A LONG STORY SHORT:

Outcomes of ulna shortening osteotomy

Joris Sebastiaan Teunissen

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The work described in this thesis was performed at the Department of Plastic, Reconstructive and Hand Surgery of the Radboud University Medical Centre, Nijmegen, The Netherlands.

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Outcomes of ulna shortening osteotomy

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CHAPTER 1

General introduction & outline of this thesis

PREFACE

Imagine having pain on the ulnar side of your wrist. At first, you think you will manage the pain by taking some rest. After the pain does not go away or even worsens, you decide to visit your general practitioner, who refers you to a specialized hand surgeon. After several examinations, the hand surgeon explains that you have "ulna impaction syndrome" and an "ulna shortening osteotomy" may be necessary. You have heard of an aunt with carpal tunnel syndrome, but these terms do not sound familiar. You decide to do some research on the internet and find the following blog "Ulnar shortening – Avoid this Barbaric Procedure".[1] You become nervous as you read that the suggested treatment for your condition is in the "top 10 dumb surgeries list", "a complication fest", and there is "no high-level research that shows this procedure is effective"….

Before a patient can make an informed decision to opt for elective hand surgery, some information on treatment outcomes might be helpful. For example, patients might want to know whether surgical treatment makes them better (more specifically; whether they might expect relief in pain or an increase in hand function); when work can be resumed; whether benefits are long-lasting; what complications can occur, and how often they happen; and how previous patients experienced the treatment.

Treatment outcomes have been well investigated for some hand and wrist pathologies to facilitate shared-decision making. For example, for patients with carpal tunnel syndrome or thumb base osteoarthritis considering surgical treatment, a prediction model is available that estimates the chance of successful treatment based on the patient's characteristics.[2,3]

Treatment outcomes for ulnar-sided wrist pathology are relatively understudied compared to surgical outcomes for other hand and wrist pathologies. We think evaluating these outcomes is essential as treating ulnar-sided wrist pain is a challenging part of hand and wrist surgery.[4–7] Over the years, ulnar sided-wrist pain has acquired a notorious reputation as the "black box" of the wrist due to the dense and complex anatomy of the ulnar carpus and the diverse nature of chronic complaints.

This thesis investigates several surgical treatment outcomes of ulnar-sided wrist surgery. We mainly focus on the outcomes of ulna shortening osteotomy; a corrective osteotomy frequently used to treat ulnar impaction syndrome. This thesis also discusses some outcomes of the pisiformectomy and open triangular fibrocartilage complex repair, which are other relatively common ulnar-sided wrist surgeries.

We aim to produce high-level outcome data to facilitate the shared-decision making process in patients considering ulnar-sided wrist surgery. In addition to discussing questions from a patient's perspective, we will explore some dilemmas clinicians might struggle with: What patient-related and surgeon-related factors are associated with complications and revision surgery?; What patient-related and surgeon-related factors are associated with return to work?; How does the patient's psychosocial profile influence treatment outcomes?; How to treat patients with combined wrist pathology? Answering these questions can aid surgeons and patients in optimal patient selection according to personal preferences or demands.

This general introduction will briefly discuss the ulnar impaction syndrome, its clinical presentation, etiology, diagnosis, and treatment options. Furthermore, we will discuss the outcome measures chosen to evaluate in this thesis. Finally, we will summarize the specific aims of each chapter in this thesis.

THE ULNA IMPACTION SYNDROME

The ulnar impaction syndrome (UIS), sometimes called ulna abutment syndrome or ulnocarpal impaction, is a common cause of ulnar-sided wrist pain.[4,7–9] It is a spectrum of symptoms and pathologic degenerative changes in the ulnar carpus and triangular fibrocartilage complex (TFCC) due to continuous or intermittent chronic excessive loading across the ulnocarpal joint.[7,9,10] Palmer described that UIS has a progressive nature starting with wear of the TFCC that can ultimately lead to arthritis of the ulnocarpal and distal radioulnar joints[9,11]; schematically visualized in Figure 1.

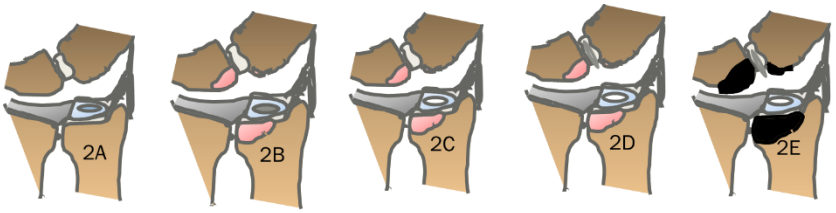

Figure 1. Schematic visualization of the progressive nature of ulna impaction syndrome as described by Palmer. Illustrator: E.P.A. van der Heijden (M.D., PhD)©.

Excessive loading through the ulnocarpal joint might happen due to a disturbance in length between the radius and the ulna.[9] In a neutral wrist position with a good congruence between the radius and ulna, the distal ulna bears approximately 18-20% of the applied axial load, whereas 80-82% is born by the distal radius.[9] However, the ulnocarpal increases when the ulna is relatively long compared to the distal radius (this is called ulnar-positive variance; UPV) (Figure 2). Biomechanical studies have shown that the ulnocarpal load increases from 18% to 42% when the ulnar length relative to the radius increases by 2,5 mm.[12]

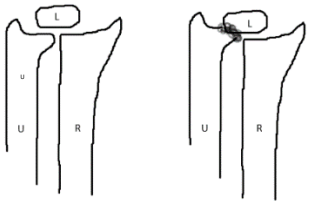

Figure 2. Schematic visualization of neutral variance (left) and ulnar positive variance (right). L= Lunate bone; U= Ulna; R= Radius.

A common classification for UIS etiology is idiopathic versus acquired/secondary.[8,13,14] In idiopathic UIS, there is often a congenital UPV (i.e., present since birth), while in secondary UIS, there is a specific cause that changes the ulnar variance. Events that might lead to secondary UIS include a malunion of the distal radius, radial head excision, Essex-Lopresti fracture, and premature closure of the radius.[8,13,14]

While most patients with UIS have UPV, UIS can also exist in patients with an ulnar neutral variance or negative variance.[15] One of the reasons for this is a dynamic relative increase in ulnar length during forearm pronation and forceful gripping.[16,17] Therefore, repetitive pronation and forceful gripping can cause dynamic UIS. Another reason is that the thickness of the TFCC is inversely related to the ulnar variance.[18] In other words, patients with an ulnar negative variance have a thicker TFCC that can still be excessively compressed during activities.

