attention should be paid to exploring the experiences of living with wrist OA. Knowledge is needed about the optimal time for introducing different treatment options in relation to the patient's thoughts and wishes. This should be done in order to improve treatment strategies that, in the future, could benefit both the patient and the healthcare system.

With this in mind, the current thesis has addressed the lack of research into the management and treatment of wrist OA, concentrating on increasing present knowledge about it from different viewpoints, with the focus on the patient's functional ability. The threefold aim of this thesis was to explore the experiences of

patients living with wrist OA and how they reason when faced with a surgical decision; the effect of a self-managed neuromuscular exercise therapy program; and the evaluation of patient-rated outcome measures (PROMs) commonly used when planning an intervention or evaluating the effects of different treatments for wrist OA.

Background

The wrist

Anatomy of the wrist

The wrist is a complex, composite joint comprising multiple smaller joints which connect the hand to the forearm (17). The biomechanics of the wrist joint depend on its skeletal structure, ligamentous composition and the tendons surrounding the joint, providing a delicate balance between mobility and the ability to withstand tremendous load-bearing forces (18). Its unique feature is the fundament of the hand that enables us to grasp objects and move them with force and precision (19).

The wrist is divided into three main joint regions; the radiocarpal, midcarpal, and distal radioulnar joints. The bones connecting to the wrist include the distal radius, the ulna, the carpal bones and the bases of the metacarpals (18). The carpal bones are divided into proximal and distal rows, which indicates an anatomic and functional relationship between the two rows of bones. The proximal carpal row comprises (from radial to ulnar) the scaphoid, lunate, triquetrum, and pisiform. The distal carpal row consists of (from radial to ulnar) the trapezium, trapezoid, capitate, and hamate (18) (Figure 1). The mobility of the distal row is restricted; it moves as one functional unit with stable attachments to the metacarpals (16). The bones of the proximal row have a greater mobility in relation to each other, and the movement is reliant on the articulations and soft tissues surrounding them and the force being applied on the bones (20). The proximal articulations of the proximal row and radius create the radiocarpal joint, and the articulation between the proximal and distal rows forms the midcarpal joint. The bones of the carpus are connected and stabilized by numerous ligaments, most of which are enclosed within the wrist joint capsule (21). The scaphoid provides an important link between the carpal rows, and the ligaments that surround and attach to the scaphoid are fundamental to the stability of the carpus (20).

There are around 30 ligaments connecting the carpal bones and numerous tendons and muscles responsible for both movement and stability in the wrist (22). The ligaments are classified into two groups: the extrinsic ligaments which originate from the radius or ulna and insert into the carpal bones, and the intrinsic ligaments, which originate and insert on the carpal bones (21). The muscles that impact the wrist are located within the forearm, where six of these are inserted at the distal

carpal row or the base of the metacarpal bones [the extensor carpi radialis longus and brevis muscles (ECRL/ECRB), the extensor carpi ulnaris muscle (ECU), the flexor carpi radialis muscle (FCR), the flexor carpi ulnaris muscle (FCU) and the Palmaris Longus (PL)]. While the ligaments operate as static stabilizers, the extrinsic muscles that surround the wrist joint act as dynamic stabilizers and must be kept constantly active and ready to counteract any attempts to make the wrist unstable (23).

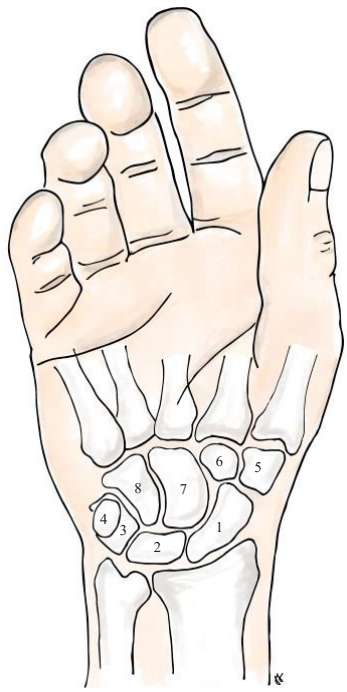

Figure 1. Anatomy of the wrist. The proximal carpal row (from radial to ulnar) comprises the 1) scaphoid, 2) lunate, 3) triquetrum, and 4) pisiform. The distal carpal row (from radial to ulnar) consists of the 5) trapezium, 6) trapezoid, 7) capitate, and 8) hamate. Illustration by Linnea Arvidsson, with permission.

Wrist stabilisation

The ligaments of the wrist are not merely static stabilizers, they also contain mechanoreceptors – a sense organ that responds to mechanical stimuli – that react to joint pressure, motion, and velocity (24, 25). The existence of mechanoreceptors in the palmar wrist ligaments was first documented by Petrie et al. (26). The features of these mechanoreceptors have subsequently been further investigated by several research teams who have concluded that adequate wrist stability depends on a finely tuned balance between the mechanoreceptors and the muscles (24, 25, 27-30). The distribution of the mechanoreceptors in the wrist ligaments differs with prominent innervation in the dorsal and triquetral wrist ligaments, compared to the radial and

volar wrist ligaments which consist of densely packed collagen fibres with little or no innervation (27). Nerve endings of the mechanoreceptors have predominantly been found close to the ligament insertions into the bone, where a strong stiffness in collagen fibres within the ligament supports a firing of the receptors only at the extremes of joint movements. In short, when mechanoreceptors are stimulated, through joint pressure, motion and velocity, they send afferent information to the spinal cord, where it can take one of two sensorimotor pathways: 1) an immediate monosynaptic path, a direct and simple reflex arc, of information from the dorsal to the anterior horn, which serves to provide fast control of muscles around the joint; or 2) a secondary polysynaptic path (involving several neurons) where afferent information is transmitted alongside the dorsolateral and spinocerebellar tracts of the spinal cord for a higher supraspinal control of the muscles around the joint (8) (Figure 2). Third-order neurons of the spinocerebellar tract are situated in the thalamus, a crucial part of the brain with a central role in sensory processing and the regulation of consciousness, where information is passed to the primary motor and sensory cortex for the generation of a conscious recognition of joint motion (31). A distinct portion of the spinocerebellar tract bypasses the thalamus and terminates in the cerebellum which is the main site for the intricate integration of somatosensation and proprioception related to the unconsciously controlled neuromuscular movement of a joint (31). The sensorimotor pathways involve a complex network of sensory and motor neurons, as well as the processes and structures in the brain that are responsible for processing sensory information, coordinating motor responses and maintaining functional joint stability (8). This sensory and motor interaction is often labelled "proprioception", with any or all of the sensory and motor control processes, balance, coordination and joint stability included in the term (8). However, research dealing with joint control exclusively has in recent years coined the term "sensorimotor function", defined as the integration of sensory, motor, and central processes relating to joint stability (8, 32). Another term commonly used synonymously, especially in the field of rehabilitation and exercise therapy, is "neuromuscular control", defined as the unconscious trained response of a muscle to a signal concerning dynamic joint stability (3, 33). All of these terms – proprioception, sensorimotor function/control, and neuromuscular function/control – are used in research to describe systems controlling joint stability (34). However, the sensorimotor system can be seen as an umbrella term that includes both conscious and unconscious sensations (8). The conscious sense pertains to the body's voluntary recognition of joint motion and joint position and depends mainly on cutaneous and muscle receptor sensory input producing the sense of kinesthesia and joint position (8, 34). The unconscious sense represents the body's involuntary, neuromuscular response to joint motion and loading to maintain and restore functional joint stability which is linked to the feedforward muscle control system heavily regulated by the cerebellum (8, 32, 34).

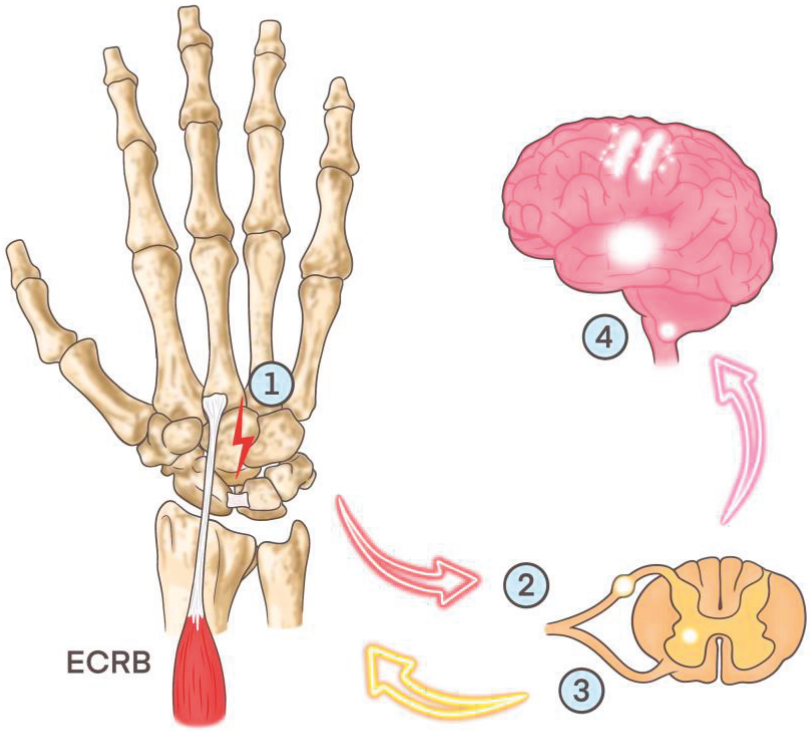

Figure 2. The principles of wrist sensorimotor pathways. 1) Stimuli obtained by mechanoreceptors in ligaments of the wrist sends afferent information to the dorsal horn of the spinal cord, via the dorsal root ganglion (2) where a monosynaptic transmission of information from the dorsal to the ventral horn takes place to provide fast control of muscles around the joint (3). In the secondary polysynaptic pathway (4), afferent information is transmitted alongside the dorsolateral and spinocerebellar tracts of the spinal cord to the cerebellum and cortex for a higher supraspinal control. ECRB: Extensor Carpi Radialis Brevis. Illustration by Therése Andersson, with permission.

Wrist stability and optimal function are dependent on an intricate balance amongst several factors, including the articular surfaces and congruity of the bones, intact or sufficiently competent ligaments, a finely tuned sensorimotor system and reactive muscle reflexes capable of reacting efficiently when a warning message is received from the sensorimotor system (23) (Figure 3). An injury to the wrist may lead to a disturbance in the afferent information from receptors in ligaments, tendons and the muscles around the wrist joint (ECRL/ECRB, ECU, FCR, FCU and PL), which can cause disruption of the neuromuscular control around the joint leading to muscle weakness (35). This muscle weakness can result in successive loss of muscle endurance, slower reflex control and impaired co-contraction, eventually resulting

in a vicious circle of impaired joint stability and excessive joint load, often present in a joint affected by OA (36).

Previous studies have found significant deficits in the sensorimotor control system in patients with a distal radius fracture, especially affecting the joint position sense (JPS) included in the conscious part of the sensorimotor system. This can cause impairment in the detection of a changed joint motion and adaptation to it (37, 38). In addition, an earlier ligament injury to the wrist can cause the gradual development of carpal instability, leading eventually to carpal collapse and a degenerative process; a situation often seen in post-traumatic wrist OA (39). It has been reported that, for optimal stability, the positioning of the wrist, when using the hand in daily activities, needs to be acknowledged (40). This has been labelled the "neutral wrist position" where the wrist is positioned in approximately 20° of extension (41). In this position, the least amount of tension is placed on the ligaments, muscles and tendons, creating a stable wrist.

In conclusion, a thorough knowledge of the complex anatomy of the wrist, in combination with an understanding of the sensory and motor processes involved in creating functional stability, is needed in the treatment of wrist OA.

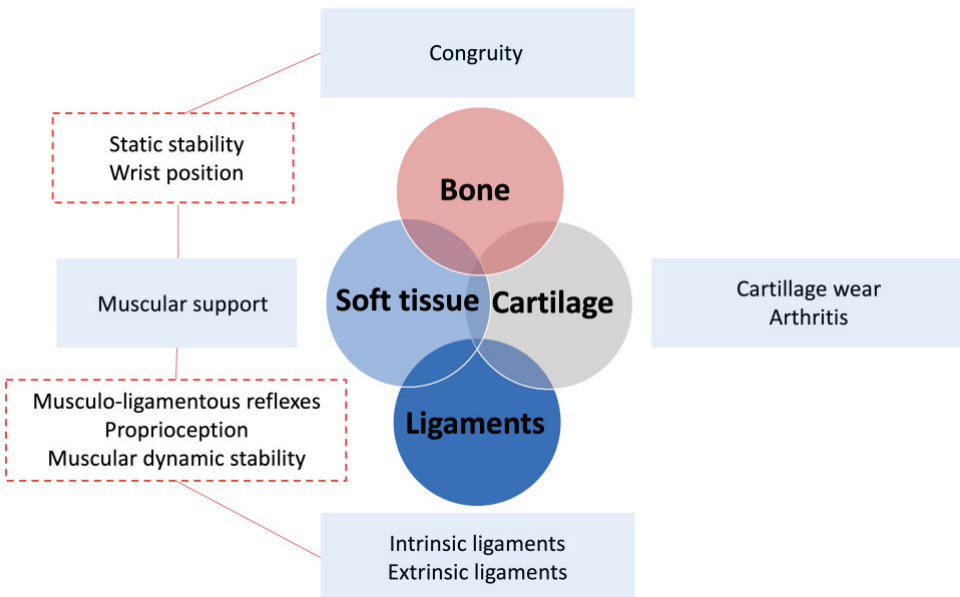

Figure 3. An overview of the structures and mechanisms involved in creating wrist stability. Illustration by Simon Farnebo, with permission.

Rehabilitation of the wrist

It is important to consider and address the complex sensorimotor interplay between the conscious and unconscious senses in the creation of rehabilitation programs for the wrist, as has been acknowledged in previous research. First, however, some definitions need to be explained. Previous research regarding rehabilitation of the wrist has traditionally used the terms *proprioception* or *sensorimotor control* when describing rehabilitative factors related to enhancing joint stability (34, 42, 43). This is in contrast to the exercise therapy management of OA, which often uses the term *neuromuscular control* when describing exercises to correct impairments, restore muscular and skeletal function and improve functioning (3, 44). These terms are often synonymously used, and they all describe the conscious and unconscious interaction of the sensory and motor processes involved in creating and maintaining functional joint stability (8).

The evidence regarding the effect rehabilitation has on different wrist injuries and pathologies is uncertain. However, a review by Hagert from 2010 (34), highlighted the theoretical importance of sensorimotor control of the wrist and its function, thus setting a new standard for wrist rehabilitation. Clinical reviews by Valdes et al. (45), Karagiannopoulos and Michlovitz's (42), and Lotters et al. (43) followed and provided further support for including exercises focusing on joint stability and sensorimotor control in the rehabilitation of the wrist. Most recently, a review by Hagert and Rein (46) has provided an update on the scientific insights and clinical implications regarding wrist proprioception and rehabilitation of the wrist. In addition, descriptive cross-sectional studies have found that the sensorimotor function of the wrist is significantly reduced following distal radius fractures compared with uninjured wrists. This supports the theory that sensorimotor control exercises should be included in wrist rehabilitation programs (37, 38).

Clinically, there are a small number of case reports and cohort studies which indicate clinical benefits from including exercises with a sensorimotor approach following various wrist injuries. In a recent prospective cohort study by Milner et al. (47), 93 patients with various distal upper extremity disorders completed an eight-week sensorimotor group rehabilitation program. This study showed statistically significant improvements in both patient-reported and clinical outcome measures. Unfortunately, the full effectiveness of this rehabilitation program cannot be firmly established as the study utilized a sample of convenience and did not have a control group. In a case series study by Cheuquelaf-Galaz et al. (48), 39 patients diagnosed with radial or ulnar carpal instabilities were successfully treated using personalized exercise-based interventions. This study found significant improvements for pain and function after eight weeks of wrist-stabilizing exercises combined with proprioceptive training and strengthening of the unaffected hand. However, the long-term effect of these improvements remains unknown. A service evaluation by Holmes et al. (49) described a progressive three-stage exercise program for a stage-

one scapholunate (SL) instability and found clinically relevant improvements in pain and impairments. However, no general conclusions could be drawn from these results as only five individuals were included. Two retrospective cohort studies by Mulders et al. (50) and Videler (40), have shown promising results concerning long-term pain-relief in patients with midcarpal instabilities and chronic non-specific wrist pain following a sensorimotor control-based exercise program. Two case studies, made by Chen (51) and Hincapie (52), showed promising positive outcomes for one patient with a triangular fibrocartilage complex (TFCC) injury and one with a partial SL-ligament injury both being treated with progressive sensorimotor rehabilitation programs.

The main goal of the rehabilitation is a pain-free and stable wrist that has the ability to tolerate forces involved in the activities of daily life. The clinical importance and evidence regarding the effect of rehabilitation using a sensorimotor approach on different wrist injuries is still at a very early stage and is mainly dependent on theoretical assumptions, outcomes from the above-mentioned cohort and case studies, and clinical research carried out on other joints such as the shoulder, ankle, and knee (42, 52). Any effects that rehabilitation might have on wrist OA have not previously been evaluated.

Osteoarthritis

Definition and symptoms

OA is a chronic, degenerative joint disease that results from the breakdown of joint cartilage and the underlying bone. It is a common and disabling condition that signifies a considerable and accumulative health burden with substantial implications for the individuals affected, healthcare systems and socioeconomic costs (53). OA is defined as a whole-organ disease that affects all the tissues of the joint – the articular cartilage, subchondral bone, capsule, ligaments and periarticular muscles (53). OA can develop in any joint, but most commonly affects the knees, hands, and hips. An overall incidence of clinically diagnosed knee and/or hip OA among people aged 40 years and older, is reported to be 6.5/1000 person-years for knee OA and 2.1/1000 person-years for hip OA (54).

The symptoms of OA vary in severity but, in its more severe form, can be a painful condition that restricts mobility, interrupts sleep and reduces the quality of life (55). OA develops slowly, over 10-15 years, and typically occurs later in life, although the onset may be earlier in the case of joint injury (12). Pain is the main symptom and the principal reason for seeking help from healthcare providers. It is also the chief motivator in clinical decision making. However, pain and radiological severity of joint damage are not always associated, which can complicate the disease assessment, making the diagnostic criteria ambiguous (55). Apart from pain,

reduced range of joint motion, crepitus, joint instability, swelling, muscle weakness and pain-related psychological distress can also be seen in patients with OA (53).

OA is defined as a heterogeneous disease with several underlying pathomechanisms that can cause similar results of joint destruction. It has, therefore, been proposed that OA should be thought of as a syndrome rather than a single disease (53). Several factors are involved in the complex pathogenesis of OA, such as mechanical, inflammatory and metabolic features, which eventually lead to structural destruction of the synovial joint. The osteoarthritic development is a dynamic adjustment that arises from an imbalance between the repair and destruction of joint tissues (56). This pathogenic progression may be initiated by multiple factors, including genetic, developmental, metabolic and traumatic issues (57). Several changes – morphologic, biochemical, molecular, and biomechanical – are included in the degenerative process, causing loss of articular cartilage, joint inflammation, sclerosis, osteophytes and subchondral cysts (57).

Self-management

Self-management strategies

The acknowledged treatment of OA is a patient-centered staged approach, starting with self-management strategies – including patient education, exercises, and weight loss (if needed) – and ending with surgery (12) (Figure 4). Self-management is crucial in the treatment of OA since it empowers individuals to actively participate in their own care, improve their quality of life and better manage the challenges associated with this chronic condition (58). In the effort to achieve this goal, it is recommended that patient education should be part of the self-management treatment of chronic diseases, such as OA (4). The educational component should include information about the disease, its causes, diagnostic criteria, and the management of the disease (59). Patient education, in combination with other treatments, can help individuals to understand their condition better and comply more closely with the treatment (60). There is thus strong evidence that all patients with OA should try a self-managed first-line treatment, and surgical interventions should be considered only if non-surgical treatments have failed (12). Treatments for OA should include preventive and self-management strategies and comprehensive care models, as for other chronic diseases (44). Although there is no cure for OA, patients may benefit from self-management treatment options that enable them to manage their symptoms and optimize their quality of life (13).

In combination with patient education, exercise is considered the core component in the treatment of individuals with knee and/or hip OA (61-64). The effects of exercise in people with knee OA have been evaluated in more than 50 RCTs (63), and in around 10 RCTs for people with hip OA (64). To summarize, these studies

showed that pain and function improved following exercises in people with knee and/or hip OA, however, the mechanisms behind these positive effects are inadequately understood (65). For individuals with knee OA, improved upper-leg strength, increased knee extension, and improved proprioception have been identified as possible positive facilitators (66), and for individuals with hip OA, lower limb strength is related to better self-reported physical function (67). There could also be a general positive physiological response, including weight loss, to the cardiovascular exercise training usually incorporated when treating knee and hip OA (68). The types of exercises in the treatment of OA vary, with neuromuscular exercise therapy being one type of conservative management for hip and knee OA (13). Neuromuscular exercise is a regimen of physical activities designed and prescribed to meet precise therapeutic goals aimed at training the performance of specific exercises to improve neuromuscular control, reduce pain, and achieve joint stability (1, 3). Neuromuscular exercise therapy has long been recognized as the basis for functional recovery in cases of injuries or disorders in the musculoskeletal system (69). It is regularly used when impairments such as pain and sensorimotor insufficiencies – reduced balance, coordination, muscle weakness – and instabilities exist (70). Postural control, proprioception, muscle activation, muscle strength and coordination are targeted in the training to improve neuromuscular control and enhance dynamic joint stability (71). In combination with this, good movement quality and appropriate positioning of the joint are emphasized (3).

Several international and national organizations recommend self-management programs, including structured education and exercises, as a first-line treatment for OA. The European League Against Rheumatism (EULAR) recommends OA education and exercise for hand, knee, and hip OA (61, 72). The Osteoarthritis Research Society International (OARSI) recommends education and exercise programs as core treatments for knee, hip, and polyarticular OA (62). Furthermore, several evidence-based self-management programs have been developed for hip and knee OA and are implemented and used as first-line treatments with good results (73, 74). Cochrane reviews have found high quality evidence that therapeutic exercises can reduce pain and improve function in knee and hip OA (63, 64). There is less evidence for hand OA, owing to the lack of blinding of participants, the small number of included studies, and the inclusion of few individuals in the analyses (75). In the studies reported, hand OA refers to the thumb carpometacarpal (CMC) and the finger joints. The effect a first-line self-management approach – including structured education and neuromuscular therapeutic exercises – can have on individuals with wrist OA has not previously been evaluated.

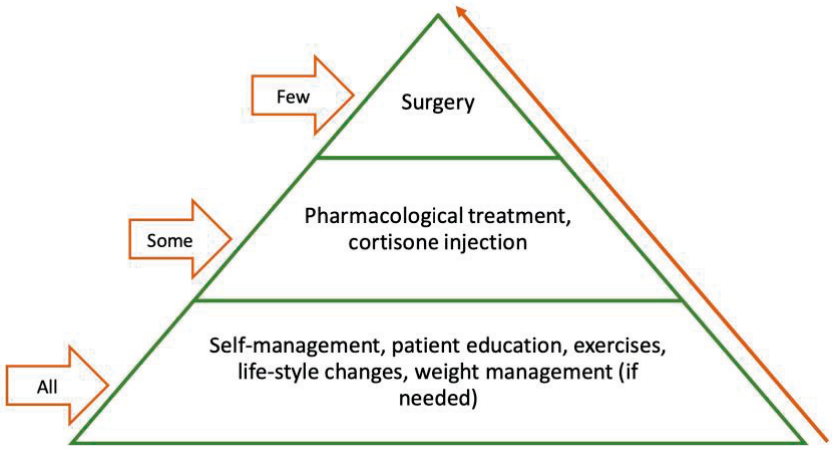

Figure 4. The osteoarthritis treatment pyramid.

Self-efficacy

A central component in self-management is self-efficacy. Self-efficacy is a psychological concept that refers to a person's belief that they can perform a task, activity, or behaviour in order to achieve the desired goal (6). The construct of self-efficacy was coined by Bandura, who described, in his social-cognitive theory, how cognitive and social factors contribute to disease (76). According to Bandura, perception of high self-efficacy increased the likelihood of consideration, adoption and maintenance of self-management skills. Self-efficacy goes beyond a person's actual skills or abilities and encompasses their confidence that they can apply those skills to overcoming challenges and attaining desired outcomes (6). High self-efficacy is associated with increased motivation, persistence, and resilience, while low self-efficacy can lead to self-doubt, reduced effort and a greater likelihood of giving up in the face of obstacles (77). Self-efficacy seems to play an important facilitating role in a person's adoption and maintenance of behavioural changes and in outcomes related to their health (76). In patients with knee and hip OA, high self-efficacy has been associated with favourable health-related outcomes (78-80), and taking part in a self-management program can enhance self-efficacy (81). In an observational study of 11 906 patients with knee and hip OA, patients with a low education level, comorbidity, walking difficulties or physical inactivity reported lower self-efficacy, whilst younger age and exercise during the intervention were associated with an increase in self-efficacy (82). Measurement of self-efficacy could therefore be used to identify patients in need of enhanced support.

Patients with OA have different needs regarding support in order to enhance their self-efficacy since their motives for engaging in exercise programs also differ (83).

Exercises should, therefore, be supervised by a trained physiotherapist (PT) who provides encouragement, answers questions and initiates individual adjustments in order to help enhance self-efficacy (84). Barriers need to be identified and specific, measurable and realistic goals should be set for maintaining or enhancing self-efficacy. An increased focus on people with low self-efficacy, or those who seem to have difficulty enhancing and maintaining self-efficacy, might also help to improve long-term outcomes after intervention.

Taken together, OA is not just a disease of the cartilage, but of any component affecting joint structure and stability. This view enhances our ability both to target our treatment more effectively and to include exercises to improve overall dynamic joint stability. Well-coordinated neuromuscular control can contribute to improved biomechanics, reduced joint stress and can help to optimize the distribution of forces over the joint during movement; all of which can potentially alleviate the pain associated with OA (35). Engaging OA patients in self-management programs and identifying barriers and facilitators to such programs, empowers individuals with OA to participate actively in their rehabilitation and provides them with tools for managing their symptoms.

Wrist osteoarthritis

Epidemiology of wrist OA

Wrist OA is rare compared to OA in other joints, and both prevalence and incidence have received less attention. Wrist OA, in contrast to OA affecting the hand, knee and hip, is also different in that it can occur at an earlier age and is more common in men (85, 86). The prevalence of wrist OA increases with age affecting around 1.6-1.7% of men and 0.8-1.0% of women aged >60. The prevalence of wrist OA in individuals aged 44-59 ranges from 0.5-0.6% in men and is 0.1% in women (85, 86). In radiologically defined OA, the prevalence of hand and wrist OA increased from 4.8% in individuals aged 35-44 years to 79% in those aged 75-79 years (85). A cumulative nine-years incidence of wrist OA ranges between 1.6% in men and 0.2% in women (86).

Risk factors for wrist OA

Wrist OA has several different causes, both idiopathic and traumatic (10). However, prior trauma to the wrist, such as fractures, dislocations and ligament injuries, is the most prevalent cause of degenerative changes, and the joints surrounding the scaphoid bone are usually the ones most affected (9, 87). Other, less common, causes of wrist OA include articular chondrocalcinosis, primary avascular necrosis (Kienböck disease and Preiser disease), and deformities, such as Madelung's disease (9).

Two common types of wrist OA patterns are the scapholunate advanced collapse (SLAC) (39), and the scaphoid non-union advanced collapse (SNAC) (88) (Figure 5). Even though injury to any of the wrist ligaments can progressively lead to wrist OA, scapholunate tears, in particular, are the most common factor in the generation of intercarpal instability, altered wrist kinematics, and joint loading. This eventually creates a specific SLAC pattern causing a gradual degeneration of the radiocarpal joint (39). OA due to a SNAC progression is brought about by an unhealed fracture of the scaphoid bone (88). SNAC can also cause a series of predictable degenerative changes that first involves the radial styloid and then progresses to the more proximal radioscaphoid joint (88). Both SLAC and SNAC cause carpal instability, altered wrist kinematics, and joint loading with eventual arthritic degeneration of the radiocarpal and midcarpal joints ultimately leading to pancarpal arthritis (9).

In 1984, Watson and Ballet suggested a three-stage classification for SLAC wrist describing a predictable and progressive pattern based on plain radiographs: grade 1 arthritic changes confined to the radial styloid; grade 2 arthritic changes between the radius and the entire scaphoid; and grade 3 in addition to grades 1 and 2, arthritic changes at the capitate-lunate joint (39). A similar sequence of events was reported for SNAC wrist by Vender et al. (88), but the Watson and Ballet classification is currently the most widely used for both SLAC and SNAC. Subsequently, a fourth stage for SLAC and SNAC wrist was described, including arthritic changes in the radio-lunate fossa (10, 89) (Figure 6).

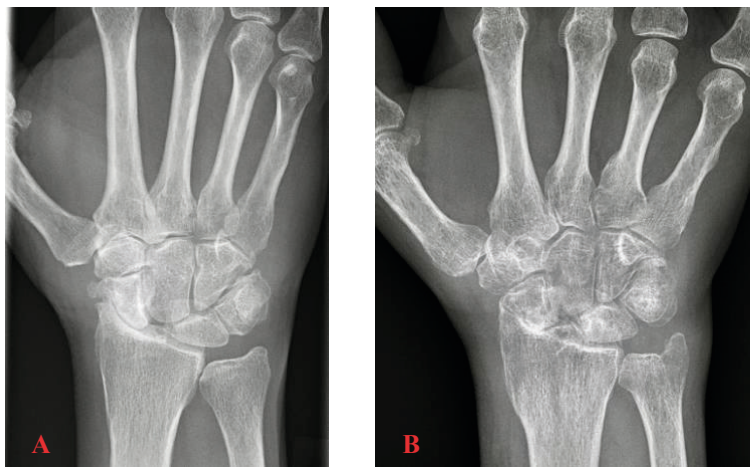

Figure 5. **A** The Scapholunate Advanced Collapse (SLAC). **B** The Scaphoid Non-union Advanced Collapse (SNAC). Radiographs, with permission.