The diagnosis of UIS is based on medical history, clinical examination, and supportive findings on imaging. Clinical signs include ulnar-sided wrist pain, positive ulnocarpal stress test[19], decreased range of motion, impaired grip strength, swelling and tenderness over the ulnocarpal compartment, and limitations in daily living. Symptoms are usually worse after a period of activities that include pronation, ulnar deviation, and forceful grip.

Pathological signs of UIS during imaging include 1) (static or dynamic) UPV with(out) cystic changes in the lunate, triquetrum, or ulnar dome on posterior-anterior radiographs[20]; 2) bone marrow edema in the proximal-ulnar corner of the lunate and a central TFCC lesion/perforation, ulnar chondromalacia, as well as a lunotriquetral ligament tear in more advanced stages on magnetic resonance imaging[10,20]; 3) arthroscopic degenerative (type II) lesions of the TFCC such as described by Palmer (Table 1).[9,11] A more recent classification of TFCC injuries was proposed by Atzei, but this classification was not used in this thesis.[21]

Table 1: The Palmer classification of TFCC lesions. Degenerative (type II) lesions are often found during wrist arthroscopy in patients with ulna impaction syndrome.

Traumatic lesions: Type I	
IA	A central rupture
IB	Ulnar avulsion with/without disruption of the ulnar styloid process
IC	Distal avulsion
ID	Radial avulsion with/without osseous lesion of the radius
Degenerative lesions: Type II	
IIA	Superficial degenerative lesion
IIB	Degenerative tear with cartilage lesion of the lunate or the ulnar head
IIC	Degenerative disc perforation with cartilage lesion of the lunate or the ulnar head.
IID	IIC + lunotriquetral instability
IIE	IID + ulnocarpal arthrosis

TREATMENT OPTIONS FOR ULNA IMPACTION SYNDROME

Generally, ulnar-sided wrist pain is treated nonsurgically at first.[7,8,14] Treatment modalities include non-steroidal anti-inflammatory drugs (NSAIDs), orthoses, corticoid injections, and hand therapy. While nonsurgical treatment might relieve pain and improve function, it does not alter the underlying pathology. Surgical intervention is indicated when nonsurgical treatment fails to treat symptoms adequately.

Surgical treatment aims to decompress the excessive load across the ulnocarpal joint, which is the underlying cause of the complaints. Previous biomechanical research has shown that decreasing the ulnar length relative to the radius by 2.5mm lowered the axial load through the ulna from 20% to 5%.[12,22] Therefore, ulna shortening has become an established procedure for UIS.

The most common surgical method for shortening the ulna is the ulna shortening osteotomy (USO). Besides decompressing the ulnocarpal joint, USO also tightens the ulnocarpal ligaments and suspends the TFCC.[23] Therefore, some surgeons have broadened the indication of USO to treat mild DRUJ instability.[24]

While USO is still considered the "golden standard" treatment for UIS[8,14,25], the Wafer procedure is also a treatment option.[26] During this procedure, the ulnar head is partially resected. Advantages of the Wafer procedure over USO include avoiding the risk of nonunion and hardware irritation; it can be performed arthroscopically; the TFCC can be debrided in the same procedure.[27] On the other hand, the Wafer procedure is more technically demanding than the USO; the amount of resection is limited to 2-3 mm and might not be planned as accurate as in USO; it does not have a stabilizing effect on the

DRUJ like the USO; there is a risk of damaging the ulnocarpal ligaments and DRUJ that can lead to early arthritic changes.[27] Furthermore, in patients with a prominent ulnar styloid causing stylocarpal impaction, the USO is preferred as the Wafer does not address this.[28] The surgical outcomes of the Wafer procedure are outside the scope of this thesis.

ULNA SHORTENING OSTEOTOMY: SURGICAL PROCEDURE

The ulna shortening was first described by Milch in 1941 as a treatment for ulnar-sided wrist pain after a Colles fracture.[29] Since its first description, several techniques have been described to decompress the ulnocarpal joint. As ulnar shortening might increase the peak pressure in the DRUJ, the minimum required amount of shortening should be performed.[30] In symptomatic wrists with UPV, the amount to resection should be planned to achieve a 0 to -1 mm variance after USO.[31] In a wrist with ulnar neutral and ulnar negative variance, the amount of resection should be based on the extent of the dynamic UPV.

The osteotomy can be performed at the level of diaphysis or metaphysis. Multiple osteotomy techniques have been described: transverse[32–35], oblique[36–41], and step-cut (Figure 3).[42] Nowadays, most surgeons prefer the oblique cut, which is believed to reduce nonunion by increasing the contact area and preventing malrotations and angulation.[43]

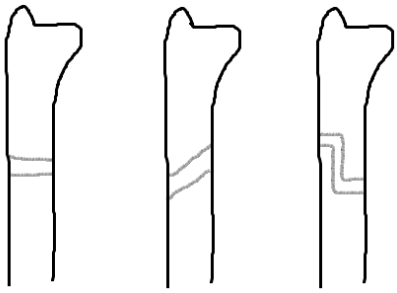

Figure 3. Schematic visualization of the types of osteotomies for the ulna. From left to right: transverse, oblique and step-cut.

The osteotomy can be made "freehand"[33–35,44–46], or with the help of precise osteotomy-assisted jigs and compression devices.[37,38] Freehand USO might have some disadvantages compared to precise cutting systems, including angulation, rotation, and insufficient or excessive resection.

After two parallel osteotomies are made, the bony disc segment is removed, and the osteotomy site is reduced and fixated with a compression plate. The plates can be placed at the anterior[40,47–49], or (ulno)dorsal side of the ulna (Figure 4).[41,48,49] Anterior placement is thought to minimize irritation of the plate on the surrounding soft tissue. However, this is still widely discussed as the data is not conclusive.[40,41,48–50]

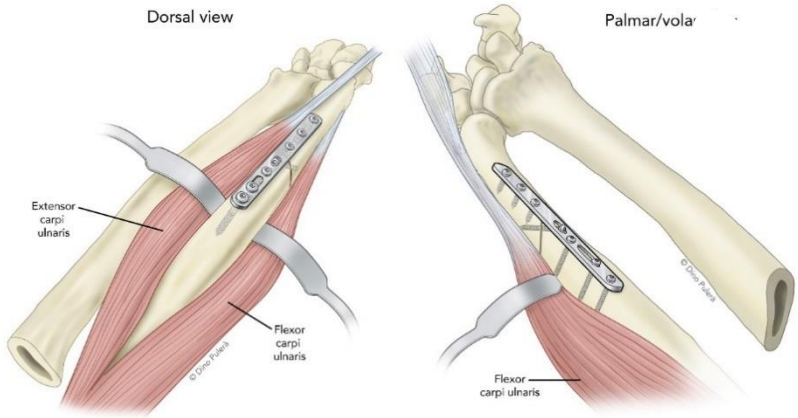

Figure 4. Schematic illustration of a dorsal (left) and anterior (right) plate location on the ulna after ulna shortening osteotomy. Illustrator: Dino Pulerà©.

OUTCOMES OF ULNA SHORTENING OSTEOTOMY

Measuring treatment outcomes has lately become increasingly important as it is a key requisite of value-based healthcare.[51,52] To implement value-based healthcare, government organizations endorse using a "standard set" of outcome measures, preferably condition-based.[53,54] Using standard set outcome measures enables valid outcome comparisons between different treatment modalities or treatment centres regionally or globally and facilitates shared-decision making.[51,52]

A standard set comprises condition-specific outcome measures and instruments to measure essential outcome domains. Also, a standard set should include predetermined time points for outcome measurement. For instance, surgical outcomes should be evaluated after a follow-up period in which the expected treatment effect should have occurred. Ideally, patients should be measured before treatment to investigate the change

in health outcomes. Furthermore, these standard sets should include case-mix variables (such as baseline demographics or operative characteristics) to allow risk-adjustment analyses.

In 2021, the International Consortium for Health Outcome Measurement (ICHOM) Hand and Wrist Group published their standard set for hand and wrist conditions.[55] While numerous studies have investigated outcomes of USO, studies often did not or only partly evaluated outcomes according to the standard set as recommended by ICHOM. For instance, while time-to-union has been thoroughly investigated, patient-reported outcome measurement (PROM) data is scarce. Also, limited studies accurately reported case-mix variables or did not relate those variables to outcomes. The core outcome domains and recommended case-mix variables for major wrist surgeries (including USO, open TFCC repair, and pisiformectomy) are displayed in Table 2.

The following paragraphs briefly discuss the previous outcomes of USO, their limitations, and current gaps in the literature.

Table 2. Outcome domains and case-mix variables for extended wrist surgery according to the International Consortium for Health Outcome Measurement (ICHOM).

Patient-Reported Outcome Measures	
Hand function	Patient-Rated Wrist Hand Evaluation (PRWHE)[56–58], Patient-Specific Functional Status (PSFS)
Pain	Patient-Rated Wrist Hand Evaluation (PRWHE)[56–58], Numeric Pain Rating Scale (NPRS)
Health-Related Quality of Life	EuroQol-5D[59]
Satisfaction with Treatment Results	ICHOM Satisfaction with Treatment Results questionnaire[55,60]
Return to Work	ICHOM return to work questionnaire[55]
Clinician-Reported Outcome measures	
Complications	ICHOM Complications in Hand and Wrist conditions (ICHAW) (modified and derived from Clavien-Dindo 2009)[55,61]
Revisions	Registration of any repeat operation for the same condition in the same patient due to disease progression or recurrence.
Grip Strength	According to Mathiowetz[62]
Range of Motion	According to Mathiowetz[62]
Case-mix variables	
Age, sex, level of education, type of work, smoking status, comorbidities, specific medical history, hand dominance, hand affected, description of treatment, and whether consultation was a second-opinion.	

Several concerns with current literature on the pain and function outcome domain following USO can be raised. First, reports use inconsistent outcome measurement methods, and the usage of standardized questionnaires with proven validity and reliability is limited. Second, studies using appropriate outcome measures often have a small sample size or miss preoperative measurements. Third, previous studies often included patients with only idiopathic UIS or secondary UIS or did not state the etiology. Comparative outcome analyses based on the etiology of UIS have barely been reported. Therefore, it is unclear whether outcomes differ based on etiology. Fourth, limited long-term PROM data after USO are available, mainly focusing on radiographic and clinician-reported outcomes.[42] Multiple studies have found that degenerative radiographic changes might occur after several years of follow-up.[13,32,34,69] For instance, De Runz et al. found that 63% of the patients developed or had worsening of distal radioulnar joint osteoarthritis (DRUJ OA) at a mean follow-up of 5 years after USO.[13] As DRUJ OA can result in symptoms requiring subsequent treatment (such as DRUJ arthroplasty), it is crucial to know whether patients still benefit from USO after long-term follow-up or whether DRUJ OA symptoms develop in time instead of UIS symptoms. More extensive

studies using validated and reliable outcome questionnaires, including preoperative measurements and appropriate case-mix variables, are needed to evaluate the effectiveness of USO in patients with UIS.

Grip strength and range of motion

While PROMs are increasingly considered a valid and reliable method to evaluate the health outcome after surgery, the clinician-reported functional assessment remains an important outcome domain as well.[55] Clinician-derived outcomes such as grip strength and range of motion (ROM) after USO have been more extensively studied than the PROMs. A meta-analysis by Stockton found that grip strength improved from 71% to 88% of the uninjured arm.[25] Range of wrist motion has also been reported to improve after USO.[45,47,70] However, it is unclear whether clinician-derived outcomes change irrespective of etiology. Furthermore, most studies did not use a prespecified time-point for the postoperative measurement or only had one. Prespecified time-dependent repeated measures of grip strength and ROM might extend our knowledge on the course of these clinician-derived outcomes following USO.

Return to work

Return to work (RTW) can be defined as a "resumption of normal work following a hiatus or period of absence because of an injury, a disability, or other reasons".[71] As hand and wrist function is integral to one's ability to work, time until RTW is a vital outcome domain in hand surgery for patients and policymakers.[55]

Several studies have reported on RTW data following USO.[34,36,37,42,72] Unfortunately, their estimates are not always comparable due to variations in RTW definitions, follow-up duration, statistical methods, and the healthcare/reimbursement system.

Previous studies did not or only partly perform risk adjustment based on case-mix variables.[36,37,72] Therefore, prognostic factors for a delayed RTW after USO are mainly unknown. For other types of hand surgery, several studies have investigated factors associated with RTW.[73–76] These studies reported that patient characteristics, such as sex, type of work, and pain before surgery, might influence RTW in patients with hand disorders and injuries. However, these factors might be specific to condition-treatment

combinations and not be generalizable to USO. Furthermore, while freehand USO is expected to have a delayed RTW compared to the newer ulnar-specific jig-guided osteotomy systems, this has not yet been thoroughly investigated.[72,77] More studies are needed to inform patients better when they can resume their usual work after USO.

Complications and reoperations

While USO might be suitable for relieving pain and improving hand function, the drawbacks of USO should also be thoroughly investigated. Almost every clinical study on the outcomes of USO mentions what complications were encountered. The two predominant complications in literature are nonunion and hardware removal due to irritation.[78–80] In their publication "*Ulnar shortening osteotomy: are complications under reported?*"[81], Chan et al. summarized the prevalence of complications after USO across studies and raised two concerns: 1) they found a considerable variation in complication rates between studies; 2) they had higher complication rates than previous studies. Therefore, they suggested that complications might be underreported.