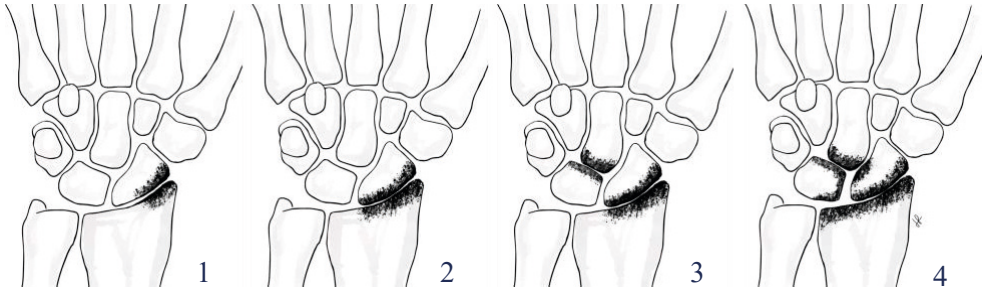

Figure 6. The four-stage pattern of wrist osteoarthritis caused by SLAC and SNAC (10, 89). Illustration by Linnea Arvidsson, with permission.

Diagnosis

Diagnosing wrist OA typically involves a combination of medical history, physical examination and imaging (87). A thorough history of the patient's symptoms is required, with special attention paid to exacerbating and alleviating circumstances, as well as to how the symptoms interfere with everyday life. Palpation of each articulation of the joint is important in order to identify tender areas or crepitus (10). Conventional radiographs with posteroanterior and lateral views are traditionally used to confirm the diagnosis (87). Although plain radiographic examination is the most widely used technique for assessing wrist OA, Computerized Tomography (CT) is better at finding degenerative changes and provides more detailed information because of its spatial ability. It is sometimes used when planning surgery or when emerging or mild OA is difficult to diagnose from plain radiographs (90-92). There is currently no standardized interpretation of degenerative patterns in SLAC and SNAC wrists for CT, although several authors have described diagnostic features similar to the Watson and Ballet classification on different CT modalities (90, 93, 94).

Impact of wrist osteoarthritis

A health perspective

A framework for describing health and health-related conditions has been provided by the World Health Organization: the International Classification of Functioning, Disability, and Health (ICF) (95). The ICF is a biopsychosocial model in two parts: 1) functioning and disability; and 2) contextual factors. The first part includes “body functions” (the physiological functions of body systems), “body structures” (anatomical parts of the body), “activity” (the performance of a task or action), and “participation” (involvement in a life situation). The second part comprises personal and environmental factors which can be both facilitators or barriers with reference to functioning and health. There is a dynamic relationship between these ICF

components which can illustrate why people with the same injury achieve different levels of functioning after an injury or a disease.

Wrist OA typically causes impairments involving body functions and body structures. The extent of these impairments can eventually give rise to activity limitations and participation restrictions, influenced by both environmental and personal factors. All of this can have an impact on an individual's level of function, recovery and quality of life.

Consequences for the individual

Individuals with wrist OA commonly suffer from pain, reduced range of motion (ROM) and decreased grip strength (9, 96). These impairments can have a significant impact on an individual's ability to perform daily activities and to participate in society (97). Although individuals with wrist OA can have diverse experiences, pain is often the most central problem negatively affecting all aspects of life (97). Pain caused by OA is characteristically intermittent and primarily instigated by weight-bearing (53). The pain is often anticipated and acceptable, but it is when it becomes more frequent, severe and random that the situation becomes unacceptable, making individuals seek help from the healthcare system (53). Apart from pathological progression, such as inflammation and damage to body functions and body structures, several individual factors influence pain, such as self-efficacy, mood, avoidance behaviour, sleep disturbance, and the type and level of activity and participation throughout the day (98). In addition to pain, wrist OA can cause impairments of the joint such as stiffness, instability and swelling, all of which can aggravate activity limitations and participation restrictions (87). Nevertheless, living with wrist OA can be tolerated well for many years with the individual not even recalling the original trauma (97).

Compared to previous research regarding the consequences of living with knee and hip OA, the impact wrist OA can have on an individual's life has been described much less frequently (99, 100). However, we do know that wrist OA can affect a younger population of working age which can be particularly disabling and problematic (97). There is an increased risk of long sick leaves or changes of occupation; incapacitating and problematic mainly among individuals whose work involves heavy labour (97). The symptoms of wrist OA and its impact on daily life may affect all levels in the ICF (Figure 7).

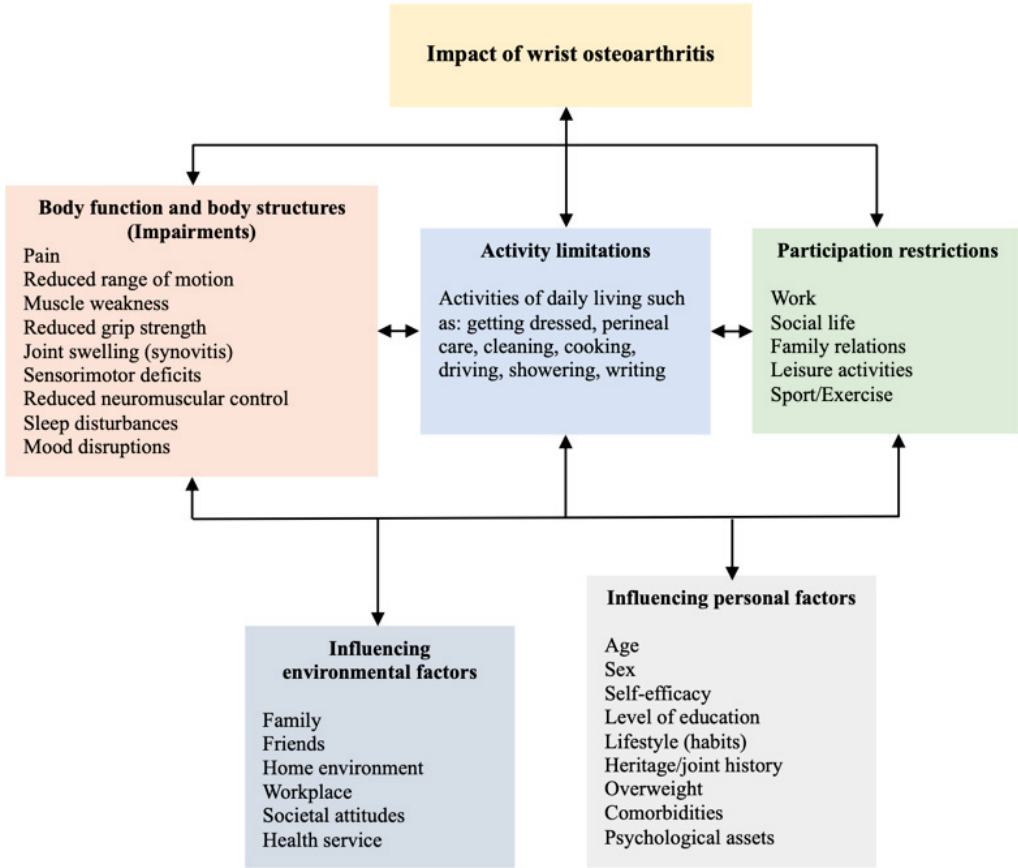

Figure 7. Impact of wrist osteoarthritis according to The International Classification of Functioning, Disability, and Health (ICF).

Measuring outcome in wrist osteoarthritis

Clinical and patient-reported outcome measures

There are a variety of outcome measures that can be used to evaluate impairments caused by wrist OA. Clinical outcome measures that are commonly used are isometric grip strength and range of wrist motion (flexion, extension, radial deviation, ulnar deviation, pronation and supination) of the affected wrist (101, 102). Isometric grip strength is usually measured using a hydraulic hand dynamometer (103) and range of wrist motion in degrees using a goniometer (104). However, the patient's self-perceived symptoms and disabilities are often

indications for interventions in the case of wrist OA. Therefore, it is important to include patient-reported outcome measures (PROMs) when assessing the effects of different treatments for wrist OA as they provide a more complete picture of the disability from the patient's perspective (105, 106).

With reference to wrist and hand outcome assessments in general, a recent overview of PROMs used for hand and wrist disorders found a total of 27 outcome assessments in eleven different systematic reviews (107). In this overview, the Disabilities of the Arm, Shoulder and Hand (DASH) (108), the Patient-Rated Wrist Evaluation (PRWE) (109), and the Michigan Hand Outcome Questionnaire (MHQ) (110), were the PROMs most reported. A systematic review by McPhail et al. (101) identified a range of condition-specific PROMs used in clinical trials amongst patients with wrist OA, with DASH being the most commonly used instrument. Another systematic review by Dacombe et al. (102) evaluated PROMs used in randomized controlled trials to assess outcomes for hand and wrist trauma patients. They also found that DASH and PRWE were the most commonly used instruments showing evidence of reliability, validity and responsiveness in a hand and wrist trauma population.

The DASH measures self-reported upper extremity physical function and symptoms taking the whole upper extremity into account, irrespective of which hand or if both hands are used (108). The PRWE is a wrist-specific PROM originally developed for the assessment of perceived disability after a distal radius fracture (109). The MHQ is a hand-specific PROM, which measures outcomes for upper limb musculoskeletal disorders in various health state domains – overall hand function, activities of daily living (ADL), work, pain, aesthetics, and satisfaction with hand function – that can be experienced by patients with hand disorders (110). Pain scales, such as the Numerical Pain Ratings Scale/Numerical Rating Scale (NPRS/NRS) (111) or the Visual Analogue Scale (VAS) (112), are another group of patient-reported outcome measures that have also been widely used in the evaluation of wrist OA (101, 113). The NPRS/NRS is a numeric 11-point box scale for rating pain with numerical descriptors, ranging from 0 representing one pain extreme (no pain) to 10 representing the other pain extreme (worst pain imaginable). The VAS is in the form of a horizonal line, 100 mm long, where 0 mm indicates “no pain” and 100 mm indicates “most severe pain”. A high correlation between VAS and NRS has been established (114). NPRS/NRS is, however, recommended for use when assessing pain intensity as it has higher compliance rates, better responsiveness, is easier to use, and has good applicability relative to VAS (114).

Psychometric properties of outcome measures

We need outcome measures with good psychometric properties in order to evaluate the effects of different interventions, both in clinical practice and in research. The quality and usefulness of any outcome measure depends mainly on its ability to measure what it is intended to measure (validity) and on its stability over time

(reliability) (5). Validity is the degree to which an outcome measures what it is intended to measure and mainly comprises content validity, criterion validity and construct validity (5). Ensuring the validity of an outcome measure is essential if meaningful and accurate results are to be obtained after an intervention (5). Content validity assesses whether the items or questions included in an outcome measure are relevant, comprehensive and representative of the construct or concept being measured. Criterion validity evaluates the degree to which the scores on a particular outcome measure are related to an outcome that is considered to be the true measure, the gold standard, of the construct being assessed. Construct validity focuses on whether an outcome accurately measures the theoretical construct or concept it is intended to measure (5). In other words, it evaluates whether the scores obtained align with the underlying theoretical construct. Since there are no ´gold standards´ for PROMs, the most common way in which to investigate construct validity is to test hypotheses about 1) expected relationships with other outcome measures of good quality; convergent or divergent validity, and/or 2) expected differences between relevant groups; discriminative or known-groups validity (115). Convergent validity assesses whether the outcome measure correlates positively with other outcome measures that theoretically measure the same construct. This is in contrast to divergent validity which instead evaluates whether the outcome measure does in fact not correlate strongly with other measurements that it should theoretically differ from (5). Reliability is the consistency and stability of an outcome measure over time; the measure should produce similar results under consistent conditions (116). There are several different types of reliability evaluations including test-retest reliability, inter-rater reliability, intra-rater reliability and internal consistency (5). Test-retest reliability evaluates the agreement and measurement error of repeated measurements at two or more time points. The focus is on evaluating whether the same rater (intra-rater reliability), using the same measurement tool, will obtain similar results when measuring the same set of outcome measures at different time points. Ideally, the outcome measures should produce similar results from one test occasion to the next indicating that the measures are stable over time (116). Inter-rater reliability evaluates the consistency and degree of agreement between two or more raters when they independently assess or score the same set of observations, behaviours, or data. Internal consistency is a measure of the extent to which items within a text are consistent or correlated with each other (5). A high degree of reliability indicates improved precision of the outcome measure, which can enhance its ability to detect changes over time and after interventions (5).

The psychometric properties of an outcome measure are closely linked to the population it is intended for and needs to be evaluated in specific patient groups (5). Excellent test-retest agreement for DASH has been found in patients with various upper extremity disorders (117-122), and a systematic review also found excellent test-retest reliability for PRWE and VAS in 24 studies of various types of wrist and hand injuries (123). Strong psychometric properties have also been demonstrated

for the MHQ in hand conditions including rheumatoid arthritis, hand OA, nerve compressions, systemic sclerosis and distal radius fractures (124-127). PRWE content validity has previously been evaluated in the context of hand and wrist arthritis (27% with OA, 67% with rheumatoid arthritis and 6% with psoriatic arthritis) (128). However, the investigations into the validity and reliability of these PROMs included mixed clinical population groups with few patients with wrist OA. More studies are therefore needed to evaluate the psychometric properties of commonly used condition-specific PROMs in the context of wrist OA.

In summary, DASH and PRWE are the most commonly used PROMs in the evaluation of various wrist disorders. For patients with wrist OA, pain is often the central problem and the most important indicator for interventions. Pain should, therefore, be specifically evaluated using either NPRS/NRS or VAS. Evaluating psychometric properties in outcome measures contributes to the overall quality of research and clinical assessments, ultimately improving the accuracy and effectiveness of interventions and decision-making processes.

Current treatment norms

Current treatment strategies for wrist osteoarthritis

Since there are no treatment options that can restore damaged structures in an OA affected wrist joint, treatment is directed towards alleviating pain and enabling a return to a desired lifestyle. The treatment options available do not cause regression or reversal of the OA process but are valuable for transient pain relief (129). Currently, the treatment norm for wrist OA is initially aimed at alleviating pain through splint or cast immobilization, pharmacological treatments and surgical procedures (87, 130).

Pharmacological treatment options for wrist OA include symptomatic pain relief treatments with anti-inflammatory medications, and intraarticular steroid injections (87, 130). If pharmacological treatments fail, various types of surgical procedures can relieve pain for wrist OA. Neurectomy (partial wrist denervation) may be used as a primary surgical procedure in wrist OA since it can be easily performed, does not require immobilization and preserves motion (131). Radial styloidectomy is most commonly used for patients with early SLAC or SNAC where OA is confined to the radial styloid. Proximal row carpectomy (PRC) involves excision of the scaphoid, lunate and triquetrum and is a good salvage option for the wrist with significant radioscaphoid arthritis and preserved proximal capitate and lunate fossa of the radius articular surfaces (87). If the radio-lunate joint is intact, scaphoidectomy and midcarpal fusions can be performed. This is usually accomplished with a two-corner fusion including the lunate and capitate, or a four-corner fusion involving the lunate, capitate, triquetrum and hamate (132). PRC and

midcarpal fusions result in less pain and improved functional outcomes but also cause a reduced range of motion and grip strength (133). Total wrist fusion (TWF) is the standard final surgical treatment for patients with painful, advanced wrist OA including destruction of both the radiocarpal and midcarpal joints (134) (Figure 8). It is considered a safe and reliable method resulting in improved grip strength and reduced pain (135, 136). But despite its creation of a stable wrist with minimal pain, the price of TWF is the loss of joint motion (134). Previous studies have shown, nevertheless, that in spite of the loss of wrist motion, the majority of patients surgically treated with a TWF are satisfied with the result (135, 136). Total wrist arthroplasty (TWA) is a motion-preserving surgical alternative where modern implants have been shown to produce good results regarding pain relief, increased grip strength, improved patient-reported outcome and preserved wrist motion with an implant survival of more than 90% at five years (137-139) (Figure 8). TWF and TWA are both surgical alternatives that offers pain relief for chronic wrist pain but TWA is a more expensive and surgically challenging procedure with a history of higher risk of complications (140). Implementing a new surgical treatment, such as TWA, should be contingent on comparison with the current standard of care. The benefit of a motion-preserving surgical procedure, TWA, compared to the standard care, TWF, has previously only been evaluated in systematic reviews (140-142) and small retrospective case series (143, 144), showing similar results regarding pain relief and patient satisfaction for both procedures. In addition, a recent prospective cohort study with a 2-year follow-up, comparing the outcomes of TWF and TWA, found no superiority for TWA over TWF in terms of patient-reported function, pain or grip strength (145). This study also found that persistent pain and activity limitations were common among patients with both TWF and TWA (145).

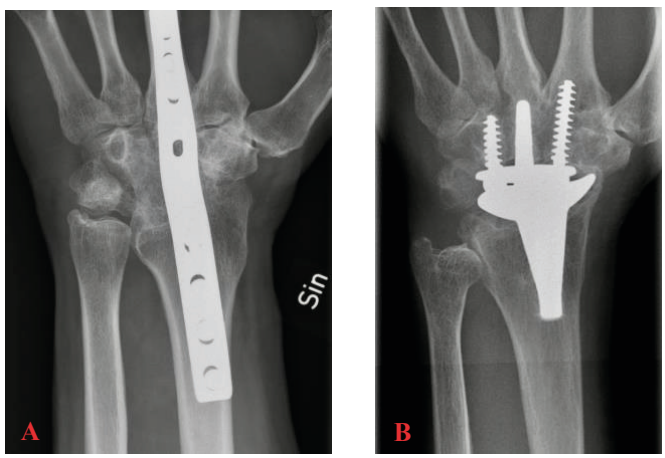

Figure 8. A Total wrist fusion (TWF). **B** Total wrist arthroplasty (TWA). Radiographs, with permission.

A multimodal treatment approach

For hand, hip and knee OA, the American College of Rheumatology/Arthritis Foundation strongly recommend a comprehensive plan for the management of OA that includes educational, behavioural, psychological and physical interventions, as well as topical, oral and intra-articular pharmacological treatments (129). There is strong evidence that the treatment for all patients with OA should be a patient-centered staged approach, starting with self-management strategies including patient education and exercises (61, 62, 72). Treatment options should be tailored to the individual, expectations should be addressed to ensure that they are realistic, and healthcare providers should support a shared decision-making process to promote the ability of OA patients to make an informed decision about their choice of treatment (146-148).

However, this comprehensive, multimodal approach to treating OA patients, including first-line self-management programs with patient education and exercises, is lacking for patients with wrist OA. Participating in a self-management program could empower patients with wrist OA to actively engage in their care and could also widen the possible options in the shared decision-making process. More studies are needed to evaluate the effect of a first-line treatment approach involving education and exercises on patients with wrist OA.

Rationale

Beyond the well-established impairments and difficulties patients with wrist OA face in their everyday life, very little attention has been paid to evaluating the effects that non-pharmaceutical and non-surgical treatments can have. Previous research on wrist OA has mainly focused on exploring and evaluating different surgical treatments, which seems arbitrary since most patients with OA in other joints are first-line treated with patient education and exercises.

When work on this thesis started 2018, I first wanted to explore how individuals with wrist OA experience living with this chronic condition and how they manage their life after being surgically treated with either a TWF or a TWA. What were their main expectations? How important is it to preserve motion (TWA) in contrast to having reduced motion (TWF) in relation to pain-relief? This in-depth understanding of what it is like to live with wrist OA made me realize that there is an obvious research gap in this field: wrist OA is excluded from the first-line treatment approach being offered to those with other OA affected joints, such as the knee, hip and hand. I found a need to include wrist OA in this first-line multimodal treatment approach and to determine whether wrist OA could benefit from self-management programs including patient education and therapeutic exercises. I also found there was a lack of outcome measures with good psychometric properties available to assess the effects of these interventions for wrist OA.

More attention needs to be paid to a number of aspects: to wrist OA itself and increasing knowledge about its effects on the individual; to motion-preserving contra motion-depriving surgery; to the possible benefit of a self-management program; and to the use of psychometrically valid outcome measures. Taken together, this could lead to improved future treatment strategies that could benefit both the patient and the healthcare system. Against this background, an overall aim and more specific aims for the thesis were developed.

Aims

The overall objective of this thesis was to investigate and increase the knowledge of wrist OA from different viewpoints with the patient's ability to function in focus, from acquiring a deeper understanding of patients' experiences of living with a painful wrist to evaluating a novel self-managed neuromuscular joint-protective exercise therapy program.

Specific aims

- To explore patients' experiences of living with advanced wrist OA before and after surgery with either TWF or TWA; the expectations from surgery; appraisal of the results; and the adaptation strategies used to overcome challenges in everyday life after TWF or TWA (Paper I).

- To assess and compare the psychometric properties of the NRS, DASH and PRWE in patients with wrist OA regarding test–retest reliability and construct validity (Paper II).

- To evaluate the placebo-controlled treatment effect of a self-managed neuromuscular exercise therapy program in patients with wrist OA (Papers III-IV).

Material and methods

Study designs

This thesis is based on studies that have three different designs: a qualitative study (Paper I), a cross-sectional test-retest study (Paper II), a study protocol and a randomized controlled trial (RCT) (Papers III and IV). An overview of the study designs, participants, inclusion criteria, data collection and data analyses are shown in Table 1.

Table 1. Overview of study designs, participants, inclusion criteria, data collection and data analyses

	Paper I	Paper II	Papers III and IV
Design	Qualitative	Cross-sectional test-retest	Study protocol and a Randomized controlled trial (RCT)
Participants	Total n=13 (TWF n=7, TWA n=6). TWF: 4 men, 3 women. TWA: 4 men, 2 women	Total n=50 (40 men, 10 women)	Total n=48 Intervention n=24 (20 men, 4 women) Control n=24 (20 men, 4 women)
Inclusion criteria	Surgery with TWF or TWA due to advanced and symptomatic wrist OA	Radiographically confirmed wrist OA and age ≥18	Radiographically confirmed and symptomatic wrist OA - SLAC and SNAC stage 1–3, and age ≥18 years
Data collection	A semistructured interview with open-ended questions	The questionnaires were self-administered by the participants in a postal survey on two occasions	Assessments of pain and patient-reported function performed at baseline and 12 weeks post-inclusion
Data analysis	Conventional content analysis with an inductive approach	Kappa statistics using quadratic weights and the Spearman rank correlation coefficients (rho)	Descriptive statistics. Mann-Whitney U test, Wilcoxon signed-rank test and Chi-square test

Participants

Individuals with wrist OA, seeking care at the Department of Hand Surgery, Skåne University Hospital, Malmö, were retrospectively and prospectively recruited from October 2016 to June 2023. Participants were retrospectively identified via the hospital's administrative system (Papers I and II) and prospectively identified via referral of potential participants by the treating hand surgeon and by monitoring referrals of patients seeking care for wrist OA (Papers III and IV). Descriptive and demographic data such as age, gender, hand dominance, type of OA, type of surgery, OA grade, affected wrist, duration of symptoms, the use of pain medication, social and vocational status were collected in Papers I, II and IV. Figure 9 shows an overview of participants and the timeline for recruitment.

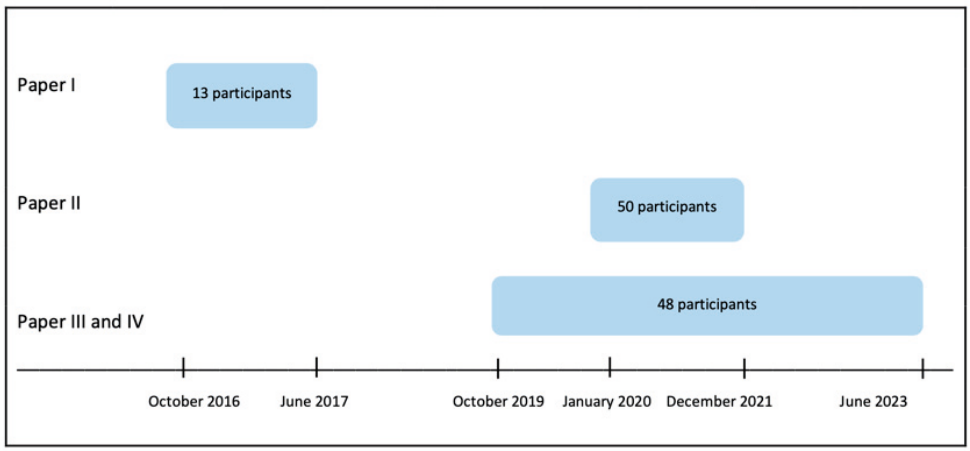

Figure 9. Timeline for recruitment and an overview of participants in Papers I, II and IV.

Experiences of living with advanced wrist OA before and after TWF or TWA surgery (Paper I)

In Paper I, a sample was recruited of 13 patients with advanced wrist OA surgically treated with TWF (n =7) or TWA (n=6). The inclusion criteria were TWF or TWA surgery because of advanced and symptomatic wrist OA. Exclusion criteria were current psychiatric disorders and the inability to communicate in Swedish. In the TWA group, 7 out of 13 patients met the inclusion criteria. One could not be reached due to a lack of contact details, leaving 6 potential participants. In the TWF group, 43 patients met the inclusion criteria, and 8 patients, matching the TWA group, were initially selected. Purposive sampling was used in order to achieve variation in age, gender and year of surgery (TWA, range 2011-2014; TWF, range 2010-2014). Written information about the study was sent out and the potential participants were then contacted by telephone and an interview time was scheduled. All patients with

TWA and 7 of the 8 initially selected patients with TWF agreed to participate in the study. After interviewing the 7 participants in the TWF group and the 6 participants in the TWA group, very little new information was obtained, indicating that data saturation had been reached. In the TWF group, 3 women and 4 men were included with a median age of 49 years; the median time from surgery to interview was 5 years (2-7 years). The TWA group comprised 2 women and 4 men with a median age of 55 years; the median time from surgery to interview was 4.5 years (2-5 years). Characteristics of participants in Paper I are presented in Table 2.

Table 2. Characteristics of the 13 participants surgically treated with TWF or TWA in Paper I

	TWF (n=7)	TWA (n=6)
Gender male/female (n)	4/3	4/2
Age (min-max)	49 (44-75)	55 (38-68)
Surgery dominant hand (n) yes/no	4/3	2/4
Time from surgery to interview (years)	5 (2-7)	4.5 (2-5)
Occupation (n)		
- Retired	2	2
- Unemployed	1	1
- Working	4	3

Values are numbers (n), min-max and years. TWF; total wrist fusion, TWA; total wrist arthroplasty.

Psychometric properties of NRS, DASH and PRWE (Paper II)

In Paper II, 66 patients (54 men, 12 women) were identified via the hospital's administrative patient system and by reviewing the patients' medical records. Inclusion criteria were radiographically confirmed wrist OA and age≥18. Exclusion criteria were the presence of other diseases or disorders that could affect arm and hand function, previous surgery to the wrist and inability to understand and follow test instructions due to communicative impairments, mental or cognitive. Thirteen patients did not respond and three declined to participate, leaving 50 patients (40 men, 10 women) who were included in the study. The mean age was 66 years (41-79) and 76% had wrist OA due to SLAC. Background data – such as gender, age, affected side and handedness – were obtained from medical records. All the participants had wrist radiographs and/or CT scans taken prior to referral to the hand surgery clinic. The characteristics of the participants in Paper II are presented in Table 3.

Table 3. Characteristics of the 50 participants with wrist osteoarthritis in Paper II

Variable	
Age, mean (SD; min-max)	66 (9; 41-79)
Male sex, n (%)	40 (80)
Affected wrist, dominant, n (%)	33 (66)
Type of OA, n (%)	
SLAC	38 (76)
SNAC	6 (12)
Idiopathic OA	5 (10)
Mb Kienböck	1 (2)
Days between T1-T2, mean (SD; min-max)	16.7 (17.4; 4-86)

Values are standard deviations (SD), min-max, numbers (n), percentages (%) and means. SLAC; Scapholunate Advanced Collapse, SNAC; Scaphoid Non-union Advanced Collapse, OA; osteoarthritis, T1 ; Test occasion 1, T2 ; Test occasion 2.

Effects of a neuromuscular exercise therapy program (Paper III and IV)

In Papers III and IV, 111 potential participants were identified as eligible for possible inclusion. The inclusion criteria for participation were radiographically confirmed and symptomatic wrist OA - SLAC and SNAC stages 1–3, and age ≥18 years. Exclusion criteria were the presence of other diseases or disorders that could affect arm and hand function, wrist OA secondary to avascular necrosis of carpal bones, previous surgery to the wrist, intraarticular wrist cortisone injection within the last 3 months and inability to understand and follow test instructions due to communicative impairments, mental or cognitive. Forty-one patients did not meet the inclusion criteria, 18 declined to participate and 4 were already scheduled for surgery, leaving a total of 48 participants who were included in the trial and randomized to either a neuromuscular exercise therapy program (intervention group) or to a placebo training program with range of motion (ROM) exercises (control group). The 22 non-participants (declined participation or scheduled for surgery) did not differ regarding distribution of sex (p=0.30) but were slightly older (p=0.035) than the participants included. Three participants in the intervention group and four in the control group dropped-out before completing the 12-week treatment program. Figure 10 shows a flowchart of recruitment and inclusions in Paper IV.

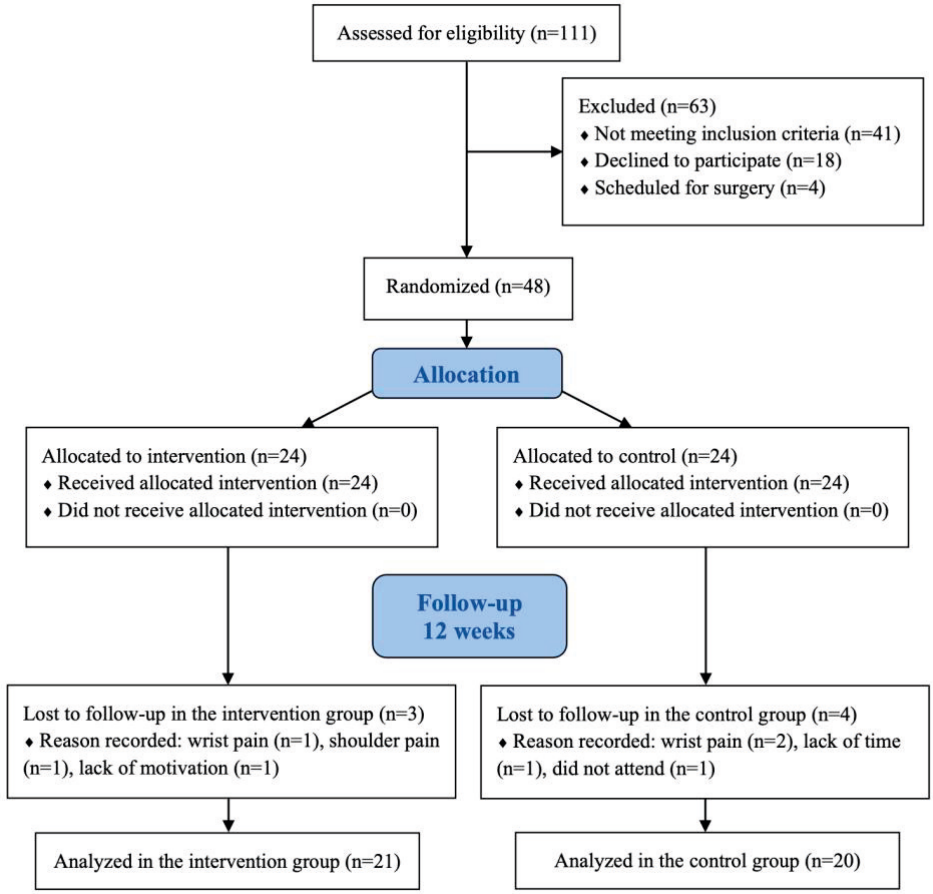

Figure 10. Flowchart of recruitment and inclusions in Paper IV.