Differences in complication and revision reporting can stem from different definitions or variations in the follow-up time evaluated for complications. Following ICHOM, a complication is defined as "an adverse or unexpected event arising from an intervention", and a revision as "any repeat operation for the same condition in the same patients due to disease progression or recurrence".[55]

To improve standardization and enhance the transparency of complication registration, the ICHOM Hand and Wrist group recently developed the Complications in Hand and Wrist conditions (ICHAW) classification.[55] This tool, modified from the Clavien-Dindo classification for general surgery[61], classifies complications 12 months after surgery into different grades based on the treatment required. Evaluating complications after USO using the ICHAW might provide more accurate data and enhance our understanding of the potential harms of this surgical treatment.

Plate removal due to hardware irritation seems to be the most prevalent reintervention after USO.[49,81] In contrast to some countries where metalwork is permanently removed per protocol[33], hardware removal is not routinely performed in the Netherlands. It is indicated based on clinician-based arguments or patient-based symptoms.[82,83] Hardware

removal is not without risk, as refractures or other complaints might occur.[82,84] Furthermore, substantial costs are associated with every additional surgical treatment.

The rate of hardware removal varies largely (0-71%) between studies.[40,85] This variance is unclear as little is known on the prognostic factors for hardware removal following USO. Few retrospective studies report on prognostic factors of hardware removal after USO.[41,49,50,81,86] Plate location is one of the most discussed prognostic factors relating to hardware removal. No consensus has been reached on the optimal plate location to decrease plate irritation and the need for subsequent removal.[40,41,48,50] Some surgeons advocate anterior placement of the plate[40,47], others favour dorsal placement[41], while others did not find a significant difference in hardware removal rates between plate locations.[48,49] Apart from plate location, heavy physical work[87], and higher age have also been described as prognostic factors for hardware removal.[49]

Previous studies often had a low sample size, were not randomized, or did not adjust for potential confounders. Furthermore, the association between surgical expertise and hardware removal has not been investigated. To better understand predictive factors associated with hardware removal, a more extensive study with adequate power combining several patient-related and clinician-related factors in one model is needed.

While several studies describe the complications after USO, little data is available on perioperative findings and complications following hardware removal. Furthermore, it is unknown whether complication rates after hardware removal differ based on initial plate locations. Evaluating complications after hardware removal using the ICHAW might provide more accurate data and enhance our understanding of the potential harms of this surgical treatment.

COMBINED TREATMENT OF ULNA IMPACTION SYNDROME AND SCAPHOLUNATE DISSOCIATION USING A SINGLE-STAGE PROCEDURE

Kakar and Garcia-Elias described that patients with ulnar-sided wrist pain sometimes have coexisting pathology (illustrated by the overlapping circles in Figure 5).[88] For example, they explain that some patients present with UIS signs and osteoarthritis of the pisotriquetral joint.

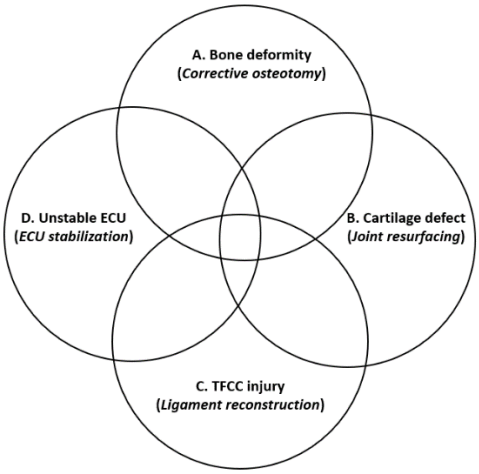

Figure 5. Modified Venn diagram of the Four-Leaf Clover Treatment algorithm proposed by Kakar and Garcia-Elias.[88]

Our multicentre institution frequently treats patients with complaints and clinical signs of UIS and scapholunate dissociation (SLD) confirmed in wrist arthroscopy. A scapholunate dissociation might happen due to a chronic scapholunate ligament (SL) tear. Interestingly, in contrast to well-documented coexisting wrist pathologies, there is almost no literature describing this combination of pathologies and how to treat it.[89]

When a patient presents with a combination of wrist pathologies, surgeons are challenged to decide which pathology to treat first or to combine the treatments in one procedure. Guidelines for combining or staging interventions for multiple wrist pathologies are largely unavailable.

When faced with combined UIS and SLD, it is unknown whether initial treatment should be focused on either UIS or SLD. Leaving either UIS or SLD untreated might lead to persistent discomfort and impaired function in the wrist. Staging the procedures into sequential events will lead to extended rehabilitation times. Therefore, combined treatment might be needed. On the other hand, the safety risks should be considered as the prolonged anaesthetic time and operation time might be associated with a higher incidence of complications or a more prolonged and painful recovery.

In August 2020, Garg and Dave were the first to report on one patient with this combined pathology treated with diaphyseal ulna shortening osteotomy (USO) and three-ligament tenodesis (3LT) in one procedure.[89] They found a decrease in the 0-10 scaled pain scores

and concluded that treatment should be directed towards a single combined intervention. However, whether both procedures can be safely combined into one procedure remains unknown and more research with larger sample size, including standardized outcome measures, is needed to evaluate their potential benefits and harms.

THE ROLE OF PSYCHOSOCIAL FACTORS ON PAIN AND FUNCTION IN ULNAR-SIDED WRIST SURGERY

Patients with ulnar-sided wrist pain often report similar complaints (depending on their diagnosis), while the symptom severity might vary. While effort has been put into understanding ulnar-sided wrist complaints based on the anatomy and biomechanics[4,7,88], psychosocial factors have been scarcely investigated in these patients. However, this might be equally important as previous studies have shown that anatomical findings during diagnostic workups only partly relate to the amount of ulnar-sided wrist pain.[90–92]

Psychosocial concepts frequently studied in musculoskeletal disorders include pain catastrophizing, psychosocial distress, and illness perception.

Pain catastrophizing is a negative cognitive-affective coping response to anticipated or actual pain.[93] The Pain Catastrophizing Scale (PCS) is a self-reported questionnaire to assess the amount of pain catastrophizing based on its three subcategories: rumination (the patient cannot stop thinking how much it hurts); magnification (the patient is afraid that something serious might happen); and helplessness (the patient feels there is nothing he can do to reduce the intensity of the pain).[94,95] Psychological distress, consisting of anxiety and depression, can be measured with the Patient Health Questionnaire-4 (PHQ-4).[96,97] This self-reported questionnaire consists of the PHQ-2 and Generalized Anxiety Disorder (GAD)-2. High scores on pain catastrophizing and psychological distress correlate with higher scores of pain and dysfunction at presentation in patients with hip[98], thumb[99], or spine pathology.[100] Illness perception represents the context of the disease and its effect on daily life. Illness perception is often divided into subdomains based on Leventhal's Self-Regulatory Model[101,102], as in the Illness Perception Questionnaire (IPQ).[103] More negative illness perception is associated with higher pain and dysfunction in Quervain's tenosynovitis [104], thumb base osteoarthritis[99], and carpal tunnel syndrome.[105]

Although multiple studies report that a more negative psychosocial profile was associated with more severe patient-reported symptoms, this has not yet been established in patients with ulnar-sided wrist conditions. Previous research has shown that illness perception might be disorder-specific[106]; therefore, results might not be generalizable to ulnar-sided wrist pathology. Studying psychosocial concepts in the context of ulnar-sided wrist disorders might enhance our understanding of patient-reported pain and dysfunction in these patients.

Furthermore, the influence of psychosocial factors on surgical outcomes has been broadly studied in recent years.[107] A meta-analysis on the outcome of total knee replacement reported that a more negative psychosocial profile was associated with worse outcomes.[108] However, other studies on spinal surgery or carpal tunnel release found that a more negative preoperative psychosocial profile did not compromise the outcome of surgery.[100,109]

Understanding the influence of psychosocial factors on the outcome of surgery is important to prepare patients for surgery optimally.[110] Subsequently, studies for ulnar-sided wrist pathology are needed to evaluate the impact of pain catastrophizing, psychological distress, illness perception, and patients' outcome expectations on patient-reported pain and hand function after surgery.

GENERAL AIMS AND OUTLINE OF THIS THESIS

This thesis investigates the outcomes of surgical treatment of ulnar-sided wrist disorders in different domains. We mainly focus on the outcomes of ulna shortening osteotomy (USO), a surgical procedure used to treat ulnar impaction syndrome (UIS). We also discuss the outcomes of the pisiformectomy and open TFCC repair.

In **Chapter 2**, we investigate the effectiveness of USO in relieving pain and increasing hand function in patients with idiopathic and secondary UIS. We compare the baseline PRWHE scores with standardized postoperative time points (3 months and 12 months). We also report on the change in range of motion and grip strength after surgery. The surgical outcomes are stratified for idiopathic UIS and UIS secondary to DRF to investigate if USO was effective for both etiologies of UIS. Furthermore, complications following USO are evaluated using the transparent ICHAW.

To evaluate whether patients with UIS still benefit from USO at long-term follow-up, we explore the late follow-up (mean of 6 years) functional outcomes using the PRWHE in **Chapter 3**. Late follow-up PRWHE scores are compared with preoperative and 12 months postoperative scores. Furthermore, patient satisfaction with treatment outcomes and the need for subsequent treatment are assessed.

Chapter 4 aims to understand which patients undergo reoperation for hardware removal after USO. Therefore, we test for independent associations between hardware removal and multiple patient-related and clinician-related factors. Furthermore, we evaluate complications following hardware removal using the ICHAW and compare complication rates after hardware removal based on initial plate location.

The return to usual work (RTW) following USO is explored in **Chapter 5**. We evaluate the median duration until RTW in weeks and the cumulative incidence of patients who met the RTW criteria 12 months after USO. Furthermore, we aim to identify risk factors for a delayed RTW. RTW following open TFCC repair was consecutively and similarly investigated in **Chapter 6**.

Chapter 7 evaluates the functional patient-reported outcomes of a single-stage USO and three-ligament tenodesis within the first year after surgery in a subgroup of patients with combined UIS and scapholunate dissociation. Furthermore, grip strength, range of motion, return to work, acute postoperative pain, and complications are investigated.

In **Chapter 8**, we aim to understand the variation in pain and dysfunction between patients with ulnar-sided wrist disorders before surgery. We investigate how psychosocial constructs (such as pain catastrophizing, anxiety and depression, and illness perception) are associated with patient-reported pain and function in these patients. We also explore how the psychosocial constructs are associated with the patient-reported surgical outcome after 12 months.

In **Chapter 9**, we reflect on the main findings and limitations of the studies performed. Furthermore, we provide a set of take-home messages for informing patients and considerations for surgeons. Lastly, we propose suggestions for future research.

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CHAPTER 2

Outcomes of ulna shortening osteotomy: a cohort analysis of 106 patients

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ABSTRACT

Background: Ulna shortening osteotomy (USO) for ulnar impaction syndrome (UIS) aims to improve pain and function by unloading the ulnar carpus. Previous studies often lack validated patient-reported outcomes or have small sample sizes. The primary objective of this study was to investigate the patient-reported pain and hand function at 12 months after USO for UIS. Secondary objectives were to investigate the active range of motion; grip strength; complications; and whether outcomes differed based on etiology.

Materials and methods: We report on 106 patients with UIS who received USO between 2012 and 2019. In 44 of these patients, USO was performed secondary to distal radius fracture. Pain and function were measured with the Patient Rated Wrist/Hand Evaluation (PRWHE) before surgery and at 3 and 12 months after surgery. Active range of motion and grip strength were measured before surgery and at 3 and 12 months after surgery. Complications were scored using the International Consortium for Health Outcome Measurement Complications in Hand and Wrist conditions (ICHAW) tool.

Results: The PRWHE total score improved from a mean score of 64 (SD = 18) before surgery to 40 (22) at 3 months, and 32 (23) at 12 months after surgery ($p<0.001$; effect size Cohen's d = -1.4). There was no difference in the improvement in PRWHE total score ($p=0.99$) based on etiology. Also, no clinically relevant changes in the active range of motion were measured. Independent of etiology, mean grip strength improved from 24 (11) before surgery to 30 (12) at 12 months ($p=0.001$). Sixty-four percent experienced at least one complication, ranging from minor to severe. Of the 80 complications in total, 50 patients (47%) had complaints of hardware irritation of whom 34 (32%) had their hardware removed. Six patients (6%) needed refixation because of nonunion.

Conclusion: We found beneficial outcomes in patients with UIS that underwent USO, although there was a large variance in the outcome and a relatively high number of complications (which includes plate removals). Results of this study may be used in preoperative counselling and shared decision making when considering USO.

Level of evidence: Therapeutic III

INTRODUCTION

Ulnar impaction syndrome (UIS) is a condition at the ulnar side of the wrist that occurs because of continuous or intermittent chronic excessive loading across the ulnocarpal joint.[1] It occurs mainly in patients with positive ulnar variance. Palmer showed that an increase of the ulnar length by 2.5 millimetres increases the ulnar load by 42%.[2] Patients with UIS may suffer from symptoms such as ulnar-sided wrist pain, decreased range of motion, impaired grip strength, and limitations in daily living.[1,3] Most patients with UIS start with nonoperative management such as NSAIDs, orthoses, corticoid injections, and hand therapy. When nonoperative management is insufficiently effective, surgical treatment can be considered.