The median age in both groups was just above 60 years and most participants had wrist OA on their dominant side. There were more men included in both the intervention (83%) and the control (83%) groups. SLAC wrist was the most common cause of OA in both groups, with a higher frequency of SNAC wrist in the intervention group (21%; control group 4%; p=0.08). Most participants in both groups had grades 2-3 SLAC/SNAC. Participants in the study were also examined with CT of the affected wrist to enable a detailed view of osteoarthritic signs. This resulted in five participants (two in the intervention group and three in the control group) being re-graded from SLAC/SNAC 3 to 4. Characteristics of participants in Paper IV are presented in Table 4.

Table 4. Characterstics of the 48 participants with wrist osteoarthritis in Paper IV

Variable	Intervention group (n=24)	Control group (n=24)
Age, median [IQR]	63 [55-69]	66 [56-70]
Sex, male, n (%)	20 (83)	20 (83)
Occupation, n (%)		
Retired/unemployed	8 (33)	11 (45.8)
Office-based duties	6 (25)	1 (4.2)
Moderately heavy duties	8 (33)	8 (33.3)
Manual labour	2 (8)	4 (16.7)
Type of OA, n (%)		
SLAC	19 (79)	23 (96)
SNAC	5 (21)	1 (4)
OA grade, n (%)		
Grade 1	0 (0)	3 (12.5)
Grade 2	10 (42)	9 (37.5)
Grade 3	12 (50)	9 (37.5)
Grade 4	2 (8)	3 (12.5)
Affected wrist, dominant, n (%)	15 (63)	20 (83)

Values are numbers (n), medians, interquartile range [IQR] and percentages (%). OA; Osteoarthritis, SLAC; Scapholunate Advanced Collapse, SNAC; Scaphoid Non-union Advanced Collapse.

Outcome measures

A variety of outcome measures were used to capture the participants impairments, activity limitations and participation restrictions due to wrist OA. In the qualitative study (Paper I), the outcome measures were used to obtain an overview of the characteristics of the participants. The outcome measures used in Paper IV are described in detail in the study protocol (Paper III). The outcome measures used in all four papers are shown in Table 5 and their relation to ICF is shown in Figure 11.

Table 5. Overview of the outcome measures used in the four papers

Outcome measure	Paper I	Paper II	Papers III and IV
Grip strength, Jamar dynamometer	X		X
Range of wrist motion, goniometer	X		X
Patient-Rated Wrist Evaluation (PRWE)*	X	X	X
Disabilities of the Arm, Shoulder and Hand (DASH)	X	X	X
Generalized Self-Efficacy Scale (GSES)			X
Numerical Pain Rating Scale (NPRS/NRS)		X	X
Visual Analogue Scale (VAS)	X		

*Primary outcome in Paper IV

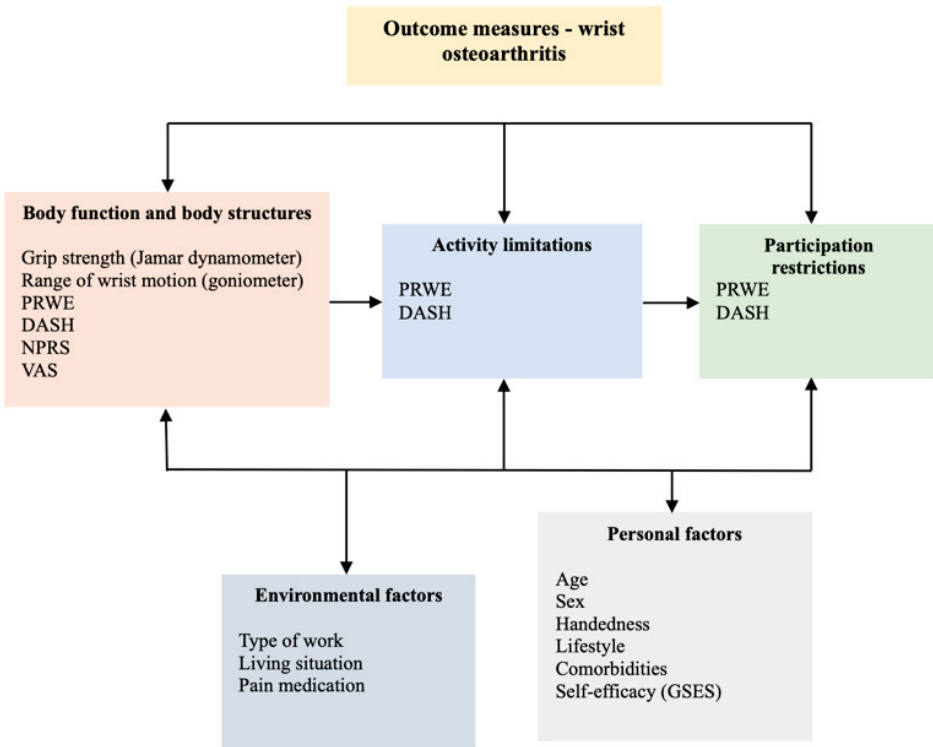

Figure 11. The International Classification of Functioning, Disability, and Health (ICF) model including outcome measures used in this thesis.

Grip strength

Grip strength was measured for both hands using the Jamar hydraulic hand dynamometer (TEC, Clifton, New Jersey, US) (103). According to standardized instructions outlined in the manual developed by the National Quality Registry for Hand Surgery (HAKIR) in Sweden, the participants were seated at a table with the elbow close to the waist, elbow joint in about 90° flexion, forearm and wrist in neutral (149). The dynamometer was supported by the examiner. The measurement started with the non-affected hand and three trials for each hand were measured and recorded. The mean value, recorded in kilograms (kg), for each hand was calculated.

Range of wrist motion

The range of wrist motion (flexion, extension, radial deviation, ulnar deviation, pronation and supination) of the affected wrist (Paper IV) or the surgically treated wrist (Paper I) was measured in degrees with a goniometer. Standardized instructions according to HAKIR were followed (149). Pronation and supination were measured for TWF participants in Paper I.

Patient-Rated Wrist Evaluation

The Patient-Rated Wrist Evaluation (PRWE) is a wrist-specific PROM originally developed for the assessment of perceived disability after a distal radius fracture (109). The questionnaire includes 15 items, divided into two subscales assessing pain (5 items) and function (10 items, 6 concerning specific tasks and 4 the ability to perform daily activities) over the preceding week (109). The questions are scored on a 10-point ordered categorical scale, ranging from no pain or no difficulty (0 points), to worst pain or inability to perform (10 points). The total score of the subscales pain (sum of 5 items) and function (sum of 10 items divided by 2) ranges from 0 to 50. The maximum total score for PRWE is 100 and represents the worst disability, while 0 represents no disability. The Swedish version of PRWE, which is a responsive, valid and reliable patient-rated outcome measure, was used in this thesis (150) (Appendix 1). PRWE was the primary outcome in Paper IV.

Disabilities of the Arm, Shoulder and Hand

The Disabilities of the Arm, Shoulder and Hand (DASH) measures self-reported upper extremity physical function and symptoms taking the whole upper extremity into account, irrespective of which hand or if both hands are used (108). The main part of DASH is a 30-item disability/symptom scale concerning the patient's health status during the preceding week. The items ask about the degree of difficulty in performing various physical activities because of arm, shoulder or hand problems (21 items), the severity of each of the symptoms of pain, activity-related pain,

tingling, weakness and stiffness (5 items), as well as the problem's impact on social activities, work, sleep and self-image (4 items). Each item has five response options. The scores for all items are then used to calculate a scale score ranging from 0 (no disability) to 100 (most severe disability). The validated Swedish version of DASH was used in this thesis (121) (Appendix 2).

Generalized Self-Efficacy Scale

The Generalized Self-Efficacy Scale (GSES) was used to evaluate the participants general beliefs in their ability to solve problems and achieve goals. Self-efficacy affects one's actions, attitudes and outcomes, thus serving as a significant determinant of health behavior (77). The GSES was developed to assess the strength of a person's belief in their ability to respond to novel or difficult situations and to deal with any associated obstacles or setbacks (151). The GSES is a ten-item scale, where each item ranges from 1 ("not at all true") to 4 ("exactly true"). Scores are summed across the ten-items to give a total score, with a possible range of 10-40. Higher scores indicate greater confidence in generalized self-efficacy. The validated Swedish version of GSES was used in this thesis (152) (Appendix 3).

Numerical Pain Rating Scale/Numerical Rating Scale

The Numerical Pain Rating Scale (NPRS), also called the Numerical Rating Scale (NRS), is a numeric 11-point pain-rating box scale with numerical descriptors beneath the box, ranging from 0 representing one pain extreme (no pain) to 10 representing the other pain extreme (worst pain imaginable) (111). Participants select a value that is most in line with the intensity of pain they have perceived in the affected wrist over the last week. Three measures of pain were used: 1) pain at rest, 2) pain on motion without load and 3) pain on load.

Visual Analogue Scale

The Visual Analogue Scale (VAS) was used to rate pain in Paper I (112). The VAS consists of a horizonal line, 100 mm long, where 0 mm indicates "no pain" and 100 mm indicates "most severe pain". A high correlation between VAS and NRS has been established, allowing both scales to be used for the rating of pain (114). The participants in Paper I rated VAS pain at rest, pain on motion without load and pain on load.

The two following outcome measures are described in the study protocol (Paper III) and will be used in the future 6- and 12-month follow-ups of the participants in Paper IV.

Global Rating of Change

The Global Rating of Change (GROC) measures self-perceived changes in health status over time and has come to be widely used in both research settings and clinical practice for determining clinically important change and measuring outcome (153). The GROC score involves a single question that asks the participant to rate the change they have experienced with respect to a particular condition, from the time they began treatment to the time they answered the question. The question outlined in Paper III was "Regarding your wrist problems, how would you describe your wrist now compared to before the training period?". The rating is based on an 11-point self-report Likert scale (from −5 to 5), where a "−5" indicates "a very great deal worse," "0" indicates "about the same," and "+5" indicates "a very great deal better".

Conversion to Surgery

Conversion to surgery is also described in the study protocol (Paper III). The percentage of participants requiring surgery 6- and 12-months post-inclusion in both groups is compared. Comparison of conversion to surgery has been used in previous clinical trials to determine the success of non-surgical management (14).

Data collection

Experiences of living with advanced wrist OA before and after surgery with TWF or TWA (Paper I)

In Paper I, all interviews were conducted by the first author (SL). The interviews were tape-recorded and lasted a mean of 42 minutes (range 29-55 minutes). A semistructured interview guide was developed by the first author in order to cover different aspects of wrist OA both before and after surgery (Appendix 4). The participants were asked to describe their experiences of living with a painful wrist, their expectations and involvement in the decision to undergo surgery, their appraisal of results after having a TWF or TWA, the consequences of surgery on their level of activity, and participation in daily life and the coping strategies they used. To obtain a rich description, follow-up questions such as "Can you describe that in more detail?", and "How did you experience that?" were asked. The interviews were transcribed verbatim by the first author and a secretary.

Psychometric properties of NRS, DASH and PRWE (Paper II)

In Paper II, information about the study together with an informed consent form was sent to the participants by surface mail together with the PROMs (NRS, DASH and

PRWE) for test occasion 1 (T1). The participants noted the date when the questionnaires were completed and returned them in a prepaid envelope. When the responses to the T1 questionnaires were received, the same questionnaires for test occasion 2 (T2) were sent to the participants. If a participant failed to send T2 within two weeks, they were reminded by telephone or a second surface mail communication. The time interval for the responses between T1 and T2 was approximately two weeks.

Effects of a neuromuscular exercise therapy program (Papers III and IV)

In Paper IV, PRWE was the primary outcome measure, and grip strength, range of wrist motion, NPRS, DASH and GSES were the secondary outcome measures. The outcome measures were assessed at baseline and 12 weeks.

Randomisation and blinding

Participants were randomly assigned to the neuromuscular exercise therapy program (intervention group) or to the placebo training program with ROM exercises (control group) by selecting a sealed envelope indicating the group allocation. The sequence was generated using block randomization with the size of 10 in each block. Participants were not told which group they had been allocated to. An experienced blinded PT at the clinic performed all the evaluations at baseline and the 12-week follow-up. The treating hand surgeons and the hand surgeons assessing the radiological wrist OA stage were also blinded to group allocation.

Baseline assessment

Background information regarding 1) medical and social history, 2) demographic data, and 3) the use of pain medication was collected at the baseline assessment. The participants also reported, in pre-defined box alternatives, their main problem with the wrist, their main expectation of the allocated treatment program, whether or not they had discussed surgical treatment with their hand surgeon and their own thoughts about surgery.

Trial procedure

Both groups received a booklet with structured education about wrist OA pathophysiology, the rationale behind exercise treatment, self-management strategies, activity modification principles, and their allocated exercise program. The participants were instructed to adopt the functional and most stable neutral wrist position, shown in Figure 12, in activities of daily living and were equipped with a stable wrist orthosis to wear, particularly during pain-provoking activities but also at night-time if needed.

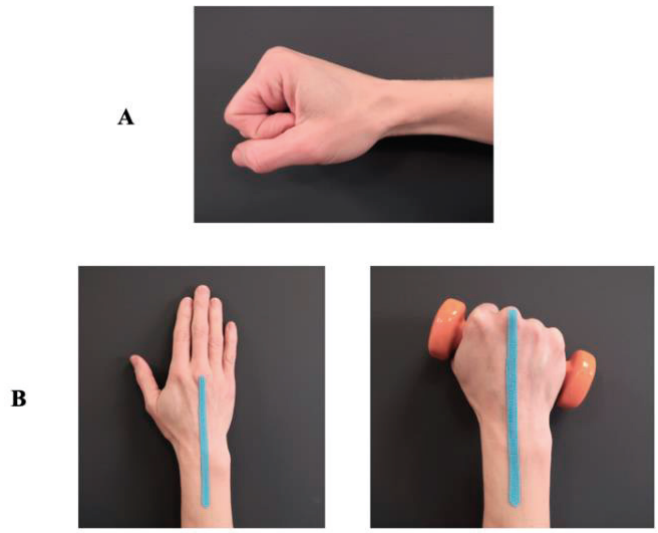

Figure 12. The neutral wrist position. **A** In the sagittal plane, the wrist is in slight extension. **B** In the frontal plane, the third metacarpal bone is in line with the forearm.

The participants were told how to perform the allocated treatment program on the same day they had their baseline assessment, and the treatments were then continued as structured home-based programs performed by the participants twice a day for 12 weeks. The participants were instructed to perform their exercises within a pain-free range with good quality of movement – smooth, coordinated and without compensatory movements. To ensure compliance with the treatment programs, participants in both groups were followed up at the clinic at 2, 6 and 12 weeks after baseline, and by phone at 4 and 8 weeks after baseline. A detailed explanation of the self-management strategies, the structured education and the two treatment programs is given in the study protocol (Paper III). A flowchart of the content and follow-ups for the intervention group compared to the control group is shown in Figure 13.

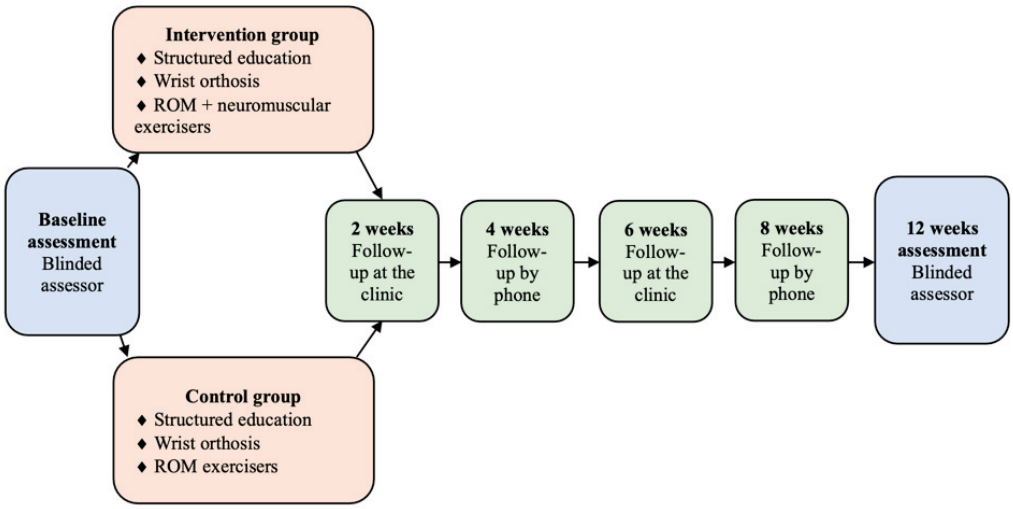

Figure 13. Flowchart of the content and follow-ups for the intervention group compared to the control group. ROM: Range of Motion.

The neuromuscular exercise therapy program (intervention group)

The neuromuscular exercise therapy program was designed based on findings from previous studies on wrist stability and proprioception (34, 40, 42, 43). The program focused on functional re-learning and strengthening of the musculoskeletal system with the aim of creating a stable wrist that could be used in a pain-free manner in daily activities (40). The program consisted of two parts. The first part included unloaded active ROM exercises for the wrist in flexion/extension, radial-/ulnar deviation, and pronation/supination (Figure 14). The second part consisted of neuromuscular exercises that focused on coordination, wrist stability and strength (Figure 15). The exercises in the first part of the program were performed with 10 repetitions and in the second part with 10 x 2 repetitions, twice daily for 12 weeks.

The ROM training program (control group)

The training program for the control group included the above-mentioned ROM exercises (Figure 14). The exercises were performed with 10 x 2 repetitions twice a day for 12 weeks.

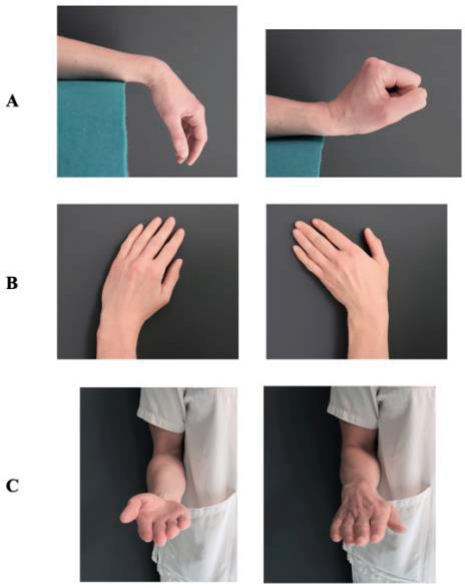

Figure 14. The training program with the range of wrist motion exercises performed by both groups. **A** Flexion and extension. **B** Radial- and ulnar deviation. **C** Supination and pronation.

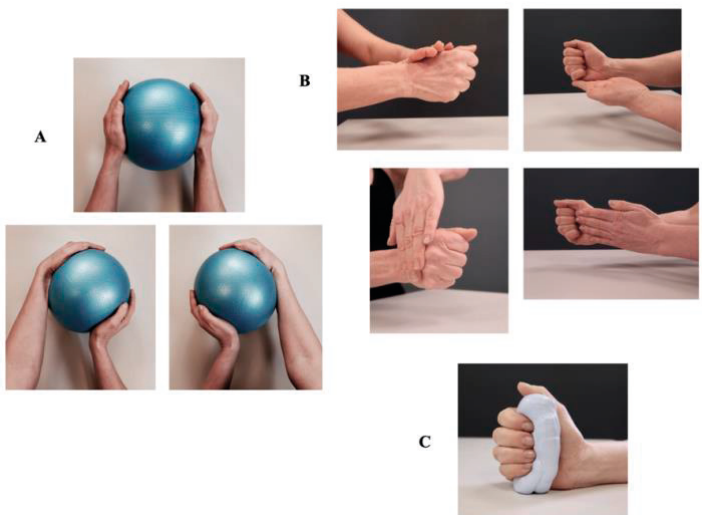

Figure 15. The neuromuscular exercise therapy program performed by the intervention group. **A** Coordination and co-activation exercise. This is a closed-chain isometric and active range of wrist motion exercise with a ball, training co-activation and coordination. **B** Isometric exercise. The participants applied manual isometric resistance to the long extrinsic muscles of the wrist, while at the same time maintaining a stable and neutral position. **C** Strength exercise. The patients squeezed a silicon putty dough while maintaining the wrist in a neutral position.

Data analyses

Qualitative content analysis

A qualitative descriptive research design was used in Paper I to reach a deeper understanding of patients' experiences of living with painful wrist OA and how they managed their life after being surgically treated with either TWF or TWA (154). The addition of qualitative methods can help us better understand and appraise a phenomenon and also find new ways of addressing research (154). Qualitative research is an important complement to quantitative research since it can generate hypotheses and provide more in-depth knowledge.

Conventional content analysis with an inductive approach was used in Paper I as the aim was to describe a phenomenon, i.e., the participants' experiences before and after surgery with TWF or TWA (154, 155). This type of design is appropriate when knowledge of the phenomenon is limited and when the analysis, involving codes and categories, has to emerge from the textual data. Both a manifest content, with a focus on the descriptive surface structure of the text, and a latent content analysis, involving a low degree of interpretation, were used (154-157).

The first step in the analysis in Paper I was that all interviews were read and re-read by the first, second and last authors in order to gain a sense of the entire study. Meaning units, words or sentences related to the aim of the study, were identified and coded while still preserving their core meaning, i.e., the manifest content. Codes that were similar regarding their content or context were grouped together. Categories and sub-categories were identified and similar statements were analyzed critically and questioned in order to arrive at a reasonable interpretation and latent analysis (154). The categories were then discussed with the third and fourth authors and adjustments were made to ensure that the categories covered all aspects of the text. In the final step, the categories were compared with the text and with each other.

The quality criteria in qualitative research – trustworthiness – involves the concepts of *credibility, dependability, confirmability and transferability* (154, 158).

Credibility deals with the focus of the research and determines whether the research findings represent believable information drawn from the participants' original textual data and are an accurate interpretation of their views (154).

Dependability describes how reliable the data are over time. When data are broad and the collection period prolonged, there is a risk of inconsistency during data collection (154).

Confirmability concerns the neutrality and accuracy of the data. The interpretation should be grounded in the data, and not in personal preferences or viewpoints (158).

Transferability refers to the magnitude of which the data can be applied and transferred to other contexts or groups (154). To ensure transferability, a thorough description of the participants and the research process needs to be presented.

Statistical analyses

Descriptive statistics – such as frequencies, means and standard deviations (SD) and medians, interquartile range (IQR), minimum and maximum (min-max) – were used to present demographic data and clinical characteristics in Papers, I, II and IV. In Paper I, the data were presented descriptively to obtain an overview of participant characteristics.

In Paper II, test-retest reliability of NRS (pain at rest; pain on motion without load and pain on load), DASH (total score) and PRWE (total score and subscales pain and function) were evaluated using the Kappa coefficient (quadratic weights). The Kappa coefficient is used when the data are non-parametric and is calculated as the proportion of agreement observed beyond the expected chance agreement (159-161). The strength of the Kappa coefficient can be interpreted as follows: <0.40 poor; 0.40 to 0.75 fair to good; and >0.75 excellent (162). The Spearman rank correlation coefficients (rho) were calculated to evaluate construct validity. The PRWE and DASH were correlated to NRS, and the correlation between PRWE and DASH was also calculated. Data from the first test occasion were used in the construct validity analyses. The strength of the correlations was interpreted as: rho <0.5 low; 0.5 to <0.7 moderate; and >0.7 high (163). Data were analyzed with the IBM SPSS Statistics version 27 (IBM Corporation, Armonk, New York, United States). P-values <0.05 were considered statistically significant.

In Paper III, the sample size estimate of the RCT (Paper IV) was calculated based on the minimal clinically important difference (MCID) of 12.5 for the primary outcome PRWE (164, 165). With a standard deviation (SD) of 14, power (beta) at 0.8, a significance level (alpha) at 0.05, and a 2-tailed test, the power calculations indicated a sample size of 40 patients, 20 in each group. Allowing for a drop-out rate of 20%, it was calculated that a total of 48 patients should be included in the trial (Paper IV).

In Paper IV, as data were not normally distributed according to the Shapiro-Wilks test, non-parametric tests were used in the analyses. Group demographics at baseline were analyzed using a Mann-Whitney U test and a Chi-square test. To test the effect of the intervention at the primary endpoint of 12 weeks, differences between the groups were analyzed using the Mann-Whitney U test. Within-group differences, from baseline to 12 weeks, were analyzed using the Wilcoxon signed-rank test. Data were analyzed using IBM SPSS Statistics version 29 (IBM Corporation, Armonk, NY, USA) and the level of statistical significance was set at $p<0.05$.

Ethics

The ethical guidelines stated in the Declaration of Helsinki were followed in all studies. Paper I was approved by the Regional Ethical Board in Lund (Dnr 2015/121) and Papers II-IV were approved by the Swedish Ethical Review Authority (Dnr 2019-02437). In addition, Paper IV was retrospectively registered on 10/05/2022 at Clinical Trials.gov (NCT05367817).

Prior to inclusion, written and verbal information about the studies was provided and all participants gave their written consent to participation. The information included the purpose of the study, the study procedure and the right to withdraw from the studies at any time without giving an explanation and without any negative consequences for their future healthcare. Data from all studies were decoded and stored in binders and in a secure database.

In the qualitative study (Paper I) the participants provided personal information and experiences. To safeguard the participants' integrity, the questions in the semi-structured interview guide were not couched in harmful or unpleasant terms. The interviews took place in a calm environment with time included for questions and reflections.

The participants in Paper II were contacted by telephone and given information about the study and the voluntary nature of their participation was given. They were also sent written information about the study to ensure that they thoroughly understood what their participation involved.

In Paper IV, there were no safety concerns for the participants regarding the implementation of the two treatment programs. During their participation, they were followed up several times at the clinic and by telephone to ensure they were performing the exercises correctly and that no adverse events had occurred. The clinical examinations and the questionnaires are recognized healthcare methods and were not considered to pose any threat of harm or discomfort to the participants.

Results

The general results of the studies are presented in this part of the thesis. Full details can be found in Papers I-IV included at the end of the thesis.

Patients' experiences before and after total wrist fusion or total wrist arthroplasty (Paper I)

Thirteen individuals participated in Paper I: seven treated surgically with TWF and six treated surgically with TWA, all due to symptomatic advanced wrist OA. The participants described a wide range of impairments, activity limitations and participation restrictions and how these affected the quality of life before and after surgery. The qualitative analysis of the interviews resulted in four categories: (1) *the problematic wrist*; (2) *the breakpoint*; (3) *appraisal of the results*; and (4) *adaptation to challenges in everyday life* (Table 6).

Table 6. Overview of the categories and sub-categories

Categories	Sub-categories
The problematic wrist	Living with pain. Impact on activity and participation. Dependency on others.
The breakpoint	Decision to undergo surgery. Involvement in the decision to undergo surgery. Expectations of surgery.
Appraisal of the results	Pain. Stiffness versus motion. Impact on activity and participation.
Adaptation to challenges in everyday life	Compensatory movement patterns. Adjustments to everyday domestic life. Seeking assistance. Change of occupation and work tasks. Positive thinking and acceptance.

The problematic wrist comprises the experiences of living with a painful wrist and its impact on daily life. *The breakpoint* includes the participants' experiences of involvement in the surgical decision and their expectations of surgery. *Appraisal of the results* refers to the perceived outcome after TWF or TWA surgery and how the results corresponded to the participants' expectations of the surgery. *Adaptation to*

challenges in everyday life covers the different coping strategies used by the participants.

The problematic wrist

Living with advanced wrist OA meant living with a constantly aching body part that affected the participants' whole lives. The painful wrist had an impact on daily activities and participation in social activities. The constant pain and disability meant being dependent on their work colleagues, family members, or friends to be able to carry out various tasks.

The breakpoint

Living with unbearable constant pain and the desire to be free from it caused the participants to reach a breakpoint where they felt the need to undergo extensive wrist surgery. For TWF participants, being assured that they would have an almost completely pain-free wrist was more important than trying to preserve some of the movement. However, the preservation of some wrist motion played an important role in choosing to have a TWA. All participants felt involved in the surgical decision and becoming pain free was the main expectation. No great demands on motion and strength were expressed. Instead, there was anticipation that different life roles would be regained. Several previous surgeries contributed to lower expectations about the effect of the TWF or TWA.

Appraisal of the results

Most of the TWF participants stated that it was worth having the motion-sacrificing surgery since they got rid of the pain. TWA participants valued their wrist motion highly and the level of pain relief varied from being pain-free to having less pain than before the surgery. However, if the pain got worse, TWF was seen as an alternative. Both TWF and TWA participants struggled with fine motor functions but overall improvements in the ability to perform ordinary daily activities and participate in social life were described in both groups.

Adaptations to challenges in everyday life

Compensatory movement patterns – caused by stiffness of the wrist, not trusting the wrist, pain, fatigue and the fear of damaging the wrist – were employed in order to manage daily activities. Adjusting to different ways of doing things became part of life for all participants. This required new learning skills as well as inventiveness and was described as an ongoing process. Asking for help was mentioned as a possible strategy if things became too difficult but was used with mixed feelings about being a burden and wanting to be self-sufficient. Being forced to give up manually demanding occupations and train for more administration related services was mentioned in both groups. The creation of a different mindset – positive thinking and acceptance – was one way of handling the feelings and thoughts about the limitations experienced in everyday life due to the wrist.

Psychometric properties of outcome measures (Paper II)

The NRS, DASH and PRWE demonstrated excellent test–retest reliability and moderate to high construct validity in patients with wrist OA. The Kappa coefficients for DASH, PRWE, NRS pain on motion without load and NRS pain on load were >0.90, while NRS pain at rest was 0.83 (Table 7).