Ulna shortening osteotomy (USO) aims to decompress the ulnar load and is a frequently used surgical treatment for patients with UIS.[4,5] However, there are only a few studies, with a low sample size of 10-20 patients, that evaluated the effectiveness of USO using validated and reliable patient-reported outcome measures (PROMs).[6–9] More studies with larger sample sizes are needed to validate the results of these studies. Furthermore, the influence of UIS etiology (e.g., idiopathic UIS versus UIS secondary to distal radius fracture) on treatment outcomes is unclear.

Previous studies on USO also described the complications following USO, including nonunion or the need for plate removal due to irritation.[10–12] Chan et al. summarized the prevalence of complications across studies and found large variations, e.g., plate removal ranged from 0 to 45%.[12] Furthermore, they compared their patients with previous literature and found higher complication rates, suggesting that complications after USO may not be systematically registered using a standardized tool, such as the recently developed International Consortium for Health Outcome Measurement Complications in Hand and Wrist conditions (ICHAW).

The primary objective of this study was to investigate the patient-reported pain and hand function at 12 months after USO for UIS. Secondary objectives were to investigate the active range of motion, grip strength, complications, and whether outcomes differed based on etiology.

PATIENTS and METHODS

Study design and Setting

We conducted a study involving prospectively gathered data on a consecutive cohort of patients that underwent USO between January 2012 and October 2019 at Xpert Clinics, The Netherlands. All hand surgeons at our institution are certified by the Federation of European Societies for Surgery of the Hand and over 150 hand therapists.

All patients who underwent USO were invited to be part of a routine outcome measurement system after their first consultation with a hand surgeon. Upon agreement, they received secure web-based questionnaires before and at 3 and 12 months after surgery using GemsTracker.[13] The exact research setting of our study group has been reported previously.[14]

We report this study using the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.[15] The ethics committee of the Erasmus University Medical Centre approved the study protocol. All patients provided written informed consent for their data to be anonymously used in this study.

Participants

A total of 283 patients underwent ulna shortening osteotomy during the study period. We excluded 6 patients that were younger than 18 years and 39 patients who did not complete the questionnaires before surgery. We reviewed electronic patient records of the remaining 238 patients to confirm that USO was performed for UIS, as USO may also be used for other indications. To be classified as UIS, at least one of the following criteria needed to be met: 1) the surgeons explicitly diagnosed the patients with UIS in the electronic patient records; 2) wrist arthroscopy showed signs of Palmer type 2 lesions, such as Triangular Fibrocartilage Complex (TFCC) degeneration and lunate chondropathy[16]; 3) magnetic resonance imaging (MRI) showed signs of focal abnormal signal intensity in the lunate, triquetrum, and ulnar head[17]; 4) there was evident ulnar positive variance on standard posterior-anterior wrist radiographs in a neutral position.[18] This definition excluded patients that underwent USO for other indications, such as solitary DRUJ instability or Madelung's disease. Patients who underwent simultaneous ligament reconstruction for instability (Extensor Carpi Ulnaris (ECU) loop, 3-ligament

tenodesis, and TFCC reinsertion) were also excluded. This left 155 patients, of which we included 106 patients who completed all questionnaires after 12 months. Furthermore, we classified patients as having UIS secondary to distal radius fracture malunion or idiopathic UIS. The flowchart of the patient inclusion is shown in Figure 1.

Surgical procedure and rehabilitation

Surgery was performed under general anaesthesia and/or a regional axillary or supraclavicular block by thirteen hand surgeons. A longitudinal incision was made on the ulnar surface and the ulna was exposed between the flexor carpi ulnaris and extensor carpi ulnaris. Care was taken not to damage the dorsal sensory branch of the ulnar nerve. The osteotomy was performed at the level of the diaphysis using a freehand cut or an external cutting device based on the surgeon's preference, and the ulna was shortened by several millimetres, depending on the amount of preoperative radio-ulnar variance. The ulna was fixated using a plate on the volar or dorsal surface on the ulna based on the surgeon's preference (n= 55 Acumed®, Hillsboro, Oregon, USA; n= 47 AO, Davos, Switzerland, n= 1 Recos® KLS Martin, Tuttlingen, Germany, n= 1 Trimed®, Santa Clarita, California, USA, n= 1 Zimmer Biomet, Dordrecht, The Netherlands, n=1 Medartis®, Basel, Switzerland). The skin was closed with Monocryl or Prolene (Ethicon). The experience of the surgeon was defined following the classification by Tang and Giddins.[19]

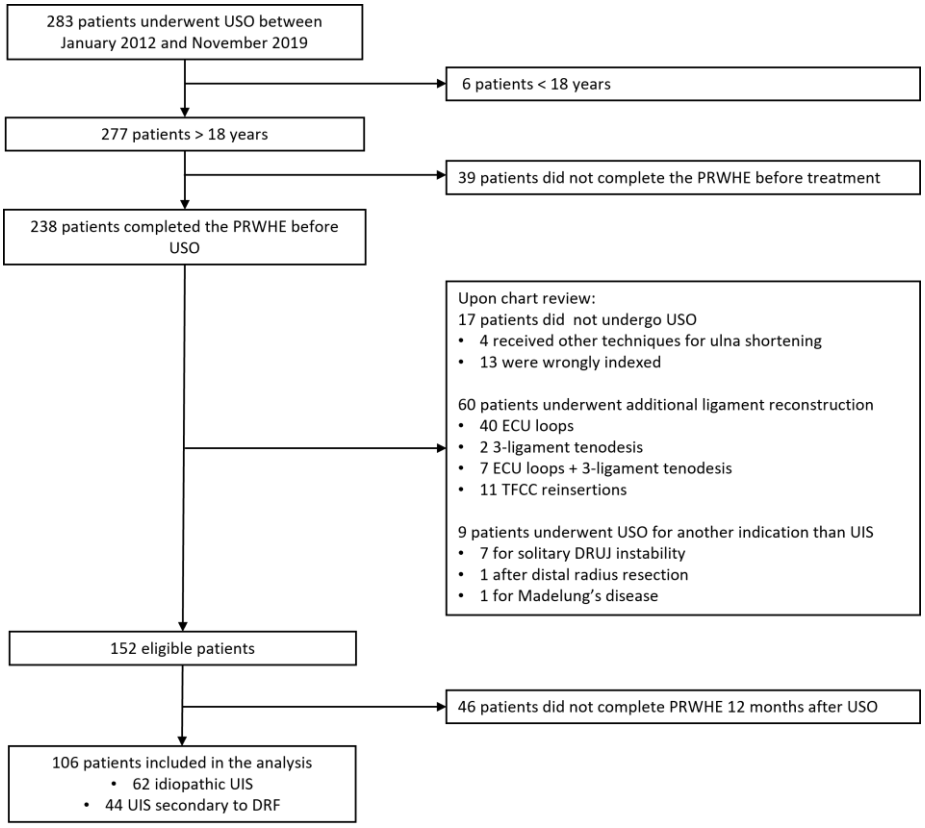

Figure 1: Flowchart of the study. USO ulna shortening osteotomy, PRWHE Patient Rated Wrist/(Hand) Questionnaire, ECU extensor carpi ulnaris, TFCC triangular fibrocartilage complex, DRUJ distal radioulnar joint, DRF distal radius fracture.

The routine postoperative immobilization protocol consisted of plaster cast (including the elbow) immobilization for 10-12 days (since 2015 this was reduced to 3-5 days) followed by thermoplastic orthosis until 6 weeks postoperatively. Wrist flexion/extension exercises were initiated 2 weeks postoperatively. Pronation/supination and strengthening exercises were initiated at 6 weeks postoperatively. All patients were encouraged to follow an extensive rehabilitation program including hand therapy exercises. The entire postoperative protocol is shown in Table S1. Our centre for hand surgery and therapy is fully integrated and postoperative hand therapy was closely monitored. Standard radiographs were taken at three and twelve months postoperatively to assess bony union, additional radiographs were made on indication (e.g., in case of delayed union, nonunion, or trauma).

Implant removal is not routinely performed in the Netherlands but may be indicated on clinician-based arguments or patient-based symptoms.[20] Patient-based symptoms are considered a valid reason for hardware removal.[21] Plate removal was considered when patients experienced irritation from the plate following full consolidation on the x-ray.

Variables and Data sources/Measurements

Demographic variables that were routinely collected included age, sex, type of work, symptom duration, treatment side, hand dominance, and the smoking status at the time of surgery. We reviewed the medical records to collect data on treatment of the initial injury, operative variables (such as the type and positioning of the fixation plate), and the occurrence of complications.

Patients completed the Dutch-language version of the Patient Rated Wrist/Hand Evaluation (PRWHE) before and at 3, and 12 months after surgery.[22] Previous research found that it is a very responsive patient-derived questionnaire to evaluate the treatment outcomes of UIS.[23–25] The minimal clinically important difference (MCID) in the PRWHE total score for patients who underwent USO for idiopathic UIS is 17.[26]

A hand therapist measured active range of motion (ROM) and grip strength before and at 3 and 12 months after surgery. In this standardized examination following ICHOM guidelines[27], the ROM was measured in degrees from neutral using a goniometer. The goniometer was placed at the dorsal side of the wrist to measure wrist flexion/extension, radial/ulnar deviation, and pronation; and at the volar side of the wrist to measure supination. Wrist flexion, radial deviation, and pronation are reported as positive values; wrist extension, ulnar deviation, and supination as negative values. Grip strength was measured using an E-LINK Jamar-Style dynamometer (Biometrics, Newport, UK) following the methods of Mathiowetz et al.[28]

Complications were scored following the International Consortium for Health Outcome Measurement (ICHOM) Complications in Hand and Wrist conditions (ICHAW) classification, which is modified from the Clavien-Dindo classification for general surgery (see Table S2).[29] This tool classifies complications within 12 months after surgery into different grades based on the treatment it requires. When a complication is not sufficiently relieved with minimally invasive treatment and more invasive treatment was given, only the complication with the highest grade is reported.

The primary outcome of this study was the change in PRWHE total score at 12 months after surgery. Secondary outcomes were complications, ROM, and grip strength.

Statistical analysis and study size

We performed a post hoc power analysis, with a conventional effect size of 0.3, the α error probability of 0.05, and a sample size of 106 patients and achieved a power of 92%.

We checked continuous data for normal distributions with histograms and quantile-quantile plots. Normally distributed data were displayed as mean values including standard deviations (SD) and skewed data were displayed as mean values including inter-quartile ranges (IQR). We used linear mixed models to compare data with more time points. We calculated the effect size of Cohen's D (d) between preoperative and 12 months PRWHE scores.[30] We compared continuous data between groups using independent T-tests or Mann-Whitney U tests, and categorical using chi-squared tests.

Because data were collected during daily clinical practice, missing data were expected in the PRWHE score at 12 months follow-up. We performed Little's test to investigate whether the PRWHE scores at 12 months after surgery were missing completely at random.[31] Furthermore, we tested for significant differences in demographics and preoperative scores between patients who completed the PRWHE before and at 12 months after surgery (defined as responders) and patients who did not fill in the PRWHE at both timepoints (defined as non-responders).

All computations were performed in R v4.0.1 (R Project for Statistical Computing, Vienna, Austria). A p-value < 0.05 was considered significant.

RESULTS

Demographics of the study population

Table 1 shows the demographics, surgical specifics, and preoperative measurements. The mean age of the study patients was 50 (Standard Deviation: ±11) and 32% of the patients were males. In 42% of the patients, the UIS was secondary to distal radius fracture. Twelve patients that were included had previously undergone a corrective osteotomy of the distal radius. Compared to the idiopathic UIS group, patients with UIS secondary to

distal radius fracture were older (p=0.044), had less range of motion in all directions except radial deviation (p<0.001-0.012), had less grip strength (p=0.008) at baseline and had more millimetres resected during the USO (p<0.001). Little's test (p=0.79) and the non-responder analysis (Table S3) suggested that missing data on PRWHE at twelve months were missing completely at random.

Patient-reported pain and function

The PRWHE total score improved from a mean score of 64 (SD = 18) before surgery to 40 (22) at 3 months, and 32 (23) at 12 months after surgery (p<0.001; d = -1.4; Figure 2). Although there was an overall improvement, a large variation in outcomes was observed at all time points (Figure 3). The PRWHE pain score improved from 34 (9) to 18 (12) at twelve months (p<0.001; d = -1.2), and the function score improved from 30 (10) to 14 (11) (p<0.001; d = -1.4). There was no difference in the improvement in PRWHE total score (p=0.99), pain score (0.894), and function score (p=0.891) based on etiology.

Active range of motion and grip strength

Table 3 shows the range of motion at all time points. Wrist extension improved in all patients, whereas wrist flexion, ulnar deviation, and radial deviation improved only in patients with secondary UIS. The overall mean grip strength improved from 24 (11) before surgery to 30 (12) at 12 months (p=0.001), improvement was seen for both etiologies (Figure 4).

Table 1: Characteristics of the study population.