Table 7. Test-retest reliability of NRS, DASH and PRWE

PROMs	T1, median [IQR]	T2, median [IQR]	Kappa coefficient (CI 95%)
NRS			
Pain at rest	3 [1–5]	3 [1–6]	0.83 (0.73–0.92)
Pain on motion without load	6 [3–8]	6 [3–8]	0.91 (0.86–0.95)
Pain on load	8 [5–9]	7 [5–9]	0.92 (0.87–0.96)
DASH	37.1 [21.5–55.4]	38.4 [22.9–54.6]	0.91 (0.84–0.98)
PRWE			
Pain	30.5 [22.5–38.0]	31.5 [23.0–38.3]	0.93 (0.90–0.97)
Function	26.8 [13.4–34.7]	24.5 [14.7–36.0]	0.93 (0.88–0.98)
Total score	56.0 [31.5–69.5]	53.5 [35.4–75.4]	0.94 (0.91–0.98)

T1; Test occasion 1, T2; Test occasion 2, IQR; Interquartile range, CI; Confidence interval, NRS; Numeric Rating Scale, DASH; Disabilities of the Arm, Shoulder and Hand, PRWE; Patient-Rated Wrist Evaluation.

The strongest correlations were found between PRWE and NRS pain on motion without load, and between PRWE total score and DASH. The PRWE subscale pain correlated more closely to NRS pain at rest than the other measures. Somewhat lower correlations were seen between DASH and NRS (Table 8). The p-value for all correlations was <0.001.

Table 8. Spearman rank correlations (rho) between NRS, DASH and PRWE

PROMS	PRWE total	PRWE pain	PRWE function	DASH
	Rho	**Rho**	**Rho**	**Rho**
NRS pain at rest	0.80	0.84	0.74	0.68
NRS pain on motion	0.91	0.89	0.89	0.80
NRS pain on load	0.86	0.79	0.80	0.71
DASH	0.86	0.83	0.84	-

NRS; Numeric Rating Scale, DASH; Disabilities of the Arm, Shoulder and Hand, PRWE; Patient-Rated Wrist Evaluation.

Effects of a neuromuscular joint-protective exercise therapy program for treatment of wrist osteoarthritis (Papers III and IV)

In Paper IV, there were no differences between the two groups in participant characteristics, patient-reported wrist function, pain, grip strength or range of wrist motion at baseline (Table 9).

Table 9. Comparison of baseline characteristics of the primary and secondary outcomes between the intervention group and the control group

Outcome measure	Intervention (n=24)	Control (n=24)	p-value
PRWE			
Pain	31 [19-39]	31 [22-35]	0.81
Function	20 [12-25]	25 [16-32]	0.17
Total	51 [33-67]	56 [40-64]	0.54
DASH	31 [21-41]	36 [28-50]	0.29
NPRS			
At rest	3 [1-5]	3 [1-5]	0.86
On motion	7 [4-8]	5 [3-8]	0.37
On load	8 [7-9]	8 [5-8]	0.07
GSES	32 [28-36]	31 [27-35]	0.73
Wrist ROM (°)†			
Extension	43 [30-55]	50 [36-55]	0.63
Flexion	40 [23-45]	30 [20-40]	0.18
Radialdeviation	10 [5-10]	10 [5-10]	0.78
Ulnardeviation	20 [15-25]	20 [20-30]	0.34
Pronation	70 [60-70]	70 [61-74]	0.56
Supination	78 [66-80]	75 [65-80]	0.43
Grip strength †	28 [23-36]	26 [18-37]	0.70

Values are medians and interquartile range [IQR], if not specified as degrees (°). PRWE; Patient-Rated Wrist Evaluation, DASH; Disabilities of the Arm, Shoulder and Hand, NPRS; Numerical Pain Rating Scale, GSES; Generalized Self-Efficacy Scale, ROM; Range of Motion. †Wrist ROM and grip strength were measured on the affected wrist and hand.

Main symptoms and expectations

At baseline the participants were asked, choosing among pre-defined answer options, about their perceived main problems with their OA wrist and their main expectations of the exercise programs. In both groups, pain was the main problem, and pain reduction was the main expectation from the allocated exercise program. Most participants had discussed surgical options with their treating hand surgeon. Regarding the participants' views on surgical treatment, a majority of the participants in both groups did not want to be treated surgically, wanted to avoid surgery as long as possible, or wanted surgery if the pain got worse (Table 10).

Table 10. Baseline characteristics of the predefined answer options to the questions

Pre-defined questions	Intervention (n=23)*	Control (n=24)
Main problem with the wrist, n (%)		
Pain	22 (96)	21 (88)
Stiffness	1 (4)	0 (0)
Impaired grip strength	0 (0)	3 (12)
Main expectation of exercise treatment, n (%)		
Reduced pain	20 (87)	19 (79)
Improved range of wrist motion	1 (4.3)	0 (0)
Improved strength	1 (4.3)	4 (17)
Don't know	1 (4.3)	1 (4)
Discussed surgery, n (%)		
Yes	21 (91)	19 (79)
No	2 (9)	5 (21)
Views on surgery, n (%)**		
Yes	3 (13)	4 (17)
No	12 (52)	7 (29)
If pain gets worse	6 (26)	2 (8)
Avoid as long as possible	2 (9)	7 (29)
Don't know	0 (0)	3 (13)

Values are numbers (n) and percentages (%).*One missing in the intervention group. ** One missing in the control group.

Effects of the neuromuscular exercise therapy program

Between-group differences

Regarding the primary outcome PRWE, there were no statistically significant differences between the groups at 12 weeks, either for the subscales or the total sum score (p=0.13-0.82). A significant difference in the DASH score was found with better patient-reported hand function in the intervention group (p=0.02). No significant differences for the other secondary outcomes were found between the groups (Table 11).

Table 11. Between-group comparisons for the primary and secondary outcomes at 12 weeks

Outcome measure	Intervention (n=21)	Control (n=20)	p-value
PRWE			
Pain	27 [13–34]	28 [21–36]	0.82
Function	16 [5–28]	25 [19–33]	0.13
Total	46 [16–63]	52 [41–68]	0.27
DASH	24 [13–35]	43 [26–53]	**0.02**
NPRS			
At rest	3 [0–5]	4 [2–7]	0.12
On motion	4 [2–7]	5 [3–8]	0.25
On load	6 [4–8]	7 [5–8]	0.69
GSES, median	33 [24–37]	32 [28–36]	0.76
Wrist ROM (°)*†			
Extension	48 [36–60]	45 [35–54]	0.53
Flexion	45 [30–45]	30 [20–50]	0.25
Radialdeviation	10 [6–15]	7.5 [5–10]	0.09
Ulnardeviation	20 [20–30]	20 [20–25]	0.95
Pronation	70 [61–75]	70 [65–79]	0.82
Supination	78 [70–80]	72 [70–80]	0.34
Grip strength*†	28 [22–39]	29 [22–34]	0.95

Values are medians and interquartile range [IQR], if not specified as degrees (°). PRWE; Patient Rated Wrist Evaluation, DASH; Disabilities of the Arm, Shoulder and Hand, NPRS; Numerical Pain Rating Scale, GSES; Generalized Self-Efficacy Scale, ROM; Range Of Motion. *Missing values in control group; 1 participant. †Wrist ROM and grip strength were measured on the affected wrist and hand.

Within-group differences

There were no significant within-group differences for the primary outcome PRWE in either group at 12 weeks (Table 12). Significant differences regarding NPRS on load (p=0.006), ROM flexion (p=0.03) and radial deviation (p=0.03) were found in the intervention group. In the control group, significant differences were found for GSES (p=0.04) and grip strength (p=0.02). However, the only clinically important within-group difference was found for NPRS on load in the intervention group. This significant difference reached a clinically important reduction in pain of 2 median points (Table 12).

Table 12. Within-group comparisons for the primary and secondary outcomes at 12 weeks

Outcome	Intervention (n=21)			Control (n=20)		
	Baseline	**12 weeks**	**p-value**	**Baseline**	**12 weeks**	**p-value**
PRWE						
Pain	31 [20–39]	27 [13–34]	0.13	31 [23–37]	28 [21–36]	0.13
Function	20 [11–24]	16 [5–28]	0.17	25 [19–35]	25 [19–33]	0.38
Total	50 [34–60]	46 [16–63]	0.13	56 [44–68]	52 [41–68]	0.17
DASH	31 [21–40]	24 [13–35]	0.09	36 [29–52]	43 [26–53]	0.91
NPRS						
At rest	3 [1–5]	3 [0–5]	0.44	3 [2–5]	4 [2–7]	0.46
On motion	6 [4–8]	4 [2–7]	0.07	5 [3–8]	5 [3–8]	0.61
On load	8 [7–9]	6 [4–8]	**0.006**	8 [4–8]	7 [5–8]	0.31
GSES	32 [28–36]	33 [24–37]	0.55	31 (27–35)	32 [28–36]	**0.04**
Wrist ROM (°)*†						
Extension	45 [30–55]	48 [36–60]	0.50	50 [35–55]	45 [35–54]	0.50
Flexion	40 [25–48]	45 [30–45]	**0.03**	30 [20–40]	30 [20–50]	0.12
Radialdeviation	10 [5–10]	10 [6–15]	**0.03**	5 [1–10]	7.5 [5–10]	0.78
Ulnardeviation	20 [18–25]	20 [20–30]	0.52	20 [16–25]	20 [20–25]	0.22
Pronation	70 [60–73]	70 [61–75]	0.23	70 [61–74]	70 [65–79]	0.41
Supination	75 [68–80]	78 [70–80]	0.33	75 [65–80]	72 [70–80]	0.85
Grip strength *†	29 [24–36]	28 [22–39]	0.06	26 [18–37]	29 [22–34]	**0.02**

Values are medians and interquartile range [IQR], if not specified as degrees (°). PRWE; Patient Rated Wrist Evaluation, DASH; Disabilities of the Arm, Shoulder and Hand, NPRS; Numerical Pain Rating Scale, GSES; Generalized Self-Efficacy Scale, ROM; Range Of Motion. *Missing values in control group; 1 participant. †Wrist ROM and grip strength were measured on the affected wrist and hand.

Discussion

This thesis focuses on increasing the knowledge available concerning wrist OA from various viewpoints, with emphasis on the patient's ability to function. Individuals with wrist OA can suffer from pain, functional limitations and difficulties in their everyday life. Regardless of this, surprisingly little attention has previously been paid to investigating the patients' own wishes and thoughts about their care. The majority of patients with wrist OA also do not seem to have been offered a first-line treatment approach, such as patient education and exercises, to the same extent as patients with knee, hip, and hand OA. The results of the studies in this thesis provide for an enhanced understanding of how patients' reason about their surgical choices between a motion-preserving procedure (TWA) as opposed to a motion-sacrificing one (TWF) and how they cope with life after TWF or TWA. This thesis also shows that pain and function in wrist OA can be reliably measured using NRS, DASH and PRWE. It made, to my knowledge, a first attempt to incorporate wrist OA in a first-line exercise therapy treatment approach. Even though the neuromuscular exercise therapy program was not superior in reducing pain and improving function compared to a training program comprising range of motion exercises at 12 weeks, the thesis has, nevertheless, highlighted the research gap within this area, paving the way for future research projects.

Impact on daily life

Impact of wrist osteoarthritis and the surgical process

In Paper I, the participants with advanced wrist OA described symptoms and consequences according to all levels of ICF, i.e., impairments, activity limitations, participation restrictions and also personal and environmental factors. Living with painful advanced wrist OA limited the participants ability to function as desired and had a huge negative impact on their daily life. Although living with wrist OA can be tolerated well for many years, the participants eventually reached a breaking point, and they wanted to discuss surgical options with a hand surgeon. The participants wanted to regain different life-roles, such as going back to work or picking up their grand-children, and surgery was now viewed as the only effective option. Such experiences of unintended changes in life-roles can negatively affect self-image and self-confidence and can create a sense of inadequacy, as was

expressed by participants in Paper I (166). The effects a change in life-roles can have on a person's quality of life have also been established in previous research exploring the consequences after a hand or wrist injury (167-169). This emphasizes the importance of acknowledging life situations and occupations of patients. The participants saw the surgical decision as part of a wider picture in which, for some, high demands on wrist motion and strength were not important. Instead, there was a desire to be able to manage daily activities without pain. The decision to undergo surgery differs from other decisions in healthcare since it is an irreversible intervention that could potentially fail to improve the patient or sometimes even cause them more harm. Surgery is often seen as "the last resort" where patients may want to try other conservative treatment options first (147). A majority of the participants in Paper I expressed that they wanted to discuss options actively and share their opinions about the treatment with their surgeon. This view highlights the importance of including patients and making them an active part of their healthcare. In fact, a shared decision-making process has been shown to lead to improvements in health outcomes since it helps patients to consider and share their preferences regarding the treatment and enables the surgeons to elicit these preferences and incorporate them into the final decision (148, 170). Recommendations and guidelines for how to achieve this have been presented stating that the healthcare provider should openly discuss the risks, benefits and consequences for each surgical option, clarifying what the person hopes to gain from the treatment and resolving any misconceptions (171). There should be enough time to answer questions and the chance to have a further opportunity to discuss options. In Paper I, some participants were only presented with TWF, and the alternative of TWA was never discussed. The reasons for this were not analysed, but it suggests that the decision-making process between the surgeon and the patient needs more attention. However, patients may also leave the final decision to the surgeon because of their own lack of knowledge and experience, which was expressed by some of the participants in Paper I (172). It may be assumed that the surgeon's personal experience and technical skills probably affect the information shared with the patient and influence the options the patient is presented with. In order to support the patient and surgeon in making careful treatment decisions, it is suggested that evidence-based decision aids, consisting of written information about the disease and the treatment options available with their associated benefits and harms, could be used (173). In addition to this, to further enable individualized treatment options and enhance empowerment, patients with wrist OA scheduled for surgery should be offered a physiotherapist-led intervention before surgery. In such an intervention, the support people need to make an informed decision , when faced with making a choice from among various options, can be tailored and individualized to ensure expectations are realistic (174, 175). In this setting, more time could be allowed for giving information and answering questions about the consequences of wrist surgery and post-operative rehabilitation, and there would be more chance of additional follow-up appointments. Extra support is often needed to redress overly

high expectations, and the opportunity to further discuss treatment options and expectations can improve adherence and postoperative satisfaction (146).

Total wrist fusion versus total wrist arthroplasty

To add to the knowledge about the benefits or detriments of TWA compared to TWF, Paper I aimed to explore how the participants perceived the outcome after a motion-preserving versus a motion-sacrificing surgical treatment. This paper found that the participants' individual expectations, previous surgical experiences, preceding wrist motion, personality, life situation and occupation, influenced the surgical choice between TWF and TWA. The main expectation of surgery was pain relief and since some of the participants had lived with chronic wrist pain for many years, resulting in both pain and limited motion in the wrist, TWF was seen as the best surgical option. For participants who had limited wrist motion before TWF, the loss of movement was also not seen as such a big problem. For participants who had more motion in their wrist prior to surgery, in combination with pain, TWA was seen as better option. TWF was also preferred if the participants had undergone previous surgeries to the wrist; they wanted a final surgery. The TWA participants differed. They were more prepared to undergo further surgery, such as TWF, if needed. This view of preserving wrist movement *now* with a TWA, even if it entailed the risk of additional future surgeries, was seen in a study exploring how knee and hip OA patients' reason regarding the optimal timing for joint replacement surgery (176). In this study, some patients in their 40s and 50s, who were told by the surgeon they were too young for surgery, still wanted joint replacement surgery to improve their quality of life despite the risk of future revision surgeries. TWA participants in Paper I shared this view and saw the preservation of wrist motion as a prerequisite for an improved quality of current life, regardless of possible future consequences. It is easy to assume that keeping some wrist motion, as with TWA, is equivalent to increased post-operative function and satisfaction. For some participants in Paper I, this was true. However, the pain-relief that TWF offered outweighed the negative consequences of losing wrist movement for most of the participants. Thus, the patients' readiness to accept the risk of additional surgery and the preoperative range of wrist motion should be taken into account when discussing different surgical options with patients. In addition, the participants in Paper I, who had either TWF or TWA as a first line treatment, experienced more pain relief after surgery than participants who had undergone several previous surgeries before the TWF or TWA. This makes one wonder whether the discussion about TWF or TWA should perhaps be taken up earlier in the surgical intervention process.

The TWA participants in Paper I thought that preserving wrist movement was essential for being able to live a normal life. TWA participants reported more subjective pain and disability than the TWF participants and, although preserving motion was important for the TWA participants, they were prepared to sacrifice it if the pain became unbearable. The TWF participants had more difficulties reaching

into narrow spaces, perineal care and fine-motor functions. Nonetheless, not all participants with a TWF considered these restrictions to be important in their everyday lives. This finding is consistent with those from previous studies which show that nearly all everyday activities can be performed regardless of limitations in range of wrist motion (177, 178).

All participants in Paper I expressed various levels of pain relief after both TWF and TWA, and they were able to regain different life-roles. Although pain and limited function improve after both TWF and TWA, the function is not likely to become normal. The TWF or TWA had an impact on the participants' whole lives. Successful coping strategies were, however, developed over time that involved using different assistive devices, a compensatory movement pattern, and making modifications to their homes. Participants in Paper 1 also coped by focusing on the positive aspects of their situation and seeing solutions instead of problems. They relied on their capacity, such as being stubborn, goal-orientated and not giving up, among other things, to manage difficult situations.

Taken together, wrist OA patients need to receive individualized and tailored treatment options. Information about the risks, benefits and consequences of each treatment option should be given to enable the patients to make informed decisions about their healthcare. Expectations need to be realistic and the patients' personality, life situation and occupation should be carefully considered by surgeons before choosing the type of surgery. In conclusion, for individuals treated surgically with TWF or TWA, the perceived ability to function seemed to be related more to the level of wrist pain than to the range of wrist motion.

Self-management

A first-line treatment approach for wrist osteoarthritis

To my knowledge, the attempt to incorporate wrist OA in a first-line exercise therapy program, reported in Papers III and IV, is the first of its kind. Although there is strong evidence both in favour of all patients with OA being offered adequate patient education and exercises, and that surgical interventions should only be considered when non-surgical treatments have failed, this treatment approach has not previously been available for patients with wrist OA (12). In addition, there is currently a global healthcare challenge involving prolonged waiting periods for surgery, emphasizing the need for physiotherapist-led interventions and new conservative treatment options (179, 180). To shine some light on this matter, the participants in Paper IV were asked, at baseline and in pre-defined questions, about their opinions and views on surgical treatment of their OA-affected wrist. A majority answered that they did not want surgery, they wanted to avoid it for as long as possible, or they wanted surgery only if the pain got worse. These views support

the perception and recommendation that individuals with OA should be offered a staged treatment approach starting with self-management, patient education, and exercises. Although there is no cure for OA, patients may benefit from self-management treatment options that enable them to manage symptoms and optimize quality of life (13). In addition, individuals with OA should be fully involved in the different treatment options available throughout their care (171). For some wrist OA patients, surgery is the way to go but for others it is not. The treatment options should be tailored to the individual and expectations ought to be addressed to ensure that they are realistic (147). Furthermore, the extended waiting times for surgical treatment for OA worldwide have increased the interest in pre-rehabilitation as a means to maintain and improve patients' functional status before surgery or even to eliminate the need for surgical interventions altogether (14-16). This support for pre-rehabilitation and pre-surgical improvements, the concept of "wating well", aims to empower patients during the waiting time and enhance their functional capacity (181). Research also shows that how well patients manage symptoms, such as chronic pain, depends more on ´what they do´ than on ´what is done to them´; most of the "work", the management, is done by the patient (182). Referral of patients with wrist OA to education and self-management programs, is therefore an attractive first-line treatment option aimed at informing patients about the disease and providing them with tools to facilitate everyday life (14). Physiotherapists can provide wrist OA patients with the support and confidence they need to succeed in their self-management program and to continue with the prescribed exercises. They can also provide more OA education, which is vital since patient education is a core component in the management of OA. In a recent qualitative study, patients with knee OA have expressed their desire for more education about their disease, and for the physiotherapist to not only focus on the physical treatment (183, 184). All of this supports the notion that patients with wrist OA should, at least, be offered the chance to try a first-line treatment including a combination of OA education and exercises.

Effects of the neuromuscular exercise therapy program

In Paper IV, a novel self-managed neuromuscular joint-protective exercise therapy program for patients with wrist OA, compared to a placebo training program with only ROM exercises was evaluated. The main results from this trial show that, at 12 weeks, the neuromuscular exercise therapy program (intervention group) was no better at reducing pain and improving function than a ROM training program (control group). There was no significant difference for the primary outcome, pain and function evaluated using PRWE, either between the groups or within the groups at 12 weeks. For the secondary outcomes, a significantly lower DASH score was found in the intervention group compared to the control group. There was also a significant and clinically meaningful within-group decrease of NPRS on load in the intervention group at 12 weeks. However, the significant difference in DASH score,

in favour of the intervention group, needs to be interpreted with caution as it could have been caused by a non-significant increase (worsening) from baseline in the control group in combination with a non-significant decrease (improvement) in the intervention group.

The neuromuscular exercise therapy program in Paper IV, described in detail in Paper III, was designed based on the principles behind neuromuscular training that focus on improving the quality and effectiveness of movements (3, 40). The rationale behind our choice of neuromuscular therapeutic exercises is that patients with OA may have impaired sensorimotor function in terms of sensory deficiency, altered muscle activation patterns and reduced functional performance (35, 70). It therefore seemed evident that the exercise therapy program should address several aspects of the sensorimotor system in order to improve function and alleviate symptoms. In Paper IV, the hypothesis was that the joint-protective nature of the neuromuscular exercise therapy program, with the added specific strengthening exercises to create muscle support, would have been better at reducing pain and improving function than the placebo training program. Joint-protective programs emphasize a better spread of the load across the joint to reduce unhealthy loading (2). Overuse of an OA affected joint can increase the inflammatory process and synovitis and cause pain and fatigue (185). These symptoms produce less efficient ways of using the joint in daily activities, which in turn can intensify the symptoms (2). One could speculate that the significant and clinically important reduction in pain on load within the intervention group could have been due to the joint-protective and neuromuscular nature of the exercise therapy program. However, in Paper IV, this could not be proved in a robust way.

The combination of structured education and neuromuscular exercise therapy has shown short- and long-term improvements in pain, physical function, function in ADL, and quality of life in individuals with knee and hip OA (186-189). In fact, most research regarding education and exercises has been done on patients with knee and hip OA, with much stronger evidence for such programs compared to hand and wrist OA (61, 62, 129). Since the neuromuscular exercise therapy program in Paper IV was not better at reducing pain and increasing function than the placebo training program, this raised the question why those with knee and hip OA improve following exercises, while there is a more limited effect observed in individuals with hand and wrist OA. It also raised questions about the optimal time in relation to the grade of OA for starting an exercise therapy program and about the type of exercises or setting that is most appropriate in the treatment of patients with wrist OA. The mechanisms behind the positive effects on knee and hip OA are, however, inadequately understood (65). There is possibly a general positive physiological response to the cardiovascular exercise training usually included when treating knee and hip OA, together with the frequently simultaneous weight loss (68). The exercise therapy program, outlined in Paper III and evaluated in Paper IV, focused

on increasing the muscle strength around the specific OA affected joint which may not be sufficient to reduce pain and enhance function. Perhaps the more proximal part of the upper extremity needs to be included when designing future exercise programs for wrist and hand OA, since the aim of joint protection is to distribute the load over several joints using the strongest, largest joint available for the task. In addition, most first-line OA treatments are given in a primary care setting, but the participants included in Paper IV were referred to the exercise therapy treatment in a tertiary care setting (73, 74). There is a possibility that, due to the late referral, the participants in Paper IV had more severe symptoms which affected the outcome of the treatment program. Early referral of patients with wrist OA, or even before the SLAC and SNAC progression occurs, for neuromuscular exercise therapy in primary care may improve outcomes to a greater extent than referral at a later stage (44). In Paper IV the exercise therapy program was standardized, based on the intervention described (Paper III), and the participants self-managed the program with home exercises twice a day with regular follow-ups at the clinic. However, some participants might have benefited from a more individualized exercise therapy program, which raises the question whether patients with wrist OA should perhaps be treated in a supervised setting at the clinic.

Outcome

Even though there are various outcome measures that can be used to evaluate wrist OA, DASH and PRWE are the most commonly used condition-specific PROMs (101, 102, 107). Pain scales, such as NPRS/NRS or VAS, are also widely used since pain is the cardinal symptom of wrist OA (113). The psychometric properties of outcome measures are closely linked to the intended population and provide a scientific basis for using the measures in clinical practice, research, and other contexts, enhancing the credibility and utility of the collected data (5). To my knowledge, no previous studies have investigated the psychometric properties for NRS, DASH or PRWE in the context of wrist OA. This was addressed in Paper II, where reliability and validity were evaluated for these PROMs in a group of patients with wrist OA. The results from the study show excellent test-retest reliability for these PROMs when applied to this specific group of patients. Strong correlations were found between PRWE, NRS and DASH, whilst moderate to strong correlations were found between DASH and NRS. This ensured that these outcome measurements were reliable and valid when the neuromuscular exercise therapy program was evaluated in Paper IV.

Test-retest reliability

The excellent kappa coefficients found for NRS, DASH and PRWE in Paper II, are in line with previous studies. Regarding NRS, earlier studies have mainly used a VAS score for evaluating general wrist pain, but also with excellent test-retest agreement (ICC 0.84) (123, 190). A close correlation between VAS and NRS has been established, but NRS is usually recommended for assessing pain on the basis of higher compliance rates, better responsiveness, ease of use, and good applicability relative to VAS (114). A lower kappa coefficient was found for NRS pain at rest (0.83), compared to the other NRS assessments. This could be explained by the complexity and variability of OA pain mainly occurring on use, movement, weight-bearing and later in the day (191). The excellent kappa coefficient found for DASH in Paper II is also in line with previous studies (117-122) which show excellent test-retest agreement for DASH with ICC > 0.90 in patients with various upper extremity disorders. For PRWE, the excellent kappa coefficient found is in line with a previous systematic review evaluating test-retest reliability for PRWE in 24 studies of various types of wrist and hand injuries that reported ICCs of 0.91-0.93 (123). To summarize, the NRS, DASH and PRWE produce similar results under consistent conditions and can be considered reliable PROMs when evaluating wrist OA.

Construct validity

In Paper II, the pre-formulated hypotheses were confirmed. A strong correlation was found between PRWE and NRS compared to the correlation between DASH and NRS. This was expected to some extent since PRWE contains a section with five specific pain questions compared to DASH which only contains two general pain questions. In accordance with findings in Paper II, previous studies, including patients with various shoulder and hand/wrist disorders as well as RA patients with upper extremity disabilities, have also mainly found moderate to strong correlations between DASH and VAS (rho 0.60-0.72) (117, 118, 120, 122). Moderate to strong correlations have also previously been found between PRWE and VAS (rho 0.50-0.74) (192-195). When PRWE and DASH were correlated to NRS, the highest correlations were found for NRS pain on motion without load. This can be explained by the fact that most items in both PRWE and DASH contain questions regarding functional activities of daily living.

In agreement with previous studies, strong correlations were found between DASH and PRWE (rho 0.86) in Paper II (123). These strong correlations are expected since DASH and PRWE largely rate the same construct, i.e., activity-based upper extremity disability. However, even if they are strongly correlated, they also differ slightly. DASH is a more generic upper limb instrument, whereas PRWE is wrist-specific. Taken together, high construct validity was found when PRWE was correlated to NRS and DASH. Moderate to high construct validity was found when DASH was correlated to NRS and PRWE.

Outcome in clinical practice

Including different types of PROMs in clinical practice – such as symptom specific, wrist-specific and more generic questionnaires – provides the opportunity to evaluate dispersed symptoms and overall self-reported upper extremity disability. The close correlation between NRS, DASH and PRWE, in relation to them also being slightly different, strengthens the concept that these PROMs can complement each other. This can ensure a more comprehensive evaluation of wrist OA, needed especially in a research setting (Paper IV). However, in clinical practice, there are barriers to integrating PROMs to measure outcomes since evaluation using outcome measures can be time-consuming and reduce productivity (196). Since Paper II found a strong correlation between PRWE and both DASH and NRS, it may not be necessary to use all three in the assessment of wrist OA. In addition, PRWE has been shown to be easier for patients to complete, quicker to administer and easier to score than DASH (196). Therefore, PRWE can be recommended for use as a sole PROM in time-limited clinical practice for assessing functional outcome of wrist OA.

Methodological considerations

Qualitative analysis

In Paper I, conventional content analysis was used in order to study individual experiences, and the trustworthiness of the findings was evaluated by establishing credibility, dependability and confirmability (156). Credibility was established by using purposive sampling; choosing participants with various experiences to shed light on the research question from a range of aspects. Dependability was accomplished by the use of investigator triangulation where the author and the co-authors read and coded the interviews independently. The authors then discussed and interpreted the text together and made an in-depth analysis (156, 197). To certify confirmability and ensure that the participants recognized the findings, the information given was constantly confirmed and clarified during the interviews. The interviews varied in depth and length but were rich in detail, enabling a focus on a descriptive manifest analysis but also a latent analysis with a low degree of interpretation. Both manifest and latent content deal with interpretation but can vary in depth and level of abstraction (154, 157). A latent analysis can create an overarching theme, an underlying meaning of a phenomenon in the text through condensed meaning units, codes or categories on an interpretative level (154). However, such a formulation of a theme was not applicable in Paper I due to the low degree of interpretation because of the broad aim of the study. The trustworthiness was achieved by including representative quotations from the

participants, making the interpretation transparent for the reader. The focus was consistently on the text so as to reduce the risk of over-interpretation.

Quantitative analysis

Several checklists and guidelines were used to ensure methodological quality in the different studies. COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN) checklist (115), guidelines for methodological quality in psychometric studies, was used in Paper II. To certify methodological quality regarding the evaluation of construct validity, three pre-formulated hypotheses were developed according to the COSMIN checklist (Paper II) (115). The NRS, DASH and PRWE, three PROMs frequently used to evaluate the effect of treatment in patients with wrist OA, were chosen for psychometrical evaluation in Paper II. Test-retest reliability in Paper II was analyzed using Kappa statistics since the NRS, DASH and PRWE are rated in ordinal scales (161). However, previous studies have mainly used the intraclass correlation coefficient (ICC) when evaluating test-retest reliability of these PROMs (123). This is not entirely correct since ICC should be used when evaluating agreement for parametric data (198). Hence, the test-retest reliability of Paper II may not be fully comparable to previous studies, even though a quadratic kappa gives approximately the same result as an ICC (199).

The Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT) checklist (200) was used to certify methodological strengths in Paper III. SPIRIT is a widely recognized international standard for clinical trial protocols and provides evidence-based recommendations for the minimum content of a trial protocol. The 33-item SPIRIT checklist and the SPIRIT figure was used in Paper III.

In Paper IV, The Consolidated Standards of Reporting Trials (CONSORT) guidelines (201) was used to ensure methodological quality. The CONSORT statement is endorsed worldwide to improve the reporting of RCTs and includes a 25-item checklist and a flow diagram (201). The intention-to-treat principle was used in Paper IV. However, all participants were treated according to the group they were allocated to. To prevent participant bias, the participants in Paper IV were not directly informed about which group they were assigned to. This also limited the risk of contamination between the two groups. To minimize assessment bias, the PT performing all the assessments was blinded to the group allocations. To ensure scientific rigor regarding the RCT and to avoid performance bias, the treating hand surgeons and the hand surgeons assessing the radiological wrist OA stage were also blinded to group allocation.

Strengths and limitations

This thesis has methodological strengths and some limitations that need to be mentioned. The main strength of the thesis lies in the increased knowledge provided about wrist OA, obtained from different perspectives focusing on the patient's functional ability.

The qualitative study, Paper I, provided an in-depth understanding of the process of living with chronic wrist pain, leading eventually to the decision to undergo surgery with TWF or TWA. The number of participants in Paper I was small (13 participants). However, a heterogeneous group was included to ensure that different views and experiences of the phenomenon were covered. The interviews were rich in length and detail and saturation was reached in both groups. The experiences and perspectives of the surgeons who conducted the surgeries and those of advanced wrist OA patients who did not want surgery were not explored in this study. Hence, this study has limitations with respect to clarifying the whole decision-making process. Recall bias should also be considered since the interviews were conducted several years after the surgery. However, the participants described strong and vivid memories from the time before surgery. Even if some details might have been lost, this was unlikely to have influenced the overall findings. The transferability in Paper I is limited as the participants represent a small study group.

The main strength of Paper II is the investigation of test-retest reliability and construct validity for NRS, DASH and PRWE in the context of wrist OA. A measure's psychometric properties are closely linked to the population they are intended for, and none of these PROMs have previously been psychometrically evaluated in patients with wrist OA (5, 116). The number of participants in Paper II (n=50) constitutes an *adequate* sample size for analyzing test-retest reliability and construct validity according to the COSMIN checklist (202). However, a sample size ≥100 would have been considered a *very good* sample size (5, 202). The time interval between the repeated ratings was approximately two weeks, in accordance with the recommendations (5). However, a few participants took longer than two weeks to respond to T2 and needed to be reminded, which can be seen as a minor limitation. Even though none of the participants were actively seeking care for their wrist problems at the hand surgery clinic during data collection, we cannot fully ensure the participants were completely stable in the interim period.

The main strength of Papers III and IV is the use of an assessor-blinded prospective randomized controlled design to evaluate a new treatment concept for patients with wrist OA. Other strengths were that the control group received the same number of follow-ups as the intervention group, with the only difference in the groups being the exercise program, and that the randomization sequence was carried out at the first training session with the treating PT.

In Papers III and IV, a sample size was calculated based on the minimal clinically important difference (MCID) of 12.5 for the primary outcome PRWE (164, 165). The MCIDs in the two studies, which the MCID in Paper IV was based on, were performed on patients with distal radius fractures (164), and patients with various atraumatic upper extremity disorders (165). No previous studies have evaluated the MCID for PRWE on patients with wrist OA. Even though the calculated sample size was reached in Paper IV, 41 participants might not be sufficient to detect potential differences between the two groups of patients with wrist OA. However, an important disadvantage of a randomized trial on patients with wrist OA is the difficulty of including large samples due to its relatively low prevalence in the general population, and the stringent inclusion and exclusion criteria often used in such trials. In Paper IV, there could also have been a risk of self-selection bias caused by the fact that individuals who agreed to join the trial may have differed in motivation to perform the exercises compared to those who chose not to participate. The 12-week follow-up time frame can be seen as a limitation. However, future 6- and 12-month follow-ups are planned for these participants, as outlined in Paper III. The neuromuscular exercise therapy program can also be seen as more challenging for the participants in the intervention group due to the larger number of exercises, which could have affected their adherence to the program. The CT scans were not analyzed until after inclusion which resulted in a few participants being re-graded from SLAC/SNAC 3 to 4. This could have affected the outcome of the trial and should be seen as a limitation.

In all the present papers, most participants were men, and SLAC wrist was the most common cause of OA. Even though this is characteristic of patients with wrist OA (39, 97), it may limit the generalizability to the whole wrist OA population.

Future research

This thesis has increased available knowledge about wrist OA through focusing on the patients' specific thoughts, wishes and goals regarding their treatment. Nevertheless, the clinical importance and evidence of the rehabilitation of wrist OA, actually the effect rehabilitation may have on wrist injuries and pathologies in general, is only beginning to be explored and future research is required.

Firstly, we need to increase our knowledge about the effect that first-line treatment can have on patients with wrist OA. This includes gauging the optimal timing for starting an exercise therapy program, taken into account what effect preventive exercise therapy treatment, before the SLAC and SNAC progression occurs, may have and in regard to the grade of wrist OA. This implies earlier awareness of patients with wrist OA in primary care, allowing exercise therapy programs to be introduced sooner.

Recruitment of patients with wrist OA for research purposes can be difficult since it is a heterogeneous condition that can affect various articulations of the wrist joint. To increase the amount of evidence, we should therefore conduct multi-center studies in order to access a larger number of participants with wrist OA.

Since the exercise therapy program in Paper IV was no better at reducing pain and improving function than a ROM training program, future research should focus on evaluating the optimal type of exercise and setting for an exercise therapy program for patients with wrist OA. Since joint protection aims at distributing the load over several joints and using the strongest, largest joint available for the task, we may need to incorporate the more proximal part of the upper extremity when designing future exercise programs for wrist and hand OA.

To evaluate the true effects of an exercise therapy program, future studies should include, in RCTs, a control group that is not prescribed exercise as treatment or compare an exercise therapy program to different types of pharmacological or surgical treatment options.

Adherence to the exercise program is probably a key factor for the success of the treatment. Digital applications with reminders or other compliance techniques could potentially further improve adherence. Future studies of wrist OA might consider using a digital application to support adherence to a self-managed exercise therapy program. Qualitative studies on how the patients experience the exercise therapy program could also help the development of an optimal exercise program that is feasible and promotes adherence.

Compensatory movement patterns, due to a stiff or motion-deprived wrist, were developed by participants in Paper I. To deepen our knowledge about the outcome after TWF or TWA, future research should evaluate the effect that a motion-deprived wrist joint can have on, for example, the shoulder and neck.

Conclusions

Paper I. Pain relief was the primary expectation of surgery and involvement in the surgical discussion affected the results positively. Successful coping strategies were developed, enabling the participants to become more independent and adapt to challenges in daily life. The participants' individual expectations, previous surgical experiences, preoperative range of wrist motion, readiness to accept the risk of additional surgery, personality, life situation and occupation, influenced the surgical choice of either TWF or TWA. The participants' ability to perform everyday tasks appeared to be related more to their level of pain than the range of wrist movement.

Paper II. The NRS, DASH and PRWE demonstrate excellent test–retest reliability and moderate to high construct validity in patients with wrist OA. These PROMs are closely related, but they also differ. They therefore complement each other in ensuring a comprehensive evaluation of perceived disability in wrist OA. PRWE showed the highest test-retest reliability and the strongest relation to the other PROMs. Thus, the use of PRWE alone can be recommended in clinical practice.

Papers III and IV. A novel neuromuscular joint-protective exercise therapy program was no better at reducing pain and improving function, at 12 weeks, than a placebo training program with ROM exercises. Future research is justified in order to evaluate the effectiveness of forthcoming exercise therapy treatment programs for patients with wrist OA.

Clinical implications

- The management of patients with wrist OA in a first-line treatment approach needs to become more established.
- A shared decision-making process in the treatment and management of wrist OA should be supported and implemented.
- Treatment options should be tailored to the individual and expectations ought to be addressed to ensure that they are realistic.
- The present neuromuscular exercise therapy program described in this thesis needs to be further developed and evaluated.
- Referral of patients with wrist OA to PTs before surgery can provide an opportunity to discuss treatment options and expectations, which could both improve compliance with exercise therapy and post-surgical satisfaction.
- Before surgery with either TWF or TWA, the patients' level of pain, preoperative range of wrist motion, readiness to accept the risk of additional surgery, personality, life situation and occupation need to be carefully considered.
- The adaptation strategies adopted to overcome challenges in everyday life can serve as an educational basis for hand therapists to pass on to patients both pre-and post-surgery with TWF or TWA.
- When evaluating the effect of different treatments for wrist OA, psychometrically reliable and valid outcome measures, including several ICF domains, should be used.
- The sole use of PRWE can be recommended when evaluating pain and function in patients with wrist OA in clinical practice.

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Appendix

Appendix 1

The Patient-Rated Wrist Evaluation (PRWE) questionnaire. Swedish version.

PRWE - PATIENTUPPLEVD HANDLEDSFUNKTION

Namn/personnummer_____ Datum_____

*Ange dina genomsnittliga handledsbesvär <u>den senaste veckan</u> på en skala från 0 till 10. Vänligen besvara **ALLA** frågor. Om du inte utförde en viss aktivitet, uppskatta den grad av smärta eller svårighet som du tror hade uppstått. Om du aldrig har utfört en viss aktivitet kan du lämna raden obesvarad.*

1. SMÄRTA

Ange din genomsnittliga handledssmärta den gångna veckan och ringa in siffran som bäst motsvarar smärtan på en skala från 0 till 10. Noll (0) betyder ingen smärta och tio (10) betyder att du har haft den värsta tänkbara smärtan eller att du inte kunde utföra aktiviteten på grund av smärta.

	Ingen smärta										**Värsta tänkbara smärta**
I vila	0	1	2	3	4	5	6	7	8	9	10
När du utför en uppgift med upprepade handledsrörelser, t ex skruva	0	1	2	3	4	5	6	7	8	9	10
När du lyfter ett tungt föremål	0	1	2	3	4	5	6	7	8	9	10
När smärtan är som värst	0	1	2	3	4	5	6	7	8	9	10
Hur ofta har du haft ont i handleden den senaste veckan?	0	1	2	3	4	5	6	7	8	9	10
	Aldrig										**Alltid**

2. FUNKTION

SPECIFIKA AKTIVITETER

Ange graden av svårighet som du har haft den senaste veckan att utföra nedanstående aktiviteter genom att ringa in siffran som beskriver svårigheten på en skala från 0 till 10. En nolla (0) betyder att du inte har haft någon svårighet och tio (10) betyder att du har haft så stor svårighet att du inte kunde utföra aktiviteten alls.

	Ingen svårighet										**omöjligt att utföra**
Öppna en ny burk, eller hårt sittande lock med den påverkade handen	0	1	2	3	4	5	6	7	8	9	10
Skära kött med kniv med den påverkade handen	0	1	2	3	4	5	6	7	8	9	10
Knäppa skjortknappar med den påverkade handen	0	1	2	3	4	5	6	7	8	9	10
Använda den påverkade handen för att skjuta ifrån och resa dig upp från en stol	0	1	2	3	4	5	6	7	8	9	10
Bära ett 5 kilos föremål med den påverkade handen	0	1	2	3	4	5	6	7	8	9	10
Använda toalettpapper med den påverkade handen	0	1	2	3	4	5	6	7	8	9	10
VARDAGLIGA AKTIVITETER											
Personlig vård (klä på sig, tvätta sig)	0	1	2	3	4	5	6	7	8	9	10
Hushållsarbete (tvätta, diska)	0	1	2	3	4	5	6	7	8	9	10
Arbete (ditt yrke eller vardagliga sysslor)	0	1	2	3	4	5	6	7	8	9	10
Fritidsaktiviteter, hobby	0	1	2	3	4	5	6	7	8	9	10

PRWE poäng: summa poäng 1.SMÄRTA (max 50) + summa poäng 2.FUNKTION (max 100)/2 = _____/100

Wilcke et al. 2009

Appendix 2

The Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire. Swedish version.

Hälsoenkät (arm/axel/hand)

Denna enkät berör Dina symtom och Din förmåga att utföra vissa aktiviteter.
Svara på **varje fråga**, baserat på hur Du har mått **den senaste veckan**, genom att kryssa för ett svarsalternativ för varje fråga.
Om det är någon aktivitet Du inte har utfört den senaste veckan får Du kryssa för det svar som Du bedömer **stämmer bäst** om Du hade utfört aktiviteten.
Det har ingen betydelse vilken arm eller hand Du använder för att utföra aktiviteten. Svara baserat på Din förmåga oavsett hur Du utför uppgiften.

	Ingen svårighet	Viss svårighet	Måttlig svårighet	Stor svårighet	Omöjligt att göra
1. Öppna en ny burk, eller hårt sittande lock	☐	☐	☐	☐	☐
2. Skriva	☐	☐	☐	☐	☐
3. Vrida om en nyckel	☐	☐	☐	☐	☐
4. Förbereda en måltid	☐	☐	☐	☐	☐
5. Öppna en tung dörr	☐	☐	☐	☐	☐
6. Lägga upp något på en hylla över Ditt huvud	☐	☐	☐	☐	☐
7. Utföra tunga hushållssysslor (t ex tvätta golv och väggar, putsa fönster, hänga tvätt)	☐	☐	☐	☐	☐
8. Trädgårdsarbete	☐	☐	☐	☐	☐
9. Bädda sängen	☐	☐	☐	☐	☐
10. Bära matkassar eller portfölj	☐	☐	☐	☐	☐
11. Bära tunga saker (över fem kilo)	☐	☐	☐	☐	☐
12. Byta en glödlampa ovanför Ditt huvud	☐	☐	☐	☐	☐
13. Tvätta eller föna håret	☐	☐	☐	☐	☐
14. Tvätta Din rygg	☐	☐	☐	☐	☐
15. Ta på en tröja	☐	☐	☐	☐	☐
16. Använda en kniv för att skära upp maten	☐	☐	☐	☐	☐
17. Fritidsaktiviteter som kräver liten ansträngning (t ex spela kort, sticka, boule)	☐	☐	☐	☐	☐
18. Fritidsaktiviteter som tar upp viss kraft eller stöt genom arm, axel eller hand (t ex spela golf, använda hammare, spela tennis, skytte, bowling)	☐	☐	☐	☐	☐
19. Friritidsaktiviteter där Du rör på armen fritt (t ex spela badminton, simma, gympa)	☐	☐	☐	☐	☐
20. Färdas från en plats till en annan	☐	☐	☐	☐	☐
21. Sexuella aktiviteter	☐	☐	☐	☐	☐

22. Under **de senaste sju dagarna**, i vilken utsträckning har Dina arm-, axel- eller handproblem stört Ditt vanliga umgänge med anhöriga, vänner, grannar eller andra?

☐ Inte alls ☐ Lite ☐ Måttligt ☐ Mycket ☐ Väldigt mycket

23. Under **de senaste sju dagarna**, i vilken utsträckning har Dina arm-, axel- eller handproblem stört Ditt vanliga arbete eller andra dagliga aktiviteter?

☐ Inte alls ☐ Lite ☐ Måttligt ☐ Mycket ☐ Väldigt mycket

Ange svårighetsgraden på Dina symtom **de senaste sju dagarna**:

	Ingen	Lätt	Måttlig	Svår	Mycket svår
24. Värk/smärta i arm, axel eller hand	☐	☐	☐	☐	☐
25. Värk/smärta i arm, axel eller hand i samband med aktivitet	☐	☐	☐	☐	☐
26. Stickningar (sockerdrickskänsla) i arm, axel eller hand	☐	☐	☐	☐	☐
27. Svaghet i arm, axel eller hand	☐	☐	☐	☐	☐
28. Stelhet i arm, axel eller hand	☐	☐	☐	☐	☐

29. Har Du haft svårt att sova, under **de senaste sju dagarna**, på grund av värk/smärta i arm, axel eller hand?

☐ Inte alls ☐ Viss svårighet ☐ Måttlig svårighet ☐ Stor svårighet ☐ Mycket stor svårighet

30. Jag känner mig mindre kapabel, har sämre självförtroende eller känner mig mindre behövd på grund av mina arm-, axel- eller handproblem.

☐ Instämmer absolut inte ☐ Instämmer inte ☐ Vet inte ☐ Instämmer ☐ Instämmer absolut

Följande frågor rör hur mycket Dina arm-, axel- eller handproblem påverkat Din förmåga att arbeta (inklusive hushållsarbete om detta är Ditt huvudsakliga arbete).

Arbetar Du? ☐ Ja ☐ Nej

Om Du inte arbetar kan Du hoppa över de följande fyra frågorna

Ange här Ditt arbete

Kryssa för det påstående som bäst stämmer in på Din kroppsliga förmåga **de senaste sju dagarna**.

Hade Du någon svårighet att:	Ingen svårighet	Viss svårighet	Måttlig svårighet	Stor svårighet	Omöjligt
1. använda Din vanliga teknik för att arbeta?	☐	☐	☐	☐	☐
2. utföra Ditt ordinarie arbete på grund av värk/smärta i arm, axel eller hand?	☐	☐	☐	☐	☐
3. utföra Ditt arbete så bra som Du skulle vilja?	☐	☐	☐	☐	☐
4. utföra Ditt arbete på den tid Du brukar använda?	☐	☐	☐	☐	☐

Följande frågor rör hur mycket Dina arm-, axel- eller handproblem påverkat Din förmåga att spela musikinstrument och/eller utöva idrott.

Spelar Du något musikinstrument eller utövar någon idrott? ☐ Ja ☐ Nej

Om Du inte spelar något musikinstrument eller utövar någon idrott kan Du hoppa över resterande frågor

Om Du spelar mer än ett musikinstrument eller utövar mer än en idrott ska Du svara med avseende på den aktivitet som är viktigast för Dig.
Ange här det musikinstrument eller den idrott som är viktigast för Dig

Kryssa för det påstående som bäst stämmer in på Din kroppsliga förmåga **de senaste sju dagarna**.

Hade Du någon svårighet att:	Ingen svårighet	Viss svårighet	Måttlig svårighet	Stor svårighet	Omöjligt
1. använda Din vanliga teknik för att spela instrument/idrotta?	☐	☐	☐	☐	☐
2. spela instrument/idrotta på grund av värk/smärta i arm, axel eller hand?	☐	☐	☐	☐	☐
3. spela instrument/idrotta så bra som Du skulle vilja?	☐	☐	☐	☐	☐
4. använda lika mycket tid som vanligt för att spela instrument/idrotta?	☐	☐	☐	☐	☐

Appendix 3

The Generalized Self-Efficacy Scale (GSES). Swedish version.

	Tar helt avstånd	Tar delvis avstånd	Instämmer delvis	Instämmer helt
1. Jag lyckas alltid lösa svåra problem om jag bara anstränger mig tillräckligt	1	2	3	4
2. Även om någon motarbetar mig hittar jag ändå utvägar att nå mina mål	1	2	3	4
3. Jag har inga svårigheter att hålla fast vid mina målsättningar och förverkliga mina mål	1	2	3	4
4. I oväntade situationer vet jag alltid hur jag ska agera	1	2	3	4
5. Till och med överraskande situationer tror jag mig klara av bra	1	2	3	4
6. Tack vare min egen förmåga känner jag mig lugn även när jag ställs inför svårigheter	1	2	3	4
7. Vad som än händer klarar jag mig alltid	1	2	3	4
8. Vilket problem jag än ställs inför kan jag hitta en lösning	1	2	3	4
9. Om jag ställs inför nya utmaningar vet jag hur jag skall ta mig an dem	1	2	3	4
10. När problem uppstår kan jag vanligtvis hantera dem av egen kraft	1	2	3	4

Appendix 4

The semi-structured interview guide of patients' experiences before and after total wrist fusion or total wrist arthroplasty.

Opening questions

How old are you?
Which wrist has been surgically treated? *(define what kind of surgery)*
When was your wrist surgically treated?
Are you right or left-handed?
What is your occupation?
What do you do in your spare time?

Questions regarding experiences before surgery

Please tell us what made you seek medical care for your wrist.
How long did you have problems with your wrist before you had surgery?
How did you perceive the movement you had in your wrist before surgery?
How did you perceive the strength in your hand before surgery?
Describe, in as much detail as possible, which daily activities you had most problems with before surgery.
Describe whether your wrist problems affected your leisure time?
Can you tell us if, and if that is the case, how your wrist problems have affected your participation in social activities with friends and family? Has it affected your work?
Describe which activities that were meaningful to you.

Expectations of surgery

Please tell us about the reasoning regarding the choice of surgery. Did you feel involved in the discussion? How did you experience the treatment at the clinic?
Describe the information you received before surgery.
Describe what expectations you had of your surgical choice regarding ordinary daily activities, leisure activities, work, social participation with friends and family, wrist motion, grip strength, and pain.

Questions regarding experiences after surgery

Please tell us how you experienced the rehabilitation after surgery.
TWF: How does the lost movement in the wrist affect you?
TWA: How does it affect you to have the mobility you have, as opposed to how it would be if your wrist was completely stiff?
Describe if you use any tricks to compensate for the lost/limited motion in your wrist.
In what way has the surgery affected your ordinary daily activities, leisure activities, work, social participation with friends and family, wrist motion, grip strength, and pain.
Would you go through with the same surgery again if you had to?
Would you recommend this kind of surgery to other people with wrist problems?

Personal qualities

How do you view your own conditions/resources in relation to the possible challenges of physiotherapy after surgery?
Which personal qualities have been important to you when facing the challenges involved with your wrist problems?
Please describe what you think is important for us working in healthcare to consider in regard to providing care.
Is there something you want to add that concerns the consequences of your wrist problems that we haven't talked about?

Exploratory follow-up questions applicable as optional questions

Could you describe that in more detail?
Could you elaborate a bit on what you mean by that?
What are your thoughts on that?
How did you experience that?

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Patients' experiences before and after total wrist fusion or total wrist arthroplasty: A qualitative study of patients with wrist osteoarthritis

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ABSTRACT

Introduction: For patients with advanced wrist osteoarthritis (OA), total wrist fusion (TWF) is the standard surgical treatment, although total wrist arthroplasty (TWA) has become a plausible motion-preserving alternative.
Purpose: To explore patients' experiences of living with advanced wrist OA before and after surgery with either a TWF or a TWA. Furthermore, we wanted to explore the expectations of surgery, appraisal of results, and the adaptation strategies used to overcome challenges in everyday life.
Study Design: Qualitative descriptive.
Methods: A purposive sample of 13 patients with advanced wrist OA surgically treated with TWF ($n = 7$) or TWA ($n = 6$) was recruited. Semistructured interviews were conducted and analyzed using qualitative content analysis.
Results: Four categories are described: the problematic wrist, the breakpoint, appraisal of the results, and adaptation to challenges in everyday life. Pain relief was the primary expectation of surgery, and involvement in the discussion regarding different surgical options had a positive effect on the appraisal of results. The participants' ability to perform tasks in everyday life appeared to be more related to their level of pain than the range of wrist motion. Successful coping strategies were developed, enabling the participants to become more independent and adapt to challenges in daily life.
Conclusions: Previous surgical experiences, occupation, and amount of wrist motion influenced the participants' expectations, surgical choice with either a TWF or a TWA, and the appraisal of results. The findings contribute valuable insights to both surgeons and hand therapists about the importance of having the patient's individual expectations and needs in focus.

Introduction

Wrist osteoarthritis (OA) is a chronic noninflammatory joint disease resulting in degenerative lesions of the cartilage and is usually secondary to a posttraumatic sequel or metabolic disease.[1] Patients with advanced wrist OA can suffer from pain and severe functional impairments. Surgical treatment is indicated when conservative treatment has failed, and the pain has become unbearable.[1,2]

Total wrist fusion (TWF) is the standard surgical treatment for patients with advanced, painful, wrist OA.[2,3] It is considered a safe and reliable method resulting in improved grip strength and decreased pain.[4-6] Despite the loss of wrist motion and reduced health-related quality of life, activity limitations, and impairments, the majority of patients with a TWF are satisfied and would undergo the procedure again.[4,6]

Total wrist arthroplasties (TWAs) of the third generation attempt to mimic the natural anatomy and biomechanics of the wrist and require minimal bone resection.[7] These implants have shown good results regarding pain relief, increased grip strength,

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improved patient-reported outcome, and preserved wrist motion with an implant survival of more than 90% at 5 years.[8-10] However, there is still no randomized controlled trial that has compared the outcome after TWA with TWF. In previous systematic reviews of patients with wrist arthritis, the outcome in terms of pain relief and patient satisfaction after a TWA of the second or third generation was similar to the outcome after a TWF, although complication rates were higher for a TWA.[11,12] In the absence of reliable comparative outcome evaluations between TWF and TWA, utility surveys have been used to compare the methods, finding that despite higher complication risks for TWA, both surgeons and patients favored a motion-preserving option, such as TWA over TWF.[13] Although TWA is a well-known treatment option, it has failed to achieve the widespread use that is seen in other joint replacement procedures.[14] Wrist arthroplasties have historically had a high complication rate, but even if the newer designs show acceptable durability, there is still no consensus regarding both the functional benefit compared with TWF and the amount of loading that a TWA would ultimately withstand.[14,15] Future implant loosening is an impending risk to consider when choosing a TWA.

Previous research regarding the outcomes after TWF or TWA has mainly focused on patient-reported outcome measurements, range of motion, grip strength, self-reported pain, and activity limitations.[3,4,9] There are no qualitative studies on how everyday life is affected by living with advanced wrist OA and how these patients experience their life after having a TWF or a TWA. Interviewing these patients could deepen our understanding of how wrist OA affects life, how the patients' reason about their surgical choices between a motion-preserving procedure (TWA) as opposed to a motion-sacrificing one (TWF) and how they cope with life after TWF or TWA. The present study can contribute with valuable insights to the debate among surgeons on when to choose a TWF or a TWA, having the patient's individual expectations and needs in focus.

Purpose of the study

The purpose of this study was to explore patients' experiences of living with advanced wrist OA before and after surgery with either a TWF or a TWA. Furthermore, we wanted to explore the expectations of surgery, appraisal of results, and the adaptation strategies used to overcome challenges in everyday life after a TWF or a TWA.

Methods

Study design and sample

A qualitative descriptive method with an inductive approach was used to deepen the knowledge of living with advanced wrist OA and the experiences after having a TWF or a TWA.[16,17] All participants were treated surgically at the department of hand surgery, Skåne University Hospital, Malmö, from 2009 to 2014. The department is a tertiary care center for patients with conditions and injuries in the hand and upper extremity. Patients with advanced wrist OA are treated by consultants in hand surgery, who are subspecialized in wrist surgery. The inclusion criteria were age 18 years or older at the time of surgery with TWF or TWA because of advanced and symptomatic wrist OA. Exclusion criteria were current psychiatric disorders and the inability to communicate in Swedish.

Participants

During 2009 to 2014, 112 patients received a TWF, and 13 patients received a TWA because of various diagnoses. Seven of the patients with TWA met the inclusion criteria. One could not be reached due to a lack of contact details, leaving 6 potential participants. In the TWF group, 43 patients met the inclusion criteria, and 8 patients, matching the TWA group, were selected initially. Purposive sampling was used in both groups giving a variation in age, gender, and year of surgery (TWA, range 2011-2014; TWF, range 2010-2014).[16,18] A letter was sent by the first author to the eligible patients in both groups informing them about the study and asking if they would like to participate. Two weeks after the letter was sent, the first author contacted the patients via telephone and informed them about the aim of the study again. An interview time was set up to take place in a quiet room at the department of hand surgery for those who agreed to participate. All patients with TWA and 7 of the 8 initially selected patients with TWF agreed to participate in the study. After interviewing the 7 participants in the TWF group and the 6 participants in the TWA group, very little new information was obtained, which indicated that data saturation was reached.[19] Thus, 13 individuals were included in the study. The median time from surgery to the interview was 4 years (range 2-7 years). Both groups represented different fields of occupation, including both office work -and manual labor. To get an overview of the characteristics of the participants, they completed the Disabilities of the Arm, Shoulder and Hand questionnaire, which is a self-administrated outcome instrument developed as a measure of self-rated upper-extremity disability and symptoms, and the Patient-Rated Wrist Evaluation questionnaire, which is designed to measure wrist pain and disability in activities of daily living.[20,21] Pain at rest, during motion and load, was measured with a Visual Analogue Scale.[22] Range of motion of the affected wrist and forearm was measured with a goniometer, and grip strength of both hands was measured with a Jamar dynamometer.[23,24] The participant characteristics are presented in Tables 1 and 2.

Data collection and ethics

A semistructured interview guide was developed by the first author and agreed by all authors (Appendix 1). The first author also performed and tape-recorded all the interviews. They were carried out at the department of hand surgery in Malmö, Sweden, over an 8-month period and lasted a mean of 42 minutes (range 29-55 minutes). The interview started with a repetition of the aim of the study and the voluntary nature of participation. Written informed consent was obtained, and the participant's confidentiality was assured. The study was performed in accordance with the ethical guidelines stated in the Declaration of Helsinki and approved by the Regional Ethical Board in Lund (Dnr 2015/121). The participants were asked to describe their experiences of living with

Table 1
Characteristics of participants

Participant	Age range	Gender	Surgery Left/right (L/R)	Year of surgery
1	71-80	M	TWF/L	2011
2	41-50	F	TWF/L	2011
3	41-50	M	TWA/R[a]	2012
4	61-70	M	TWA/L	2011
5	41-50	M	TWF/R[a]	2014
6	41-50	M	TWF/L	2014
7	61-70	F	TWA/R	2014
8	61-70	F	TWA/L	2011
9	41-50	M	TWA/R[a]	2011
10	61-70	F	TWF/R[a]	2011
11	51-60	M	TWF/R[a]	2010
12	31-40	M	TWA/L	2014
13	41-50	F	TWF/R[a]	2011

TWA = total wrist arthroplasty; TWF = total wrist fusion.
[a] Dominant hand.

Table 2
Background information on the participants (n =13) regarding demographics, patient-reported outcomes and objective measures

Characteristics	TWF (n = 7)	TWA (n = 6)
Gender male/female (n)	4/3	4/2
Age	49 (44-75)	55 (38-68)
Surgery dominant hand (n) yes/no	4/3	2/4
Time from surgery to interview (y)	5 (2-7)	4.5 (2-5)
Occupation (n)		
Retired	2	2
Unemployed	1	1
Working	4	3
Change of occupation (n; from manual labor to administrative work)	2	3
PRWE total score (0-100)	28 (6-66)	40 (0.5-83)
Pain (0-50)	15 (0-31)	29.5 (0-46)
Function (0-50)	10 (2-35)	14.5 (0.5-37)
DASH (0-100)	32 (3-54)	34.5 (15-68)
Pain VAS (0-100)		
Pain at rest	5 (0-41)	10.5 (0-70)
Pain on motion without load	3 (0-71)	25.5 (1-90)
Pain on load	11 (0-90)	80.5 (1-100)
Grip strength (kg)	27 (16-48)	26.5 (18-57)
AROM (°)		
Pronation	80 (60-90)	85 (70-85)
Supination	65 (50-80)	72.5 (45-90)
Extension	–	33 (25-65)
Flexion	–	35 (10-60)
Radial deviation	–	10 (0-15)
Ulnar deviation	–	15 (10-20)

TWA = total wrist arthroplasty; TWF = total wrist fusion.
Values are medians, range min-max, if not specified as number (n), kilo (kg) or degrees (°).
PRWE (Patient-Rated Wrist Evaluation) is a 15-item questionnaire designed to measure wrist pain and disability in activities of daily living. Five items concern pain, and 10 items concern function. Each part (pain and function) has a score from 0 to 50, where 0 represents no pain or disability. There is a total score calculating both pain and function from 0 to 100.[21]
DASH (Disabilities of the Arm, Shoulder and Hand) is a 30-item questionnaire. Total score ranging from 0 (no disability) to 100 (most severe disability).[20]
Pain VAS: a horizontal Visual Analogue Scale with verbal anchors at the beginning and end of the scale (0 representing no pain and 100 worst possible pain).[22]
Grip strength with Jamar dynamometer of the affected hand, average kilo (kg). Three measurements resulting in a mean score. One participant in the TWF group could not be measured because of pain.[23]
AROM (Active Range of Motion) of the affected wrist measured with a goniometer, degrees (°).[24]

a painful wrist, their expectations and involvement in the decision to undergo surgery, their appraisal of results after having a TWF or TWA, the consequences surgery had on their level of activity, and participation in daily life and coping strategies used. Follow-up questions were asked such as, “Can you describe that in more detail?” and “How did you experience that?” The interviews were transcribed verbatim by the first author and a secretary. The transcripts were then checked for accuracy by the first author. The first author translated the selected citations in the text from Swedish to English, and the last author verified the translation.

Data analysis

Conventional content analysis with an inductive approach was used according to the procedure described by Graneheim and Lundman.[16,17] Both a manifest content, with a focus on the descriptive surface structure of the text, and latent content analysis involving a low degree of interpretation, were used.[16,17,25,26]

In the first step of the analysis, all interviews were read and reread by the first, second, and last authors to obtain a general impression of the content. Meaning units, which are words or sentences related to the aim of the study, were then identified and thereafter coded while still preserving the core meaning and with reference to the following questions: What is it about? What does it mean? What effect does it have? Codes that were similar in their content or contexts were grouped into subcategories. This part of the analysis was still close to the data and on a descriptive level (manifest content). Subcategories that shared commonalities were identified and abstracted into categories. Similar statements were analyzed critically and questioned to reach a reasonable interpretation and latent analysis.[16]

The categories were then discussed with the third and fourth authors who had read three TWF and 3 TWA interviews each. Adjustments were made to make sure the categories covered all aspects of the text. In the final step, the categories were compared with the text and with each other. With regard to the authors' preunderstanding, the first author is a physical therapist, and the second author is an occupational therapist, both specialized in hand rehabilitation and educated in qualitative research methods. The other authors are experienced hand surgeons also familiar with qualitative research.[27,28] All authors work at the department of hand surgery in Malmö. An example of the analysis procedure is presented in Table 3.

Results

The results are presented as 4 categories: (1) the problematic wrist, (2) the breakpoint, (3) appraisal of the results, and (4) adaptation to challenges in everyday life. Each category contains several subcategories. The problematic wrist comprises the experiences of living with a painful wrist and its impact on daily life. The breakpoint includes the participants' experiences of involvement in

Table 3
Example of the analysis procedure

Meaning unit	Code	Subcategory	Category
“After the total wrist fusion, it has become worse to some extent, since I don't have the same strength and ability to bend the wrist when doing specific activities. You then have to come up with something to be able to complete the task anyway. For example, re-making the handle on the rake. Or re-making a brush for it to fit the hand. Everything is doable.” [5, TWF]	Becoming inventive in order to complete everyday activities	Adjustments to everyday domestic life	Adaptation to challenges in everyday life
“My expectation was to become pain-free. I was about to live a life without pain, where I don't have to have a dull pain every day.” [12, TWA]	Being able to live a life without pain	Expectations of surgery	The breakpoint

the surgical decision and their expectations of surgery. Appraisal of the results refers to the perceived outcome after TWF or TWA surgery and how the results corresponded to the participants' expectations of the surgery. Adaptation to challenges in everyday life covers the different coping strategies used by the participants. The categories and subcategories are described in detail in the following section, and representative quotes from the interviews illustrate the findings. An overview is presented in Table 4.

The problematic wrist

Living with pain

Living with advanced wrist OA meant living with a constant aching body part that affected the participants' whole lives. Limitations such as not being the person they wanted to be, mood disruptions, and sleeping difficulties were described. The pain was the main problem and the reason for seeking medical care for all participants. Descriptions such as the pain being bearable but very tiring or extremely limiting were mentioned.

> "I have always been very energetic, but the pain has restrained me. I haven't been able to be the person that perhaps I really am because I've been in such pain." [2, TWF]

Impact on activity and participation

The painful wrist had an impact on daily activities, such as getting dressed, buttoning clothes, showering, perineal care, washing and styling the hair, cleaning the house, cooking, writing, driving, walking the dog, and changing nappies. Not being able to manage their jobs properly or difficulties when carrying their children or grandchildren was also mentioned. These difficulties were frustrating, affected self-esteem, and had an impact on different life roles, such as being a parent, grandparent, or their role at work. Living with a painful wrist was additionally challenging regarding participation in everyday activities and sometimes led to feelings of not being fun to be around. Feelings of irritation, which distanced them from friends and family, were mentioned, whereas other participants felt that it was important not to let the pain stop them.

> "I couldn't get dressed properly and it was impossible to button a shirt, for example. I couldn't put up my hair in a ponytail. All these ordinary activities that you think you will easily manage. I just couldn't do it." [2, TWF]

Dependency on others

The constant pain and disability meant being dependent on their work colleagues, family members, or friends to solve various tasks. There were participants who felt reluctant about asking for help because of the feeling of being a burden to others and the feeling of wearing out friends or work colleagues. Family members were described as being supportive and helpful but could sometimes be even too supportive, in conflict with the participants' desires to be self-sufficient. The surrounding world's awareness of the participants' wrist problems made it easier to ask for help and decreased the feeling of being a burden.

> "My family is amazing. They even complain when I don't ask for help. But at the same time, I have this feeling … I can't ask for help all the time. I'm already falling apart and to be able to feel that I can be a father, that is important to me." [9, TWA]

Table 4
Categories and subcategories

Categories	*Subcategories*
The problematic wrist	*Living with pain*
	Impact on activity and participation
	Dependency on others
The breakpoint	*Decision to undergo surgery*
	Involvement in the decision to undergo surgery
	Expectations of surgery
Appraisal of the results	*Pain*
	Stiffness versus motion
	Impact on activity and participation
Adaptation to challenges in everyday life	*Compensatory movement patterns*
	Adjustments to everyday domestic life
	Seeking assistance
	Change of occupation and work tasks
	Positive thinking and acceptance

The breakpoint

Decision to undergo surgery

Living with unbearable constant pain and the desire to be free from it caused the participants to reach a breakpoint where they decided to undergo extensive wrist surgery. Most participants discussed the different surgical alternatives with their treating surgeon. However, it was mentioned by a few participants having a TWF that they were never presented with the alternative of a TWA. This was disturbing for some in retrospect but did not bother others.

For TWF participants, the assurance of getting an almost completely pain-free wrist was more important than trying to preserve some of the motion. The participants were informed by their surgeon about the restrictions of loading the wrist when choosing a TWA. They were also informed about the risk of needing further surgery in the future, especially for participants who worked in manual labor. This aspect of not having to undergo additional surgery in the future was seen as an important factor for choosing TWF.

> "I can't really remember the other two options, but at that precise moment, I thought that maybe it would come back again [the pain]. But with this [the TWF], it felt like it would be good, and that the pain would go away. That's why I chose it [the TWF]." [10, TWF]

The preservation of some wrist motion played a great role in the choice of having a TWA. However, it also involved a certain amount of uncertainty regarding the sustainability of the implant and the risk of additional surgery. The TWA participants valued their wrist motion highly, and a TWF was seen as the last alternative. Regardless of this, if things got worse after the TWA, the participants reasoned that there was always a way out by having a TWF.

> "To choose a total wrist fusion, that's it. That's the choice you have to live with for the rest of your life. I still have that choice now, having a fusion, but I can't first have a fusion and then an implant." [12, TWA]

Involvement in the decision to undergo surgery

All participants felt involved in the surgical decision, whether they were presented with an option or not. It was described as being both good and bad to have options to choose from. Some participants expressed that they did not know what was best for them because they were not experts on the subject. Information regarding surgery, expectations, and outcomes was given, and some even mentioned that they felt like a colleague to the surgeon.

> "I got to choose. But then I think it is both good and bad because I don't know anything about this, how am I supposed to say; 'Yes, I want to do that'? But at the same time, I can understand

why this has to be my choice because if things go wrong I could say; 'But you told me to do that'. So, I totally understand." [13, TWF]

Expectations of surgery

Becoming pain free was the main expectation mentioned by all participants. To manage daily activities without pain was strongly desired. In contrast to this, high demands on motion and strength were not expressed as expectations of the surgery. Instead, expectations of regaining different roles in life, such as returning to work or finally being able to lift their children or grandchildren again, were anticipated. Not being able to stand the pain any longer was frequently described, as was a wish that this surgery would be the last one. Participants who had gone through several previous surgeries had lower expectations about the effect of the TWF or TWA. They also reported more remaining pain compared with participants who had a TWF or TWA as a first-line treatment.

"I hardly had any expectations concerning improved movement or any other miracles. My biggest expectation, and the reason I chose to do this [surgery], was to be pain-free. I would stop Muay Thai [boxing], I would let go of these things in exchange for living a life without nagging pain." [12, TWA]

Appraisal of the results

Pain

Most of the TWF participants expressed that it was worth having the surgery because they got rid of the pain. A few of the participants mentioned that pain was still present to some extent, especially when loading the wrist. Some experienced a different kind of postsurgical ache or even a secondary pain in the arm that they referred to the lack of wrist motion. But for all participants, this pain was not comparable to the constant pain they had before the TWF.

"Things are great after surgery! Sometimes I can feel pain, but it rarely hurts too much. So, I feel things are really good. I sometimes feel pain in my arm and shoulder because I use the arm differently. I suppose it's strenuous to use my arm this way." [11, TWF]

The level of pain relief varied among the participants who had received a TWA from being pain-free to having less pain than before the surgery. Heavy loading of the wrist caused pain, but it was expressed as something they could control by adjusting their level of activity.

"Regardless of what I do with it now [the hand], 99% of the time I don't have pain. I get pain if I overload it, but I know I am not supposed to do that." [8, TWA]

Stiffness versus motion

Some of the TWF participants declared that they had not been mentally prepared for the loss of wrist motion, but they felt that it was still worth having a TWF because of the pain relief. It was also mentioned by some that because their wrist motion had been so limited before surgery, having a TWF was no big concern. TWF participants expressed that everyday life and doing ordinary daily activities were satisfying, but more forceful activities were troublesome.

"I think about it daily, missing the motion of my wrist. But it's definitely worth it to be free from the pain. I couldn't deal with the pain. But I do miss the motion of my wrist. That's just the way it is." [2, TWF]

All TWA participants valued their wrist motion, and it was seen as a prerequisite for being able to live a normal life. The range of wrist motion varied from very restricted to even greater than before surgery. The main goal of having a TWA was pain relief. A preserved motion was seen as important, but not at the expense of increased pain. If the pain got worse, a TWF was seen as an alternative.

"To be 43 years old and have a completely stiff wrist, I don't want that. But when I am 65 years old, then it doesn't matter if I have a stiff wrist. That's why this was an easy choice for me." [3, TWA]

Impact on activity and participation

Reaching into confined spaces, washing the back, taking something down from a high height, reaching into a drawer, and perineal care, all of these activities were declared difficult by most of the TWF participants and by some of the TWA participants. Both groups struggled with fine-motor function, such as opening a packet of coffee or picking up small items from the floor. To some, this was a minor problem, whereas others were bothered more. Forceful activities such as push-ups were declared impossible by most of the participants. However, feelings of not having any limitations at all were also expressed. Improvements in the ability to perform ordinary daily activities and participation in social life with family and friends were described after both TWF and TWA surgery.

For TWF participants, the loss of wrist motion could be challenging in social events. For example, having to plan where to sit for dinner so that they would not hit the person next to them with their elbow while eating, or having to stand up to be able to deal cards during a card game. These challenges could create a feeling of reluctance to participate.

"I dread going to a restaurant if I can't plan where I can sit. You know that you have to lift your left elbow to be able to reach your mouth. That makes you bewildered." [1, TWF]

For TWA participants, either work–life was still much affected or it was no problem at all. Having considered work colleagues who acknowledged the limitations made work–life easier. Demanding leisure activities such as playing tennis, badminton, floorball, and even cross-fit was described to work out well after having a TWA.

"It has affected me in the sense that I can have an active life after work, and that has helped with my daily well-being." [12, TWA]

Adaptation to challenges in everyday life

Compensatory movement patterns

Compensatory movement patterns were used to manage daily activities, for example, finding positions to rest the arm, doing things differently, using the compensatory movement of the shoulder and elbow, and using the other hand or both hands more often. The reasons for these compensatory movements were stiffness of the wrist, not trusting the wrist, pain, fatigue, and the fear of damaging the wrist. "Making it all work out," "finding the right balance," and not letting the wrist "stand in the way" were important to all participants, and using compensatory movement patterns, both consciously and unconsciously, enabled them to overcome everyday challenges. A protective behavior, as a consequence of fear of damaging the wrist again, was described by participants who had undergone several previous surgeries with inadequate results.

> "It can be problematic when I pour myself a cup of coffee or milk to the children. Sometimes I end up in a stupid, weird position with my wrist, and then I have to compensate the movement with my shoulder or elbow. So, I've learned how to compensate for my wrist." [3, TWA]

> "You know, I constantly protect my hand. I never want anything to happen to it again. Never. I protect it as much as I can and avoid dangerous situations. For example, if the road is slippery, I make sure I don't wear high heels, and I walk very carefully. In crowded places, I keep my hand close to my body. I think about protecting my hand a lot." [2, TWF]

Adjustments to everyday domestic life

Adjusting to different ways of doing things became part of all participants' lives. The participants had to prioritize activities, and assistive devices were sometimes needed. The use of different kitchen utilities was common, but even more advanced adjustments, such as rebuilding the household or buying high technology equipment, were mentioned. A simpler form of adjustment was to use a wrist orthosis as support or protection. Adjustments in domestic life required new learning skills as well as inventiveness and were described as a process being developed over time.

> "You have to be inventive. I bought new knives for the kitchen, you know the ones with straight handles, and new cheese slicers, also with straight handles. Stuff like that. You have to adjust. Of course, it would have been nice to not have to adjust, but everything is manageable. The most important thing is to be free of pain." [11, TWF]

Seeking assistance

Asking for help was mentioned as a strategy if things became too difficult, but this created mixed feelings; like being a burden and a strong desire to be self-sufficient made some of the participants reluctant to ask for help.

> "It's tough. I don't want to ask for help, but I have to, to avoid getting in a bad mood. To be honest, I've had to ask for help a lot." [1, TWF]

Change of work tasks and occupation

Being forced to retrain from manually demanding occupations, such as working with construction or in a warehouse, to more administrative-related services, was being mentioned in both groups. This was easily doable for some who were offered retraining at their existing employment, whereas others had to seek completely new occupations or had to pay for retraining or education themselves. Feelings of inadequacy and distress were mentioned by participants who still had a manually demanding job they felt they could not handle because of the wrist.

> "I've had to adjust my working life a lot over the years because of my hands. Now I've found a job where I don't have to do that since I mostly use my head and my mouth." [9, TWA]

Positive thinking and acceptance

The creation of a different mindset was a way of handling the feelings and thoughts about the limitations experienced in everyday life due to the wrist. It was mentioned that it was important not to give up on things and instead be inventive and resourceful. Having a positive attitude was seen as very important. The participants tried to live their lives as normal as possible, accepting things for what they were and focusing on tasks that they could perform, instead of thinking about things they could not do. Coping by distracting attention from their problems and shifting focus outward to happy and enjoyable things such as listening to music, taking a long walk in the forest, and seeing friends were also strategies described. Managing emotional problems by seeking social support and talking about their concerns regarding their wrist problems were important strategies mentioned. Personal resources such as being used to physical exercise, not being afraid of pain, stubbornness, being a fighter, being goal orientated, and having patience were seen as strengths.

> "I think I am positive. I find things that are enjoyable. And things that I can do. The other things you don't need to care that much about." [8, TWA]

Discussion

This study describes the process of living with chronic wrist pain leading to the decision to undergo surgery with a TWF or a TWA. Living with pain limited the participants' quality of life, their ability to function as desired, and had a negative impact on their level of activity and participation. In addition, the study also shows the resourcefulness of adapting to a stiff wrist or a wrist with limited motion. The different coping strategies that the participants developed and the involvement in the surgical decision had an effect on how the outcome of the surgery was perceived.

Although patients with advanced wrist OA have diverse experiences, pain was the central problem. Due to their painful osteoarthritic wrists, the participants experienced profound changes in various life roles. A desire to be self-sufficient and to regain different roles, such as going back to work or lifting their grandchildren, was expressed and had an impact on the participants' self-esteem. This is consistent with previous studies on wrist fractures and different hand injuries.[28-30] Also, Gustafsson et al showed that unintended changes in life roles can negatively affect self-image and self-confidence and create a sense of inadequacy.[31]

Although living with wrist OA can be well tolerated for many years, the combination of chronic pain, limitations in wrist motion, and its impact on the level of activity and participation made the participants reach a breaking point and come to the decision that they needed surgery. The main expectation of surgery was pain relief, and the preserved range of motion was wished for but depending on life situation and occupation seen as secondary for some. It is possible that these expectations were influenced by the long-time experience of living with chronic wrist pain and that higher demands on wrist motion would have been more obvious, in, for example, acutely injured wrist patients. All participants expressed various levels of pain relief after surgery, and they were able to regain different life roles. An interesting finding in our study was that participants who had either a TWF or a TWA as a first-line treatment experienced more pain relief after surgery than the participants who had undergone several previous surgeries before the TWF or the TWA. This suggests that surgeons might address the discussion about having a TWF or TWA earlier in the process. Furthermore, the fulfillment of reasonable preoperative expectations has shown, in ours as well as other studies, to be associated with postoperative satisfaction.[32,33] The decision to undergo surgery differs from other decisions in health care because an irreversible surgical intervention could potentially fail to improve the patient or sometimes even cause the patient more harm. The majority of the participants in our study wanted to actively discuss options and share their views on the treatment with their surgeon. A shared decision-making (SDM) process has been shown to improve patient satisfaction and adherence to therapy, and it can

also reduce the risk of undesired care.[34] It can help patients to consider and share their preferences of the treatment and enables the surgeons to elicit these preferences and incorporate them into the final decision.[34,35] In our study, we found that some participants were only presented with a TWF, and the alternative of a TWA was never discussed. The reasons for this were not explored in our study because we did not interview the surgeons. However, the surgeon's personal experience and technical skills probably affect the information shared with the patient and influence which options the patient is presented with. The use of evidence-based decision aids, consisting of written information on the disease and the different treatment options available with their associated benefits and harms, could help both the patient and the surgeon to make careful treatment decisions.[36] There were participants in our study that were so preoccupied with getting rid of their chronic wrist pain that the wish for keeping joint motion was suppressed. Acknowledging this in the SDM process is important and can be done by helping the patient with mental preparedness for the loss of wrist motion, both through preoperative information and education but also by simulating the loss of motion with a wrist brace.

The preserved wrist motion enabled the participants with TWA to function more easily and was seen as a prerequisite for being able to live a normal life. Interestingly, the TWA participants reported more subjective pain and disability than the TWF participants. This was supported by the Visual Analogue Scale and Patient-Rated Wrist Evaluation outcomes (Table 2). However, they managed to control their pain by changing their choice of or performance in daily activities. Although preserving motion was important for the TWA participants, they were prepared to sacrifice wrist motion if the pain became unbearable. The TWF participants had more difficulties with reaching into narrow spaces, perineal care, and fine-motor functions. Nonetheless, not all participants with a TWF considered these restrictions to be important in their everyday lives. This is consistent with previous studies that have shown that nearly all everyday activities can be performed regardless of limitations in the wrist range of motion.[37,38] In a retrospective study, patients after wrist surgery reported that loss of motion was the main regret postsurgery, and persistent pain was the main source of dissatisfaction.[39] Additional efforts to perform prospective, comparing studies are warranted to further define clinical and functional outcomes among patients who receive TWA compared with TWF.

Regarding the participant's choice of surgery, the risk of additional surgery, including a future TWF, was accepted among TWA participants. This differed from the TWF participants who expected the surgery to be the final one. In addition, to participants who had limited wrist motion before TWF, the loss of motion was not seen as a problem. The TWA participants who had a substantial range of motion in their wrists before surgery were more concerned about the potential loss of mobility. Hence, the risk of additional surgery and the preoperative range of wrist motion should be taken into account when discussing different surgical options with patients.

A significant finding in our study was the level of impact a painful wrist, as well as having a TWF or TWA, had on the participants' whole lives. In the struggle to achieve normality after surgery, the participants were forced to adapt to different challenges in everyday life. Most participants had to retrain or find new occupations, which forced them to change their work roles. New job identities needed to be created, which was easily done for some, whereas others struggled more. Successful coping strategies were developed over time, involving the use of both simpler and more complex assistive devices, using compensatory movement patterns, and making modifications to their homes. This is in line with a study that has shown that using tricks and assistive devices to perform daily activities is the most widely used problem-based coping strategy in individuals with a chronic physical impairment.[40] Emotional as well as practical problems were also managed by seeking social support and having family members, friends, or coworkers available to ask for help. For some participants, asking for help was expressed as being stressful, as they desired to be self-sufficient and have personal control of a situation. A sense of control has been pointed out to be central for positive adjustments and has been found to be a dominant coping strategy.[31,41]

Coping by focusing on the positive aspects of their problems or their situations, seeing solutions instead of problems, was used by participants in our study. They relied on their own personal capacity, such as being stubborn, goal orientated, and not giving up, to manage difficult situations. According to Lazarus and Folkman, cognitive reappraisals are coping strategies that change the meaning of a situation without changing it objectively.[42] By positive thinking, relying on a personal capacity and distracting attention, the participants in this study tried to minimize or make sense of the problem or situation. On the contrary, coping by accepting the situation as it is and try to make the best of it was also mentioned. Carver et al showed that acceptance is a coping strategy often used when a stressful situation is perceived impossible to change.[43]

Participants who had undergone several previous wrist surgeries were more prone to developing coping strategies that involved avoidance and protective behavior. The reasons for developing protective behavior are complex and not always related to clinical evidence.[44] Avoidance and anxiety should be acknowledged because it can be a hindrance to adaptation and development of useful coping strategies.[42,45] The participants with protective behavior in our study referred to the fear of breaking the wrist, which to them was a terrifying thought. Reassurance and information about loading should be given to patients who receive a TWF because breakage of a fused wrist arthrodesis is not likely. However, to participants with TWA, the risk of implant loosening due to overloading is probably a real threat. As it is not known among surgeons to what extent a TWA could be loaded, it is reasonable to assume that the uncertainty regarding load was communicated to the participants, creating a feeling of precariousness. Further studies are needed to enhance the understanding of the relationship between loading and failure of a wrist arthroplasty.

Methodological considerations

To achieve a deeper understanding of how patients experience living with a painful OA wrist and how they appraise the results after a TWF or a TWA, we used a qualitative descriptive study design.[16,17] The experiences and perspectives of the surgeons who conducted the TWFs and the TWAs, and patients with advanced wrist OA who did not want a TWF or TWA, were not explored in this study. Thus, our study has limitations in clarifying the whole decision-making process.

Recall bias should be considered because the interviews were made several years after the surgery. However, the participants described strong and vivid memories from the time before surgery. Even if some details have perished, this would not likely have influenced our overall findings.

Conventional content analysis was used to study individual experiences, and the trustworthiness of the findings was evaluated by establishing credibility, dependability, and confirmability.[25] Credibility was established with the use of a purposive variated sample in both groups. Dependability was accomplished by the use of investigator triangulation, where the author and coauthors (S.L., I.K.C., and E.B.), read and coded the interviews independently. All authors then discussed and interpreted the text together and made an in-depth analysis.[25,46] The interviews varied in depth and length

but were rich in detail, enabling a focus on a descriptive manifest analysis but also a latent analysis with a low degree of interpretation. Both manifest and latent content deal with interpretation but can vary in depth and level of abstraction.[16,26] It has been suggested that it is beneficial to use both, whenever possible.[25] Due to the broad aim of the study, a latent analysis including the formulation of a theme, was not applicable. A theme has been described to represent a thread of an underlying meaning through meaning units, codes, and categories.[16] The trustworthiness was achieved by including representative quotations from the participants, making the interpretation transparent for the reader. Constantly confirming and clarifying information during the interviews assured confirmability. The focus was consistently on the text to reduce the risk of overinterpretation. Transferability in this study is limited since the participants represent a small study group.

Clinical implications

Enabling the patients to be part of the decision-making process and being informed about the different surgical alternatives is important for surgeons to acknowledge because it has been shown to improve patient satisfaction and adherence to therapy.[34] Decision aids, consisting of evidence-based information about the disease and the treatment options, should be developed and used as part of the SDM process to help both the patient and the surgeon to focus on the patient's individual needs to optimize the choice of treatment. Furthermore, having a TWF or TWA as a first-line treatment seems to be related to a reduced risk of prolonged pain and suffering. This suggests that the surgical discussion about having a TWF or TWA may be addressed earlier in the decision-making process.

Expectations regarding surgery, when it comes to both pain relief and wrist motion, should be thoroughly discussed between the patient and the surgeon to assure that they are realistic.

To enhance the patients' independence and enable individualized postoperative treatment, these patients should also be offered to see a hand therapist before surgery. The patient can then receive information about the consequences of wrist surgery and postoperative rehabilitation. The opportunity to further discuss expectations may also improve postoperative satisfaction and adherence to therapy. Also, the adaptation strategies to overcome challenges in everyday life described in this study can serve as an educational base for hand therapists to pass on to patients both pre- and post-operatively.

Conclusions

This study provides an increased understanding of how patients reason about their surgical choices between a motion-preserving procedure (TWA) as opposed to a motion-sacrificing one (TWF) and how they cope with life after TWF or TWA. The findings contribute valuable insights to both surgeons and hand therapists about the importance of careful evaluation and information to these patients. The patients' individual expectations, previous surgical experiences, amount of wrist motion, personality, life situation, and occupation, influence the surgical choice with either a TWF or a TWA. It appears that an individual's perceived ability to perform tasks in everyday life is more related to the level of pain than the range of wrist motion.

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Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jht.2020.10.004.

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1. The study design is
   a. RCTs
   b. qualitative
   c. retrospective cohort
   d. case series

2. To date there
   a. are no published studies describing either TWF or TWA
   b. is one case series comparing outcomes of TWF with TWA
   c. are several well-regarded RCTs comparing outcomes of TWF with TWA
   d. are no RCTs comparing outcomes of TWF with TWA

3. Interviewers used
   a. a group session approach
   b. a virtual approach
   c. an inductive approach
   d. a deductive approach

4. The primary expectation of patients was
   a. some lessening of pain
   b. the elimination of pain
   c. improved function
   d. improved ROM

5. Typically the patients described a “breakpoint” wherein they felt they simply had to have the problem addressed surgically
   a. true
   b. false

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Paper II

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BMC Musculoskeletal Disorders

RESEARCH Open Access

Psychometric properties of patient-reported outcome measures (PROMs) in wrist osteoarthritis: test–retest reliability and construct validity

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Abstract

Background: Patient-reported outcome measures (PROMs) are frequently used to assess the effects of treatments in patients with wrist osteoarthritis (OA), but their psychometric properties have not been evaluated in this group of patients. Our aim was to evaluate the psychometric properties of the Numeric Rating Scale (NRS pain at rest, pain on motion without load, and pain on load), the Disabilities of the Arm, Shoulder and Hand (DASH) and the Patient Rated Wrist Evaluation (PRWE) questionnaires in patients with wrist OA regarding test–retest reliability and construct validity.

Methods: The NRS, DASH and PRWE were self-administered by 50 patients (40 men and 10 women, mean age 66 years) in a postal survey on two occasions, two weeks apart. Test–retest reliability was evaluated by Kappa statistics and the Spearman rank correlation coefficients (rho) were calculated to evaluate construct validity.

Results: The Kappa coefficients for DASH, PRWE and NRS pain on motion without load and NRS pain on load were > 0.90, 95% CI ranging from 0.84 to 0.98, while NRS pain at rest was 0.83, 95% CI 0.73–0.92. The construct validity of the PROMs was confirmed by three formulated hypotheses: a higher correlation between PRWE and NRS (rho 0.80–0.91, $p < 0.001$) was found, compared to DASH and NRS (rho 0.68–0.80, $p < 0.001$); the NRS pain on motion without load and NRS pain on load correlated more strongly to PRWE and DASH (rho 0.71–0.91, $p < 0.001$) compared to NRS pain at rest (rho 0.68–0.80) and a high correlation between PRWE and DASH was found (rho 0.86, $p < 0.001$).

Conclusions: The NRS, DASH and PRWE demonstrate excellent test–retest reliability and moderate to high construct validity in patients with wrist OA. These PROMs are highly related, but they also differ. Therefore, they complement each other in ensuring a comprehensive evaluation of perceived disability in wrist OA. As PRWE showed the highest test–retest reliability and the highest relation to the other PROMs, the sole use of the PRWE can be recommended in clinical practice.

Keywords: Wrist osteoarthritis, Patient-reported outcome measures, Psychometric properties, NRS, DASH, PRWE

Background

Patients with wrist osteoarthritis (OA) commonly suffers from pain, decreased range of motion (ROM) and reduced grip strength [1, 2]. These impairments can have a significant impact on patient's ability to perform daily activities and to participate in society [3]. Reducing pain and improving the patient's ability to use their hand and

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wrist in daily activities are a prime focus in non-surgical and surgical treatment strategies for patients with wrist OA [1, 2, 4].

Indications for interventions in patients with wrist OA are often the patient's self- perceived symptoms and disabilities [3]. Therefore, patient-reported outcome measures (PROMs) are important to include when assessing the effects of different treatments for wrist OA because they provide a more complete picture of the disability from the patient's perspective [5, 6].

In wrist and hand OA, commonly used PROMs are pain rating scales, such as the Visual analogue Scale (VAS) and the Numerical Rating Scale (NRS) [7–10] for measuring pain intensity, the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire [8, 11–13], and the Patient-Rated Wrist Evaluation (PRWE) questionnaire [14, 15]. The DASH measures self-reported upper extremity physical function and symptoms taking the whole upper extremity into account, irrespective of which hand or if both hands are used and is the most commonly used PROM in clinical trials for patients with wrist OA [8]. The PRWE is a wrist specific PROM originally developed for the assessment of perceived disability after a distal radius fracture. Content validity of PRWE has previously been evaluated in the context of hand and wrist arthritis (27% with OA, 67% with rheumatoid arthritis and 6% with psoriatic arthritis) [16], but apart from this, none of these PROMs have been evaluated regarding their psychometric properties in the context of wrist OA.

As the psychometric properties of a measure are closely linked to the population it is intended for, there is a need to investigate the psychometric properties for these PROMs in patients with wrist OA [17, 18]. The aim of our study was to assess and compare the psychometric properties of the NRS, DASH, and PRWE in a group of patients with wrist OA regarding test–retest reliability and construct validity.

Material and methods

Participants

Data were collected from January 2020 to December 2021. Inclusion criteria were 1) radiographically confirmed wrist OA and 2) age $\geq$ 18. Exclusion criteria were 1) the presence of other diseases or disorders that could affect arm and hand function, 2) previous surgery to the wrist, and 3) inability to understand and follow test instructions due to communicative, mental, or cognitive impairments.

Via the hospital's administrative patient system, 66 patients (54 men and 12 women) seeking medical care for wrist OA at the Department of Hand Surgery, Skåne University Hospital Malmö, Sweden between the years 2016 to 2021 were identified by reviewing the patients' medical records. Thirteen patients did not respond and three declined to participate, leaving 50 patients that were included in the study.

Prior to inclusion, information about the purpose of the study was provided, and all participants gave their written consent to participate. The principles of the Declaration of Helsinki were followed. The study was approved by the Swedish Ethical Review Authority, Dnr 2019–02,437. The COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN) checklist, guidelines for methodological quality in psychometric studies, was followed [19].

Outcome measures

The NRS [20–22] is a numeric 11-point pain rating box scale with numerical descriptors on the box, ranging from 0 representing one pain extreme (no pain) to 10 representing the other pain extreme (worst pain imaginable). Patients select a value that is most in line with the intensity of pain they have perceived in the affected wrist over the last week. Three measures of pain are rated in this study: 1) pain at rest, 2) pain on motion without load, and 3) pain on load [23]. The NRS have been found to be valid and reliable in different acute and chronic pain conditions and in healthy populations [20, 22].

The main part of the DASH is a 30-item disability/symptom scale concerning the patient's health status during the preceding week [11, 12]. The items ask about the degree of difficulty in performing different physical activities because of arm, shoulder, or hand problems (21 items), the severity of each of the symptoms of pain, activity-related pain, tingling, weakness and stiffness (5 items), as well as the problem's impact on social activities, work, sleep, and self-image (4 items). Each item has five response options. The scores for all items are then used to calculate a scale score ranging from 0 (no disability) to 100 (most severe disability). The score for the disability/symptom scale is called the DASH score. The DASH is one of the most important PROMs for measuring upper extremity disability, and its psychometric properties have been evaluated in a range of conditions involving the upper extremity [24, 25]. In this study, the validated Swedish version of DASH was used [13].

The PRWE [14] includes 15 questions, divided into two subscales assessing pain (5 items) and function (10 items, 6 concerning specific tasks and 4 the ability to perform daily activities) over the past week. The questions are scored on a 10-point ordered categorical scale, ranging from no pain or no difficulty (0 points), to worst pain or unable to do (10 points). The total score of the subscales pain (sum of 5 items) and function (sum of 10 items divided by 2) ranges from 0 to 50. The maximum total

score of PRWE is 100 and represents the worst disability, whereas 0 represents no disability. The PRWE has mainly been found to be valid and reliable in patients with distal radius fractures, but also in a variety of other hand and wrist-related injuries and disorders [7]. In the current study, the validated Swedish version of PRWE by Wilcke et al. was used [26].

The quality of a PROM depends on its psychometric properties, such as reliability and validity [18]. Reliability implies that the measure produces similar results under consistent conditions. We evaluated this in a test–retest situation, i.e. the outcome measures should ideally produce similar results from one test occasion to the next, thus indicating that the measurements are stable over time [17]. Validity refers to the degree of which a test measures what it is intended to measure, and can be evaluated as construct validity, where outcomes of the same construct should be related to each other [18]. As no ´gold standard´ exists for PROMs, the commonly used way to investigate construct validity is to test hypotheses about expected relationships with other outcome measures of good quality [27]. To assess construct validity, we have chosen three reliable and valid PROMs frequently used to evaluate the effect of treatment on patients with wrist OA. We formulated the following hypotheses: 1) PRWE should correlate more strongly to NRS compared to DASH and NRS because PRWE includes the subscale pain and both NRS and PRWE are wrist specific; 2) NRS pain on motion without load and NRS pain on load should correlate more strongly to PRWE and DASH compared to NRS pain at rest as both PRWE and DASH mainly contain activity based questions; and 3) PRWE and DASH should have a moderate to high correlation since they measure the same construct, i.e. upper extremity disability. However, since these questionnaires differ slightly, with DASH being more generic than PRWE, we did not expect a very high correlation (> 0.90).

Procedures

Information about the study with an informed consent form was sent to the participants by surface mail together with the PROMs (NRS, DASH and PRWE) for test occasion 1 (T1). The participants noted the date when the questionnaires were responded and returned them in a prepaid envelope. When the researcher had received the responses of the T1 questionnaires, the same questionnaires for test occasion 2 (T2) were sent to the participants. If a participant failed to send T2 within two weeks, he/she was reminded by telephone or a second surface mail. The time interval of the responses between T1 and T2 became approximately two weeks, with some outliers taking longer time, which is standard in test–retest studies [18, 28].

Background data – such as gender, age, affected side and handedness – were obtained from the medical records. All patients included in the study had wrist radiographs and/or computer tomography taken prior to referral to our clinic. The radiographs were evaluated by an experienced hand surgeon (EB), and the type of wrist OA (scapholunate advanced collapse; SLAC, scaphoid non-union advanced collapse; SNAC, idiopathic wrist OA or Mb Kienböck) was recorded (see Table 1). If the participants had bilateral wrist OA, the wrist that the participant reported as the most affected was included in the wrist specific assessments.

Statistical analysis

Descriptive statistics – such as means, standard deviations (SD), frequencies, median (range) – were calculated as appropriate.

The test–retest reliability of NRS (pain at rest, pain on motion without load, and pain on load), DASH and PRWE (total score and subscales pain and function) were evaluated by Kappa statistics (the proportion of agreement observed beyond the agreement expected by chance) using quadratic weights [28–30]. The strength of the Kappa coefficient can be interpreted as follows: < 0.40 poor, 0.40 to 0.75 fair to good, and > 0.75 excellent [31].

The Spearman rank correlation coefficients (rho) were calculated to evaluate construct validity. The PRWE and DASH were correlated to NRS, and the correlation between PRWE and DASH was also calculated. Data from the first test occasion were used in the construct validity analyses. The strength of the correlations was interpreted as follows: rho < 0.5 low, 0.5 to < 0.7 moderate, > 0.7 high [32].

Data were analyzed with the IBM SPSS Statistics version 27 (IBM Corporation, Armonk, New York, United

Table 1 Characteristics of 50 participants with wrist osteoarthritis (OA)

Characteristics	
Age, mean (SD; min–max)	66 (9; 41–79)
Male sex, n (%)	40 (80)
Affected wrist, dominant, n (%)	33 (66)
Type of OA, n (%)	
SLAC	38 (76)
SNAC	6 (12)
Idiopathic OA	5 (10)
Mb Kienböck	1 (2)
Days between T1-T2, mean (SD; min–max)	16.7 (17.4; 4–86)

SLAC Scaphoid Lunate Advanced Collapse, *SNAC* Scaphoid Non-union Advanced Collapse, *T1* Test occasion 1, *T2* Test occasion 2

States). *P*-values < 0.05 were considered statistically significant.

Results

The clinical characteristics of the 50 participants are presented in Table 1. Their mean age was 66 years (SD 9) and the dominant hand was the most commonly affected. A majority of the participants were diagnosed with a SLAC wrist. The mean interval between the responses was 16.7 days (SD 17).

The Kappa coefficients for DASH, PRWE (total score and the subscales pain and function) and NRS pain on motion without load and NRS pain on load were > 0.90, 95% CI ranging from 0.84 to 0.98, while NRS pain at rest was 0.83, 95% CI 0.73–0.92 (Table 2).

The highest correlations were found between PRWE (total score and subscales) and NRS pain on motion without load (rho 0.89–0.91, $p < 0.001$), and between PRWE total score and DASH (rho 0.86, $p < 0.001$). The PRWE subscale pain correlated higher (rho 0.84, $p < 0.001$) than the other measures to NRS pain at rest. Somewhat lower correlations were seen between DASH and NRS (rho 0.68–0.80, $p < 0.001$) (Table 3).

Discussion

This study has evaluated test–retest reliability and construct validity for the NRS, DASH, and PRWE on patients with wrist OA. Our results showed excellent test–retest reliability for these PROMs when applied to this specific group of patients. High correlations were seen between PRWE, NRS and DASH, whilst moderate to high correlations were seen between DASH and NRS.

The NRS, DASH and PRWE are rated in ordinal scales, therefore, retest reliability was analysed with Kappa statistics as recommended [27]. In a systematic review by Shafiee et al. [7], the intraclass correlation coefficient (ICC) was included when evaluating test–retest reliability, which should actually be used when evaluating agreement for parametric data [33]. Thus, the retest reliability results of the current study are not fully comparable even though a quadratic kappa gives about the same result as an ICC [34].

Excellent agreement according to the kappa-coefficient was found for the NRS (0.83–0.92). Earlier studies have mainly used a visual analogue scale (VAS) score evaluating general pain intensity for the wrist, but also with excellent test–retest agreement (ICC 0.84) [7, 35]. Although high test–retest agreement of NRS has been

Table 2 Test–retest reliability of the NRS, DASH and PRWE in 50 patients with wrist osteoarthritis (OA)

PROMs	T1, median (IQR)	T2, median (IQR)	Kappa coefficient (CI 95%)
NRS			
Pain at rest	3 (1–5)	3 (1–6)	0.83 (0.73–0.92)
Pain on motion without load	6 (3–8)	6 (3–8)	0.91 (0.86–0.95)
Pain on load	8 (5–9)	7 (5–9)	0.92 (0.87–0.96)
DASH	37.1 (21.5–55.4)	38.4 (22.9–54.6)	0.91 (0.84–0.98)
PRWE			
Subscale Pain	30.5 (22.5–38.0)	31.5 (23.0–38.3)	0.93 (0.90–0.97)
Subscale Function	26.8 (13.4–34.7)	24.5 (14.7–36.0)	0.93 (0.88–0.98)
Total score	56.0 (31.5–69.5)	53.5 (35.4–75.4)	0.94 (0.91–0.98)

T1 Test occasion 1, *T2* Test occasion 2, *IQR* Interquartile range, *CI* Confidence interval, *NRS* Numeric Rating Scale (score range 0–10), *DASH* Disabilities of the Arm, Shoulder and Hand (score range 0–100), *PRWE* Patient-Rated Wrist Evaluation (subscale pain score range 0–50, subscale function score range 0–50, total score range 0–100)

Table 3 Spearman rank correlations (rho) between NRS, DASH and PRWE in 50 patients with wrist osteoarthritis (OA)

PROMs	PRWE total		PRWE pain		PRWE function		DASH	
	Rho	*P*-value	Rho	*P*-value	Rho	*P*-value	Rho	*P*-value
NRS pain at rest	0.80	< 0.001	0.84	< 0.001	0.74	< 0.001	0.68	< 0.001
NRS pain on motion without load	0.91	< 0.001	0.89	< 0.001	0.89	< 0.001	0.80	< 0.001
NRS pain on load	0.86	< 0.001	0.79	< 0.001	0.80	< 0.001	0.71	< 0.001
DASH	0.86	< 0.001	0.83	< 0.001	0.84	< 0.001	-	-

NRS Numeric Rating Scale (score range 0–10), *DASH* Disabilities of the Arm, Shoulder and Hand (score range 0–100), *PRWE* Patient-Rated Wrist Evaluation (total score range 0–100)

reported [36], it is not as thoroughly investigated as VAS [22]. A high correlation between VAS and NRS has been established, and NRS is recommended to use when assessing pain intensity on the basis of higher compliance rates, better responsiveness, ease of use, and good applicability relative to VAS [20]. Our study showed that NRS pain at rest had somewhat lower Kappa coefficient (0.83) compared to NRS pain on motion without load and NRS pain on load (0.91–0.92). Osteoarthritic pain is complex and variable with "good days and bad days" mainly occurring on use, movement, weight-bearing and later in the day [3, 37]. All these factors probably affect pain at rest, thereby resulting in more pain variations.

An excellent kappa coefficient was found for DASH in our study (0.91). This is in line with previous studies [13, 38–42] that have shown excellent test–retest agreement for DASH with ICC > 0.90 in patients with various upper extremity disorders. The PRWE also showed excellent agreement for the total score and the subscales (Kappa coefficients 0.93–0.94). This is in accordance with a previous systematic review evaluating test–retest reliability for PRWE in 24 studies of various types of wrist and hand injuries [7] that reported ICCs of 0.91–0.93 [7]. Taken together, the NRS, DASH and PRWE can be considered reliable PROMs in wrist OA; thus, they produce similar results under consistent conditions.

When construct validity was evaluated, the formulated hypotheses were confirmed. The PRWE correlated higher with the NRS pain scale compared to DASH. Since PRWE contains a very detailed section with five specific pain questions compared to DASH, which only contains two general pain questions, this was a rather expected result. Previous studies, including patients with various shoulder-, hand/wrist disorders as well as RA patients with upper extremity disabilities, have mainly found moderate to high correlations between DASH and VAS (rho 0.60–0.72) [38, 39, 41, 42]. However, one study, including various arm, shoulder and hand problems, [40] demonstrated low to moderate correlations between DASH and VAS pain at rest (rho 0.44) and VAS pain during activity (rho 0.56). Possible explanations for this low correlation could be that the recruited subjects had heterogeneous diagnoses with variable degrees of pain intensity. In accordance with the present study, Beaton et al. [38] found a high correlation (> 0.70) between DASH and VAS in patients with various shoulder- and hand/wrist disorders. Moderate to high correlations have also been found between PRWE and VAS (rho 0.50–0.74) [43–46]. When PRWE and DASH were correlated to NRS, the highest correlations were found for NRS pain on motion without load. This can be explained by the fact that most questions in both PRWE and DASH concern the disability on activities of daily living.

High correlations were found between DASH and PRWE (rho 0.86), which is comparable to previous studies that have found moderate to high correlations between DASH and PRWE (rho 0.61–0.94) [7]. Our results are expected since DASH and PRWE to a large extent resemble each other in rating the same construct, i.e., upper extremity disability, predominantly in activities. However, even if they are highly correlated, they also differ slightly probably as DASH is a generic upper limb instrument, whereas PRWE is wrist specific.

The application of self-reported outcome measures allows healthcare professionals to assess the course of treatment; furthermore, it facilitates comparison between groups in clinical trials [8]. To include different types of PROMs – such as symptom specific, wrist specific and more generic questionnaires – provides the opportunity to evaluate separate symptoms and overall self-reported upper extremity disability. This strengthens the concept that NRS, DASH and PRWE complement each other when evaluating patients with wrist OA, especially in a research setting. However, in clinical practice, barriers exists in incorporating PROMs to measure outcomes into the clinical routine because such measurements are time-consuming; thus, they can decrease productivity [47]. As we found a high correlation between PRWE and both DASH and NRS, all three PROMs may not be necessary for the assessment of wrist OA. The PRWE has been shown to be easier for patients to complete, quicker to administer and easier to score than DASH [47]. Consequently, PRWE might be recommended to be used as a sole PROM in clinical practice for assessing functional outcome of wrist OA.

Strengths and limitations

One of the main strengths of our study is the investigation of test–retest reliability and construct validity for a specific patient group, wrist OA, since a measure's psychometric properties are closely linked to the population they are intended for [17, 18].

According to the COSMIN checklist, the number of participants in this study ($n = 50$) is an adequate sample size. However, a sample size ≥ 100 would have been considered as very good [18, 48]. The time interval between the repeated ratings in our study is approximately two weeks, which is recommended [18]. However, as there were a few participants that took longer than two weeks to respond to T2, they needed to be reminded, which can be seen as a minor limitation. None of the participants were actively seeking care for their wrist problems during the data collection since data was collected retrospectively, but we cannot fully ensure that the patients were completely stable in the interim period. Most patients were men (80%), and

SLAC wrist was the most represented diagnosis (76%). This is characteristic of patients with wrist OA [4, 49], but it can limit the generalization to the whole wrist OA population.

This study provides novel data on the psychometric properties of three important PROMs used to assess perceived symptoms and disabilities in patients with wrist OA, which can improve the evaluation of different treatments for this group of patients. The recommended sole use of PRWE could also increase the use of PROMs in clinical practice. For future research, it would also be valuable to evaluate the responsiveness of these PROMs in patients with wrist OA.

Conclusions

The NRS, DASH and PRWE demonstrate excellent test–retest reliability and moderate to high construct validity in patients with wrist OA. These PROMs are highly related, but they also differ. Therefore, they complement each other in ensuring a comprehensive evaluation of perceived disability in wrist OA. As PRWE showed the highest test–retest reliability and the highest relation to the other PROMs, the sole use of the PRWE can be recommended in clinical practice.

Abbreviations

OA: Osteoarthritis; ROM: Range of Motion; PROM: Patient-Reported Outcome Measure; NRS: Numeric Rating Scale; VAS: Visual Analogue Scale; DASH: Disabilities of the Arm, Shoulder and Hand; PRWE: Patient-Rated Wrist Evaluation; CMC: Carpometacarpal; T1: Test occasion 1; T2: Test occasion 2; COSMIN: COnsensus-based Standards for the selection of health Measurement INstruments; SLAC: Scapholunate Advanced Collapse; SNAC: Scaphoid Non-union Advanced Collapse; ICC: Intraclass Correlation Coefficient; IQR: Interquartile Range; CI: Confidence Interval; SD: Standard Deviation.

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Authors' contributions

SL, EB and EE contributed to the design of the study and SL and EE drafted the manuscript. All authors participated in the interpretation of the results and revised the manuscript. All authors have read and approved the final manuscript. In addition, SL collected the data and performed the statistical analysis together with EE and EB evaluated the radiographs.

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Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available but available from corresponding author on reasonable request. Public access to data is restricted by the Swedish government (Public Access to Information and Secrecy Act; https://www.government.se/information-material/2009/09/public-access-to-information-and-secrecy-act/). However, data may be available for researchers upon special review and includes approval of the research project by both an Ethics Committee at national level and governmental data safety committees.

Declarations

Ethics approval and consent to participate

The study was performed in accordance with the ethical guidelines stated in the Declaration of Helsinki and approved by the Swedish Ethical Review Authority (Dnr 2019–02437). Prior to inclusion, information about the purpose of the study was provided, and each person gave their written informed consent to participate.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Publisher's note

Paper III

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Trials

STUDY PROTOCOL

Open Access

A self-managed exercise therapy program for wrist osteoarthritis: study protocol for a randomized controlled trial

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Abstract

Background Post-traumatic wrist osteoarthritis (OA) can eventually lead to pain, muscular weakness, and stiffness of the wrist, which can affect the function of the entire upper limb and reduce the quality of life. Although there is strong evidence that all patients with OA should be offered adequate education and exercises as a first-line treatment, an effective self-management program, including structured education and therapeutic exercises, has not yet been introduced for individuals with wrist OA. This trial aims to evaluate the effectiveness of an exercise therapy program with joint protective strategies to improve neuromuscular control (intervention group) compared to a training program with range of motion exercises (control group).

Methods This is a single-blinded randomized controlled trial (RCT) with two treatment arms in patients with symptomatic and radiographically confirmed wrist OA. The trial will be conducted at a hand surgery department. The participants will be randomly assigned either to a neuromuscular exercise therapy program or to a training program with range of motion exercises only. Participants in both groups will receive a wrist orthosis and structured education on wrist anatomy, pathophysiology, and joint protective self-management strategies. The programs consist of home exercises that will be performed twice a day for 12 weeks. The Patient-Rated Wrist Evaluation (PRWE) is the primary outcome measure of pain and function. Wrist range of motion (ROM), grip strength, the Numeric Pain Rating scale (NPRS), Disabilities of the Arm, Shoulder, and Hand (DASH), the General Self-Efficacy Scale (GSES), Global Rating of Change (GROC), and conversion to surgery are the secondary measures of outcome. Assessments will be performed at baseline and at 3, 6, and 12 months after baseline by a blinded assessor.

Discussion The upcoming results from this trial may add new knowledge about the effectiveness of a self-managed exercise therapy program on pain and function for individuals with wrist OA. If the present self-management program proves to be effective, it can redefine current treatment strategies and may be implemented in wrist OA treatment protocols.

Trial registration ClinicalTrials.gov, NCT05367817. Retrospectively registered on 27 April 2022. https://clinicaltrials.gov.

Keywords Wrist osteoarthritis, SLAC, SNAC, Exercise therapy, Neuromuscular control, Self-management, Randomized controlled trial

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Background

The wrist joint performs complex movements in multiple directions and sustains high loads in many positions. Its involvement in most daily tasks, with great demands on mobility, stability, and load-bearing forces, puts the wrist at risk for problems after injuries and degenerative diseases, such as osteoarthritis (OA) [1]. The prevalence of wrist OA is low but increases with age [2]. In contrast to OA in other joints of the hand, wrist OA develops earlier in life and is more common in men (prevalence 1.7%) than in women (1.0%) [2, 3].

The cause of wrist OA is usually secondary due to a previous traumatic insult, such as a fracture or ligament injury. It selectively involves the joints surrounding the scaphoid bone [4]. Two common types of wrist OA patterns are the scaphoid non-union advanced collapse (SNAC), which is instigated by an unhealed fracture of the scaphoid [5], and the scapholunate advanced collapse (SLAC), which is caused by a traumatic or degenerative scapholunate ligament injury [6]. The SNAC and SLAC cause carpal instability, altered wrist kinematics, and joint loading with eventual arthritic degeneration of the radiocarpal and midcarpal joints [4]. A four-staged predictable and progressive pattern ranges from stage 1 that represents mild arthritic changes confined to the radial styloid to stage 4 that represents advanced arthritic changes affecting both the radiocarpal and midcarpal joints [6].

Post-traumatic wrist OA develops slowly, and the joint degeneration can lead to pain, muscular weakness, and stiffness of the wrist [7]. As a result, this can affect the function of the entire upper limb, which can interfere with activities of daily living (ADL) and the ability to work, thus leading to reduced quality of life [8]. In an OA affected joint, disturbed neuromuscular control can lead to a disproportionate load on the joint [9]. This unhealthy progress could aggravate the OA progression over time [10].

Currently, the treatment norm for wrist OA is initially directed at alleviating pain and decrease disability by splinting, non-steroidal anti-inflammatory medications, and intraarticular steroid injections. The surgical interventions for wrist OA include neurectomy, styloidectomy, proximal row carpectomy, fusions, or arthroplasty [11]. However, a self-managing approach, including therapeutic exercises, has traditionally not been a treatment strategy in wrist OA.

Exercise therapy is a regime of physical activities designed and prescribed for precise therapeutic goals, aiming at educating the performance of specific exercises to improve neuromuscular control, reduce pain, and achieve functional joint stability [12]. Self-management programs, including exercise therapy and joint protective strategies, are core treatments in knee and hip OA [13–17]. Due to the complexity of the wrist joint, it cannot be fully compared to larger weight-bearing joints, such as the knee and hip. Therefore, there is a need to develop exercise therapy programs specially designed for the wrist. Such a program should be part of a comprehensive joint protective standard care and could be beneficial to decrease disability and postpone, or possibly even eliminate, the need for surgery in individuals with wrist OA.

The objective of the trial is to evaluate the effectiveness of an exercise therapy program with joint protective strategies to improve neuromuscular control (intervention group) compared to a training program with range of motion (ROM) exercises (control group). To evaluate these programs, we will use the Patient-Rated Wrist Evaluation (PRWE) as our primary outcome [18]. We hypothesize that 12 weeks of exercise therapy relieves pain and improves the ability to perform daily activities to a greater extent than the ROM training program.

Methods/design

Trial design

This RCT utilizes a single-blinded (assessor) superiority trial design with two treatment arms. The Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT) checklist [19] will be used and is provided as an Additional file 1. Forty-eight individuals with radiographically confirmed and symptomatic wrist OA will be recruited and randomized either to the neuromuscular exercise therapy program ($n=24$) or to the ROM training program ($n=24$). A description of the overall trial design can be found in the flow chart (Fig. 1) and the SPIRIT diagram (Fig. 2).

Sample size calculation

The sample size estimate of this RCT is based on relevant previous studies that have shown minimal clinically important differences (MCIDs) for the PRWE between 11.5 and 14 [20, 21]. An MCID of 11.5 has been found in patients with distal radius fractures [20], while an MCID of 14 was found in patients with various atraumatic upper extremity disorders, including patients with wrist OA [21]. We have calculated our sample size of an MCID in between these two studies (MCID 12.5). Using a standard deviation (SD) of 14, power (1-beta) at 0.8, and a significance level (alpha) at 0.05, we will need to recruit a sample of 40 patients, 20 in each group. Accounting for a drop-out rate of 20%, we will ultimately need to include a total of 48 patients in the trial (Fig. 1). We will continue to recruit participants until we have reached our estimated sample size. If a participant withdraws from the trial before completing the 12-week allocated treatment program, we

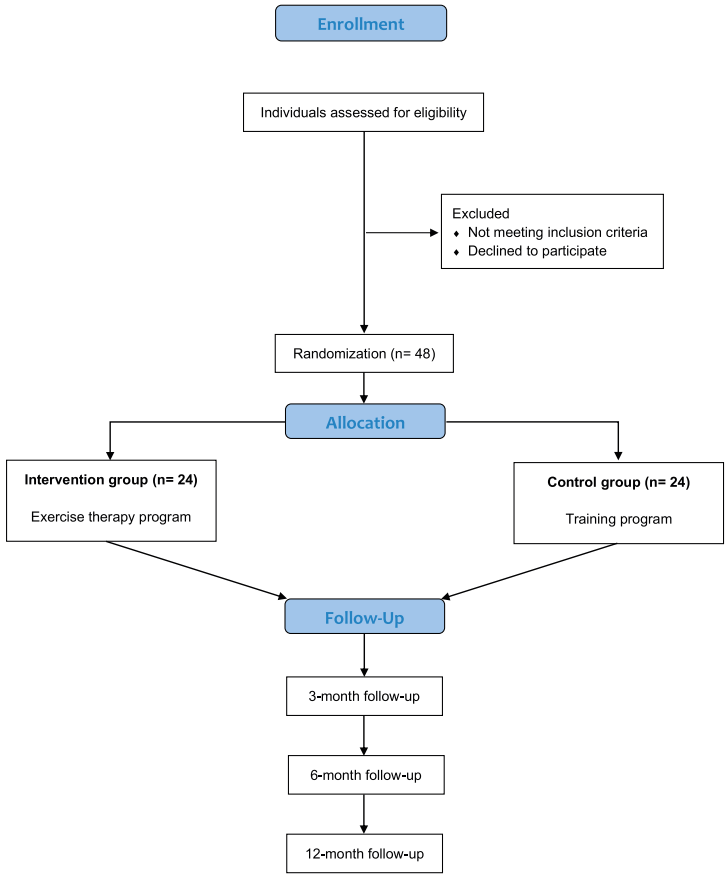

Fig. 1 Flowchart of the trial design

will recruit a new participant. Participants that withdraw from the trial between the 3- and 12-month follow-ups will not be replaced.

Eligibility criteria

Participants will be selected according to the following eligibility criteria:

Inclusion criteria:

(1) Radiographically confirmed and symptomatic wrist OA—SLAC and SNAC stages 1–3 [6]
(2) Age ≥ 18

Exclusion criteria:

(1) The presence of other diseases or disorders that could affect arm and hand function
(2) Wrist osteoarthritis secondary to avascular necrosis of carpal bones
(3) Previous surgery to the wrist
(4) Intraarticular wrist cortisone injection within the last 3 months
(5) Inability to understand and follow test instructions due to communicative, mental, or cognitive impairments

Study setting and inclusion of participants

Potential participants will be identified and recruited at the Department of Hand Surgery, Skåne University Hospital, Malmö, Sweden. The study center is the main

	STUDY PERIOD				
	Enrollment	Allocation	Post-allocation		Close-out
TIMEPOINT	$-t_1$	0	*3 months*	*6 months*	*12 months*
ENROLLMENT:					
Eligibility screen	X				
Informed consent	X				
Demographics	X				
Allocation		X			
INTERVENTIONS:					
Exercise therapy program (intervention group)		←	→		
ROM training program (control group)		←	→		
ASSESSMENTS:					
PRWE		X	X	X	X
DASH		X	X	X	X
NPRS		X	X	X	X
GSES		X	X	X	X
Grip strength		X	X	X	X
ROM		X	X	X	X
GROC			X	X	X
Conversion to surgery				X	X

Fig. 2 SPIRIT diagram of enrollment, interventions, and outcome measures. SPIRIT, The Standard Protocol Items: Recommendations for Interventional Trials; PRWE, Patient-Rated Wrist Evaluation; DASH, Disabilities of the Arm, Shoulder, and Hand; NPRS, Numerical Pain Rating Scale; GSES, Generalized Self-Efficacy Scale; ROM, range of motion; GROC, Global Rating of Change

health care facility to which individuals with wrist OA are referred in the Southern health care region; a region with approximately 1.9 million inhabitants.

When individuals with wrist OA are referred to our tertiary hand surgery clinic, their symptoms are usually advanced and affecting everyday life to the extent that they want to discuss treatment options with a hand surgeon. For this RCT, we will implement a new routine. Before deciding on surgical treatment, potential participants, diagnosed with wrist OA stages 1–3, will be referred to one treating physiotherapist (PT) who is a specialist in treating orthopedic injuries and with long experience working at the hand surgery clinic. They will be provided with all the relevant information about the trial, verbally and in writing, and be asked for participation. They will be told that they will be randomly assigned to the trial groups and that each group will be treated with different types of exercises, all of which are appropriate for their condition. The treating PT will be responsible for the treatment programs in both groups, including structured education, exercises, and follow-ups.

Ethical aspects

Prior to inclusion, information about the trial will be provided, and the participants will give their written informed consent to participate (Additional file 2). This study was approved by the Swedish Ethical Review Authority, Dnr 2019–02437, and the principles of the Declaration of Helsinki will be followed.

Randomization and allocation

An experienced occupational therapist (OT), who is also a researcher at the hand surgery clinic, will generate the block randomization sequence. This person will be independent of the research team responsible for data collection and management. The treating PT will create the sealed paper envelopes, but the independent OT will generate the allocation sequence. The sequence will be generated using block randomization with the size of 10 in each block. The block randomization intends to achieve balance for the distribution of men and women to be similar in the two groups over time, along with other known factors that could affect the outcome, such as age and severity of the OA. The treating PT will allocate the participants by sealed paper envelopes either to the exercise therapy program (intervention group, $n=24$) or to the ROM training program (control group, $n=24$) on the same day as the baseline assessment (Fig. 1). Randomization codes will be generated digitally and concealed on a secure system.

Blinding

Participants will not be directly informed about which group they have been assigned to, which limits the risk of contamination between the groups. To further avoid the risk of contamination between the groups, the same treating PT will be responsible for giving out the allocated treatment regimens and seeing the participants at all the follow-up appointments. Also, the participants will be booked to the clinic on an individual basis, which means that they will not meet each other at the clinic.

All the objective and subjective evaluations will be conducted by one blinded PT with experience of the used outcome measures. Apart from the blinded PT, the treating hand surgeons and the hand surgeons assessing the radiological wrist OA stage will also be blinded to group allocation. The blinding will be maintained as far as possible. The actual allocation should not be disclosed to the participant and/or other trial personnel nor should there be any written or verbal disclosure of the code in any of the corresponding patient documents. We do not anticipate any safety concerns of the participants in both groups that would lead to emergency unblinding. The only situation in which unblinding could occur, and would be permissible, is if a participant wants to know their group allocation. If this unblinding occurs, the participant will be excluded from further participation in the trial.

Baseline assessment

At the baseline assessment, background information will be collected concerning (1) medical and social history (civil status, occupation, sports, hobbies); (2) demographic data (age, gender, handedness, review of the nature and onset of symptoms); (3) use of painkillers; and (4) previous exercise treatment (physiotherapy or occupational therapy). The participants will also, in pre-defined answer options using a box scale, report (1) their main problem with the wrist (answer options: pain, weakness, stiffness); (2) their main expectation of the exercise program (answer options: reduced pain, improved strength, improved ROM); (3) if they have discussed surgical treatment with their treating hand surgeon (yes/no), and if so, which type of surgery; and (4) their attitude towards proceeding with surgery (yes/no).

Imaging and classification of OA

Potential participants with wrist OA seeking care at our hand surgery clinic are examined with standard wrist radiographs in posterior-anterior and lateral views. Radiological diagnosis, in combination with clinical examination by the treating hand surgeon, confirms the diagnosis of symptomatic wrist OA. Participants meeting the inclusion criteria will also be examined with computer tomography (CT) of the affected wrist to enable a detailed examination of osteoarthritic signs.

To grade the severity of wrist OA, the modified four-stage Watson and Ballet classification of SLAC and SNAC will be adopted [6]. The classification contains stage 1 (arthritic changes confined to the radial styloid), stage 2 (arthritic changes between the radius and the entire scaphoid), stage 3 (in addition to grades 1 and 2, arthritic changes at the capitate-lunate joint), and stage 4 (in addition to grade 3, arthritic changes in the radiolunate fossa) [7]. Two experienced hand surgeons will independently classify OA based on both plain radiographs and CT scans of the affected wrist. In cases of disagreement between the observers, consensus will be reached through discussions.

Interventions

Procedure

The participants will be provided with the allocated exercise therapy (intervention group) or ROM training program (control group) on the same day as their baseline assessment. They will be taught how to perform their exercises in a pain-free range with good quality of movement—smooth, coordinated, and without compensatory movements [22]. The treatment will then continue as a structured home-based program that the participants will perform twice a day for 12 weeks. All participants will receive a booklet including structured education and a description of the exercises with schematic images. The participants will also be offered a follow-up appointment with their treating hand surgeon between 3 and 6 months

after baseline to decide if further treatment or conversion to surgery is needed.

Concomitant care

While the trial is in progress, no other treatments will be allowed or prescribed. The information provided to participants will not specify any prohibitions. Participants will be able to take their usual pain medication, such as paracetamol or non-steroidal anti-inflammatory drugs (NSAIDs), if needed. However, they will not be subscribed pain medication, such as opioids, or intraarticular wrist cortisone injection during their participation in the trial.

Structured education

The participants in both groups will receive structured education on (1) wrist anatomy, (2) pathophysiology, (3) joint protective self-management strategies, and (4) management of pain and fatigue by exercises (Table 1). They will also be educated about the neutral wrist position, which is in slight extension of approximately 20° (Fig. 3). In this position, the least amount of tension is placed on the ligaments, muscles, and tendons of the hand [23].

Table 1 Structured education regarding wrist anatomy, pathophysiology, and self-management strategies

Topics	Objectives
Anatomy of the wrist	Know the basic anatomy and biomechanics of the wrist
Pathophysiology	Know the pathophysiology of wrist osteoarthritis and its symptoms and risk factors
Joint protective self-management strategies	Knowledge about: - The awareness of keeping the wrist in a stable neutral position in activities of daily living - Avoiding a monotonous load on the wrist for a long time - The awareness of compensatory movements and pain-provoking activities - Taking regular and frequent breaks when needed - Protecting the wrist with a wrist orthosis (Prisma stabil plus™ or Wrist Lacer II™) - Using ergonomic tools when needed
Management of pain and fatigue by exercises	Knowledge about: - The benefits and the purpose of the allocated exercise program - The importance of performing the exercises in a pain-free manner and with good quality of movement - The importance of adhering to the allocated program

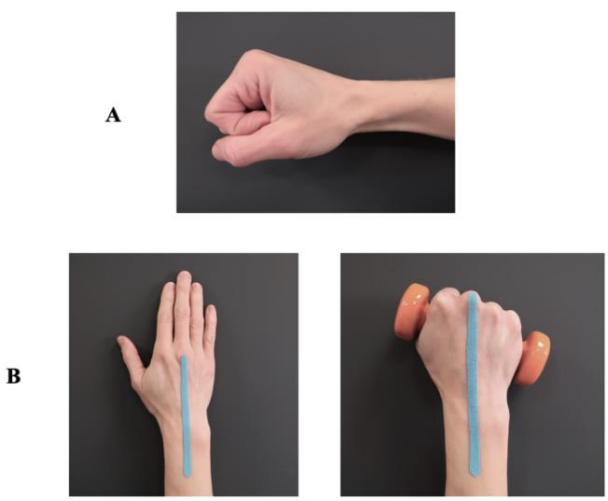

Fig. 3 The neutral wrist position. **A** In the sagittal plane (lateral view), the wrist is in slight extension. **B** In the frontal plane, the third metacarpal bone is in line with the forearm

Maintaining this neutral wrist position in unloaded and loaded situations to obtain a functional and stable joint position and adequate kinesthesia will be emphasized. The participants will also be equipped with a stable wrist orthosis with the instruction to wear it, particularly during pain-provoking activities, but also at night-time if needed (Table 1).

Adherence

Before randomization and during all contacts with the treating PT, the participants will be informed about the importance of adhering to the treatment program. Participants will be followed up by the treating PT at the clinic at 2, 6, and 12 weeks after baseline, and by phone at 4 and 8 weeks after baseline, to ensure adherence to the program and that the regimen and exercises are carried out correctly. At the appointments, the participants will show and repeat their exercises, and adjustments and corrections will be made when needed. They will also be asked about whether they are able to adhere to the program or if they find the exercise regimen challenging. All contact with the participants will be documented in their medical journals.

Exercise therapy for the intervention group

The exercise therapy program for the intervention group has been designed by the first author (SL) having applied findings from previous studies on wrist stability and proprioception [22, 24–26]. Focus is on functional re-learning and strengthening of the musculoskeletal system with the aim to create a stable wrist that can be used in a pain-free manner in daily activities [22]. A clear understanding of the program and good motivation are essential. The emphasis will therefore lie on a thorough perception of the rationale and goal of the exercise therapy program.

The program consists of two parts. The first part contains unloaded active ROM exercises for the wrist in flexion/extension, radial-/ulnar deviation, and pronation/supination (Table 2 and Fig. 4). The second part of the program consists of neuromuscular exercises (described below in A to C) that focus on coordination, wrist stability, and strength (Table 3 and Fig. 5).

A. *Coordination and co-activation exercise*. The first exercise is training the coordination and co-activation of the long extrinsic muscles acting as active stabilizers of the wrist [the extensor carpi radialis longus and brevis muscles (ECRL/ECRB), the extensor carpi ulnaris muscle (ECU), the flexor carpi radialis muscle (FCR), and the flexor carpi ulnaris muscle (FCU)] [24]. Co-activation exercises demand the use of eccentric, concentric, and isometric exercises and will be performed as closed-chain isometric and active exercises with both hands on a ball [24].
B. *Isometric exercise*. The participants will apply manual isometric resistance for the extrinsic muscles of the wrist (ECRL/ECRB, ECU, FCR, FCU) while at the same time maintaining a neutral position. Isomet-

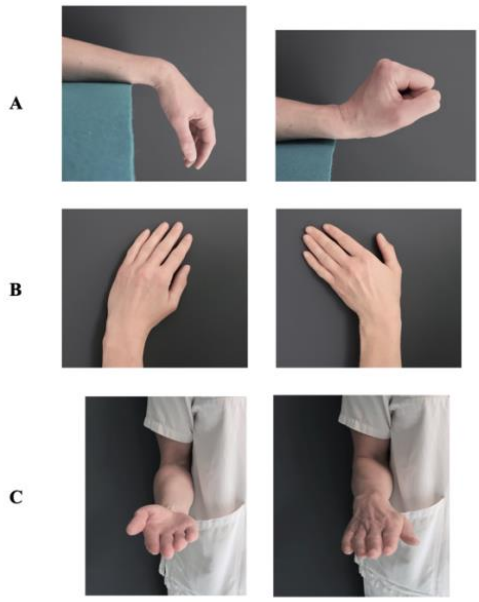

Fig. 4 The range of wrist motion training program performed by both groups. **A** Flexion and extension. **B** Radial and ulnar deviation. **C** Supination and pronation. All exercises will be completed with 10×2 repetitions for the control group and 10 repetitions for the intervention group. Both groups will perform the exercises in a pain-free manner two times per day for 12 weeks

Table 2 Details of the range of wrist motion program including the exercises, performance, and repetitions

Range of wrist motion exercises	Active range of wrist motion in: A. Flexion and extension B. Radial and ulnar deviation C. Supination and pronation
Performance and repetitions	The participants will perform the exercises slowly and with good quality of movement. They will hold in a pain-free outer position for about 3–5 s and repeat the exercises: **Control group**: 10×2 repetitions **Intervention group**: 10 repetitions

Table 3 Details of the exercise therapy program including the exercises, performance, and repetitions

Exercises	Performance and repetitions
A. Coordination and co-activation exercise	Closed-chain isometric and active range of wrist motion exercise with a ball, training coordination, and co-activation Participants will be taught to sit with the ball placed on the table. They will be instructed to gently press both hands against the ball, holding for 3–5 s. After that, they will gently press their palms against the ball while slowly turning the ball to the right and left in a pain-free manner They will perform the exercise with 10 repetitions
B. Isometric exercise	Isometric exercise, where the participants will apply moderate resistance to their affected wrist with their other hand in the opposite direction of the wrist movement They will hold for 3–5 s and perform the exercise with 10×2 repetitions
C. Strength exercise	Silicone putty dough exercise for grip strength and strength of the extrinsic muscles around the wrist The participants will be taught to hold their wrist in a stable neutral position at the whole time during the exercise They will hold for 3–5 s and perform the exercise with 10×2 repetitions

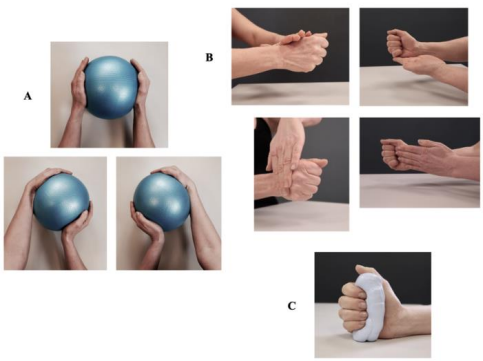

Fig. 5 The exercise therapy program performed by the intervention group. **A** Coordination and co-activation exercise. This is a closed-chain isometric and active range of wrist motion exercise with a ball, training co-activation, and coordination. **B** Isometric exercise. The participants will apply manual isometric resistance for the long extrinsic muscles of the wrist, while at the same time maintaining a stable and neutral position. **C** Strength exercise. The participants will squeeze a silicon putty dough while maintaining the wrist in a neutral position. All exercises (**A**–**C**), including the range of wrist motion exercises (Fig. 4), will be performed in a pain-free manner by the intervention group two times per day for 12 weeks

ric exercises are user-friendly, build muscle strength quickly, and appear to have a key role in functional wrist motor re-learning [22, 24].

C. *Strength exercise*. Grip strength and strength of the extrinsic muscles around the wrist will be trained. In this exercise, the participants will squeeze a silicon putty dough while at the same time maintaining the wrist in a neutral position.

Range of wrist motion exercises for the control group

The training program for the control group will, just as the intervention group, consist of home base exercises twice a day for 12 weeks. However, the training program will only include the above-mentioned ROM exercises (Table 2 and Fig. 4).

Outcome measures

Outcome measures with good psychometric properties will be used covering both physical and patient-reported measures. Valid and reliable Swedish versions of the outcome measures will be used. Missing item responses for the patient-reported outcome measures will be handled in accordance with each scale's specific recommendations. If the number of missing items makes calculating the score impossible, the lost score will not be replaced. Outcomes will be assessed at baseline and at 3, 6, and 12 months post-inclusion (Fig. 2).

Primary outcome measure

Patient-Rated Wrist Evaluation (PRWE)

PRWE is a wrist specific patient-rated outcome measure (PROM) originally developed for the assessment of perceived disability after a distal radius fracture [18]. However, strong psychometric properties of PRWE, such as excellent test–retest reliability and high construct validity, have been found in patients with wrist OA [27]. The questionnaire includes 15 questions, divided into two subscales assessing pain (5 items) and function (10 items, 6 concerning specific tasks and 4 the ability to perform daily activities) over the past week [18]. The questions are scored on a 10-point ordered categorical scale, ranging from no pain or no difficulty (0 points) to worst pain or unable to do (10 points). The total score of the subscales pain (sum of 5 items) and function (sum of 10 items divided by 2) ranges from 0 to 50. The maximum total score of PRWE is 100 and represents the worst disability,

whereas 0 represents no disability. In this RCT, the Swedish version of PRWE, which is a responsive, valid, and reliable patient-rated outcome measure, will be used [28].

Secondary outcome measures

Hand dynamometer (grip strength)

The isometric grip strength will be measured on both hands using the Jamar hydraulic hand dynamometer according to standardized instructions [29, 30]. The same hand dynamometer will be used for all measurements (TEC, Clifton, NJ, USA). Three trials for each hand will be recorded, and the mean value, recorded in kilograms (kg), for each hand will be calculated.

Goniometer (range of wrist motion)

Range of wrist motion (flexion, extension, radial deviation, ulnar deviation, pronation, and supination) of the affected wrist will be measured with a goniometer according to standardized instructions [30, 31]. We expect the intra-rater reliability of the goniometry measurements to be high, since all measurement will we performed by the same experienced PT [32].

Numerical Pain Rating Scale (NPRS)

The NPRS is a numeric 11-point pain rating box scale with numerical descriptors on the box, ranging from 0 representing one pain extreme (no pain) to 10 representing the other pain extreme (worst pain imaginable) [33]. Participants select a value that is most in line with the intensity of pain they have perceived in the affected wrist over the last week. Three measures of pain will be rated in this trial: (1) pain at rest, (2) pain on motion without load, and (3) pain on load. The NPRS have been found to be valid and reliable when measuring pain outcome in patients with wrist OA [27].

Disabilities of the Arm, Shoulder, and Hand (DASH)

The DASH measures self-reported upper extremity physical function and symptoms taking the whole upper extremity into account, irrespective of which hand or if both hands are used [34]. Excellent test–retest reliability and moderate to high construct validity have been found for DASH in patients with wrist OA [27]. The main part of the DASH is a 30-item disability/symptom scale concerning the patient's health status during the preceding week. The items ask about the degree of difficulty in performing different physical activities because of arm, shoulder, or hand problems (21 items) and the severity of each of the symptoms of pain, activity-related pain, tingling, weakness, and stiffness (5 items), as well as the problem's impact on social activities, work, sleep, and self-image (4 items). Each item has five response options. The scores for all items are then used to calculate a scale score ranging from 0 (no disability) to 100 (most severe disability). The validated Swedish version of DASH will be used in this RCT [35].

Generalized Self-Efficacy Scale (GSES)

A significant determinant of health behavior is self-efficacy, or the individual's belief that he or she can successfully complete a goal or behavior to achieve a desired outcome. The GSES was developed to assess the strength of a person's belief in his or her ability to respond to novel or difficult situations and to deal with any associated obstacles or setbacks [36]. The GSES is a ten-item scale, where each item ranges from 1 ("not at all true") to 4 ("exactly true"). Scores are summed across the ten-items to give a total score, with a possible range of 10–40. Higher scores indicate greater confidence in generalized self-efficacy. The validated Swedish version of the GSES will be used [37].

Global Rating of Change (GROC)

The GROC score measure self-perceived change in health status over time and have become widely used in both research settings and clinical practice for determination of the clinically important change and measurement of outcome [38]. The GROC score involves a single question that asks the participant to rate their change with respect to a particular condition from the time they began treatment until the time they answered the question. The rating is based on a 11- point self-report Likert scale (from −5 to 5), where a "−5" indicates "a very great deal worse," "0" indicates "about the same," and "+5" indicates "a very great deal better". At the follow-ups, the participants will be asked to "rate the overall change" and respond to the question: "Regarding your wrist problems, how would you describe your wrist now compared to before the training period?" The GROC scale has the advantages of clinical relevance, adequate reproducibility, and sensitivity to change and is intuitively easy to understand by the patient [38].

Conversion to surgery

Conversion to surgical interventions will be based on the participants' symptoms and wishes and the surgeon's recommendation. This decision will be made during a face-to-face appointment with the participant and the hand surgeon at 3–6 months following randomization. The hand surgeon will base their recommendation on surgery given the participants presentation and symptom severity at the appointment. Participants that are ambivalent about surgery will be offered another follow-up visit or telephone contact with the hand surgeon at a later stage. The percentage of participants requiring surgery in both groups will be compared. Comparison of conversion to

surgery has been used in previous clinical trials to determine the success of non-surgical management [39].

Statistical analysis

Assessments of efficacy

Primary endpoint:

1. PRWE at 3 months

Secondary endpoints:

1. PRWE at 6 and 12 months
2. DASH at 3, 6, and 12 months
3. NPRS pain at 3, 6, and 12 months
4. GSES at 3, 6, and 12 months
5. Grip strength and wrist ROM at 3, 6, and 12 months
6. GROC at 3, 6, and 12 months
7. Conversion to surgery at 6 and 12 months

Data analysis

Appropriate descriptive statistics for all outcome measures and demographic characteristics for the intervention and control groups will be reported for baseline and 3, 6, and 12 months. For continuous variables, mean values and standard deviations (SD) will be calculated. If the continuous data is not normally distributed, median values and interquartile range (IQR) will instead be calculated. For categorical variables, median and IQR will be calculated, and for binary variables, proportions and percentages will be conducted. Baseline data from possible dropouts will be described and compared to the included participants. The primary results will be interpreted based on the intention-to-treat principle. In case of crossovers, sensitivity analysis comparing the results of intention-to-treat and per-protocol analyses will be performed and reported. To analyze differences between the groups at baseline and at 3, 6, and 12 months, the Mann–Whitney test (for ordinal data) or independent sample *t*-test (for continuous data) will be used depending on normal distribution, examined by the Shapiro–Wilk test. The Wilcoxon signed-rank test or paired *t*-test will be used to analyze within-group differences. Conversion to surgery will be analyzed by a chi-square test or a Fisher's exact test. Missing data will be managed according to the algorithm described by Jakobsen et al., using multiple imputation if complete case analyses are not supported [40]. The level of statistical significance will be set at $p < 0.05$. All calculations will be performed using IBM SPSS Statistics version 29 (IBM Corporation, Armonk, NY, USA).

Withdrawal and safety

The participants will be able to withdraw from the trial at any time, without giving an explanation and without any negative consequences for their care and rehabilitation in the future according to the ethical permission. Based on international and national guidelines recommending education and exercise as core treatment of OA [41], our judgment is that there is low risk of adverse events in this RCT.

Retention plan

To promote participant retention, written educational materials to ensure that the participants fully understand the purpose, procedures, risks, and benefits of the trial will be developed. The participants will also be given trial related materials, such as a calendar, to help them track their participation, adhere to procedures, and maintain engagement. During the trial process, regular visits and communication will be maintained to ensure adherence and non-retention. If the participants cannot come to the clinic for a follow-up, they will be offered an online meeting instead. Participants, who do not wish to attend physical examinations, will be asked to fill in the questionnaires at home and send them to the research team. Flexible and convenient scheduling options for visits will be offered. The visits to the treating PT will be free of charge during the trial and the participants will also be offered appropriate reimbursement for any travel expenses. User-friendly data collection assessments to minimize errors will be used and regular monitoring of the data collection to identify missing data will be implemented.

Data management

Data from all assessments will be decoded and stored in binders and in a secure database. The decoding key will be locked in a safe and the database will be protected by a password to which only researchers responsible for the trial have access. After completion of the trial, all files will be saved for at least 10 years according to national rules.

Discussion

An effective self-management treatment program, including structured education and therapeutic exercises, has not yet been introduced for individuals with wrist OA. Although there is no cure for OA, patients may benefit from self-management treatment options that enables them to manage symptoms and optimize quality of life [42]. There is strong evidence advocating that all patients with OA should be offered adequate education and exercises and that surgical interventions only should be considered when non-surgical treatments have failed [41]. In

addition, worldwide, waiting times are long before consultation with a specialist or elective surgery is received, which emphasizes the need for physiotherapist-led interventions and new conservative treatment options [43]. Referral of patients with wrist OA to education and self-management programs is therefore an attractive first-line treatment option with the intention to inform patients about the disease and provide them with tools to facilitate everyday life and with the aim to postpone, or even eliminate, the need for surgical interventions [39]. Thus, evaluation of the present self-managed exercise therapy program may be beneficial for the individual who suffers from wrist OA as well as for the healthcare system.

Several international and national organizations recommend structured education and exercises as first-line treatment for OA. The European League Against Rheumatism (EULAR) recommends OA education and exercises for hand, knee, and hip OA [17, 44]. The Osteoarthritis Research Society International (OARSI) recommends education and exercise programs as core treatments for knee, hip, and polyarticular OA [13]. Furthermore, several evidence-based self-management programs have been developed for hip and knee OA and are implemented and used as first-line treatments with good results [16, 45]. Cochrane reviews have found high quality evidence that therapeutic exercises can reduce pain and improve function in knee and hip OA [14, 15]. For hand OA, however, the evidence is low owing to lack of blinding of participants, the small number of included studies, and inclusion of few individuals in the analyses [46]. In these studies, hand OA refers to the thumb carpometacarpal (CMC) joint and finger joint OA. For wrist OA, structured education, and exercise therapy as first-line treatment has not yet been studied.

A structured education and neuromuscular exercise therapy program is one type of conservative management for hip and knee OA [42]. Our exercise therapy program is designed based on the principles behind neuromuscular training that focus on improving the quality and effectiveness of movements [12, 22]. The rationale behind our choice of neuromuscular therapeutic exercises is that patients with OA may have impaired sensorimotor function in terms of sensory deficiency, altered muscle activation patterns, and reduced functional performance [9, 47]. Therefore, it seems evident that training programs should address several aspects of the sensorimotor system to improve function and alleviate symptoms.

The combination of structured education and neuromuscular exercise therapy has shown short- and long-term improvements in pain, physical function, function in ADL, and quality of life in individuals with knee and hip OA [48–51]. Skou et al. evaluated the efficacy of a 12-week non-surgical treatment program for patients with knee OA not eligible for total knee replacement in a RCT. They found that participants in a structured education and neuromuscular exercise group experienced significant improvements regarding pain, function, and quality of life after 1 year compared to the control group receiving usual care consisting of two leaflets with information and advice on knee OA and recommended treatments [49]. In a large study, 418 patients with chronic knee pain/knee OA were randomized to either usual care or the Enabling Self-Management and Coping of Arthritic Knee Pain Through Exercise (ESCAPE) program. Significant improvements in pain and physical function were found in the ESCAPE group at 6 weeks post-intervention and the improvement sustained at a 30-month follow-up [48]. Da Silva et al. demonstrated, in an RCT, significant improvements in pain, physical function, ADL, and quality of life at the 8-week follow-up in the structured education and neuromuscular exercise group compared to patient education for patients with knee OA [50]. A 6-year follow-up RCT in patients with hip OA by Svege et al. found significant improvement in self-reported physical function for participants in the structured education and neuromuscular exercise group compared to the control group that only received patient education. The study also found that exercise therapy in addition to patient education can reduce the need for total hip replacement by 44% in patients with hip OA [51]. The wrist, with its complex anatomy and biomechanics, cannot be fully compared to weight-bearing joints such as the hip and knee, which emphasizes the need to evaluate if a self-management program, including patient education and neuromuscular exercises, can be beneficial also for individuals with wrist OA.

A review by Hagert from 2010 [24] highlighted the theoretical importance of sensorimotor control of the wrist and its function, thus setting a new standard for wrist rehabilitation. Clinical reviews by Valdes et al. [52], Karagiannopoulos and Michlovitz's [26], and Lotters et al. [25] provided further support for including exercises of sensorimotor control in the rehabilitation of the wrist. In addition, there are a small number of single case reports [53, 54] and cohort studies [22, 55, 56], indicating clinical benefits of an exercise therapy program with a neuromuscular approach following various wrist injuries. The exercise therapy in our RCT is based on theoretical assumptions and outcomes from the above-mentioned cohort and case studies.

A potential limitation to our RCT is the fact that adherence may be more challenging for the participants in the intervention group due to the larger training intensity. To promote adherence, both treatment programs will be delivered and supervised by an experienced PT who will encourage, answer questions, and initiate individual

adjustments when needed. Moreover, there may be a risk of self-selection bias; thus, individuals that accept to join the trial may differ in terms of motivation to training compared to those who chose not to participate.

Since the clinical importance of wrist rehabilitation remains in its infancy, we want to evaluate the concept of structured education and a self-management exercise therapy program as treatment for individuals with wrist OA.

Conclusion

We have designed a self-managed exercise therapy program for individuals with wrist OA that we will evaluate in a single-blinded RCT with two treatment arms. The knowledge gained will comprehend the effectiveness of this non-surgical treatment and, depending on the outcome, may redefine the current treatment strategies. If this self-management program proves to be effective, in terms of decreased pain and improved patient-reported function, it may be implemented in treatment protocols for individuals with wrist OA.

Trial status

This protocol is version 3.0 (dated August 18, 2023). The recruitment of participants started 3 October 2019 and is estimated to be completed in June 2023. No trial amendments have been made since the enrollment of the first participants. Any substantive amendments that may impact the conduct of the trial or the ethical rigor will require a formal written modification to the protocol and an approval by the Swedish Ethical Review Authority.

Dissemination policy

The findings of this trial will be communicated to the participants and disseminated through peer-reviewed publications in scientific journals and conference presentations. It is also expected to, through presentations, generate a linkage with specialized hospitals and therapists working in this field.

Abbreviations

ADL	Activities of daily living
CMC	Carpometacarpal
CT	Computer tomography
DASH	Disabilities of the Arm, Shoulder, and Hand
ECRB	Extensor carpi radialis brevis
ECRL	Extensor carpi radialis longus
ECU	Extensor carpi ulnaris
ESCAPE	The Enabling Self-Management and Coping of Arthritic Knee Pain Through Exercise
EULAR	The European League Against Rheumatism
FCR	Flexor carpi radialis
FCU	Flexor carpi ulnaris
GROC	Global Rating of Change
GSES	Generalized Self-Efficacy Scale
MCID	Minimal clinically important difference
NPRS	Numeric Pain Rating scale
NSAID	Non-steroidal anti-inflammatory drug
OA	Osteoarthritis
OARSI	The Osteoarthritis Research Society International
OT	Occupational therapist
PROM	Patient-rated outcome measure
PRWE	Patient-Rated Wrist Evaluation
PT	Physiotherapist
RCT	Randomized controlled trial
ROM	Range of motion
SD	Standard deviation
SLAC	Scapholunate advanced collapse
SNAC	Scaphoid non-union advanced collapse
SPIRIT	The Standard Protocol Items: Recommendations for Interventional Trials

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13063-023-07668-4.

Additional file 1. SPIRIT Checklist for Trials.

Additional file 2. Consent form.

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Not applicable.

Authors' contributions

SL developed and planned this trial together with EB and ABN. EE and LD participated in design and planning. SL, EB, EE, and LD drafted the manuscript. All authors have participated in the revision of the manuscript and have read and approved the final version.

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Availability of data and materials

The datasets that will be generated and/or analyzed during the current trial will not be publicly available. Public access to data is restricted by the Swedish government (Public Access to Information and Secrecy Act; https://www.government.se/information-material/2009/09/public-access-to-information-and-secrecy-act/). Data may be available for researchers upon special review and includes approval of the research project by both an Ethics Committee at national level, governmental data safety committees, and the regional committee at the health care sector in Region Skåne, Sweden.

Declarations

Ethics approval and consent to participate

This research trial is performed in accordance with the ethical guidelines stated in the Declaration of Helsinki and approved by the Swedish Ethical Review Authority (Dnr 2019–02437). Prior to inclusion, information about the purpose of the trial will be provided, and each person will give their written informed consent to participate.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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