Characteristic	Overall	Idiopathic	Secondary to DRF	*p*-value
n	106	62	44	
Age, mean (SD)	50 (11)	48 (11)	52 (11)	0.044
Sex = Males, n (%)	32 (30)	19 (31)	13 (30)	1.000
Duration of symptoms, median [IQR]	12 [8, 30]	18 [9, 36]	12 [7, 24]	0.089
Type of work, n (%)				0.605
None	32 (30)	17 (27)	15 (34)	
Light	24 (23)	14 (23)	10 (23)	
Medium	32 (30)	18 (29)	14 (32)	
Heavy	18 (17)	13 (21)	5 (11)	
Dominant side affected = No, n (%)	47 (44)	25 (40)	22 (50)	0.430
Smoker, n (%)				0.421
Yes	22 (21)	15 (24)	7 (16)	
No	81 (76)	46 (74)	35 (80)	
Unknown	3 (3)	1 (2)	2 (5)	
Preoperative PRWHE, mean (SD)				
Total score	64 (18)	66 (17)	61 (20)	0.195
Pain score	34 (9)	34 (8)	32 (10)	0.240
Function score	61 (21)	63 (20)	58 (23)	0.210
Preoperative active ROM*, mean (SD)				
Wrist extension	-56 (14)	-60 (12)	-51 (15)	0.001
Wrist flexion	52 (17)	57 (16)	46 (18)	0.001
Ulnar deviation	-23 (9)	-25 (9)	-21 (8)	0.012
Radial deviation	18 (6)	18 (6)	16 (6)	0.108
Supination	-69 (17)	-72 (13)	-63 (20)	0.006
Pronation	74 (13)	77 (11)	69 (15)	0.003
Preoperative grip strength**, mean (SD)	24 (11)	27 (10)	20 (11)	0.008
Ulna shortening*** (mm), median [IQR]	4 [3, 4]	3 [3, 4]	4 [3, 4]	<0.001
Intervention = Concomitant, n (%)	18 (17)	6 (10)	12 (27)	0.034

SD: Standard Deviation; IQR: Inter Quartile Range; DRF: Distal Radius Fracture; PRWHE: Patient Rated Wrist/Hand Questionnaire; ROM: Range of Motion. The P-value is calculated between the groups based on etiology.

*2% missing data, **13% missing data, ***7% missing data.

ǂ Carpal tunnel release (n=1); Trigger Finger Release (n=2); Posterior Interosseous Nerve neurectomy (n=2); Pisiformectomy (n=3); Removal of hardware for distal radius fracture (n=8); Wafer (n=1).

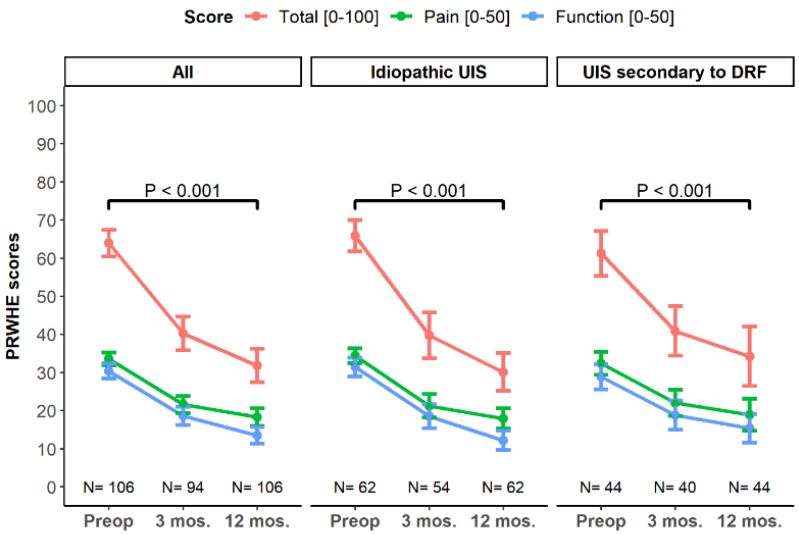

Figure 2: The mean Patient Rated Wrist/Hand Evaluation total score and subscores before ulna shortening osteotomy and at 3 and 12 months postoperatively. The error bars indicate standard errors. The P-values indicate significance over time, i.e., whether differences between baseline and follow-up were significant.

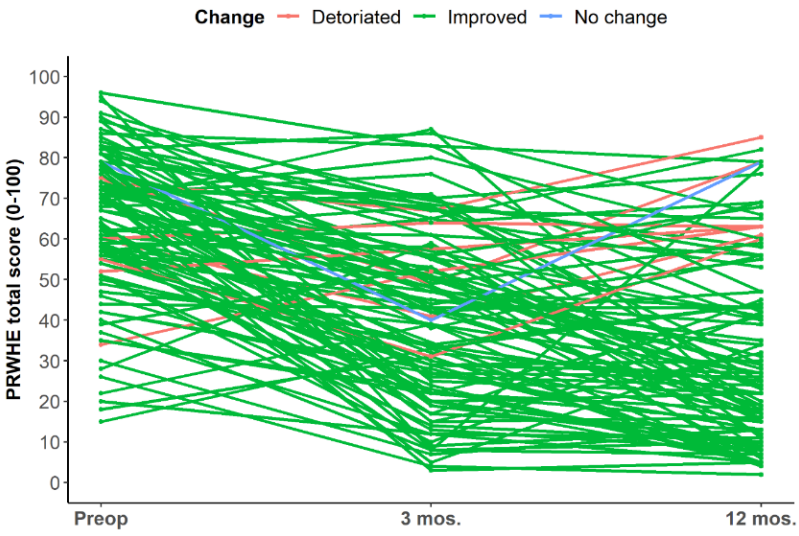

Figure 3: The Patient Rated Wrist/Hand Evaluation total score before ulna shortening osteotomy and at 3 and 12 months postoperatively plotted for each patient.

Table 3: Range of motion before ulna shortening osteotomy and at 3 and 12 months postoperatively.

Group	Movement, mean (SD)	Preoperative	3 months	12 months	*p*-value*
Overall	Wrist extension	-56 (14)	-58 (12)	-64 (8)	**<0.001**
	Wrist flexion	52 (17)	52 (12)	60 (12)	**0.002**
	Ulnar deviation	-23 (9)	-23 (7)	-27 (8)	**0.017**
	Radial deviation	18 (6)	17 (7)	20 (9)	**0.002**
	Pronation	-74 (13)	-71 (13)	-74 (11)	0.656
	Supination	69 (17)	65 (15)	70 (13)	0.835
Idiopathic	Wrist extension	-60 (12)	-59 (10)	-64 (8)	**0.022**
	Wrist flexion	57 (16)	53 (12)	60 (12)	0.062
	Ulnar deviation	-25 (9)	-24 (7)	-27 (7)	0.175
	Radial deviation	18 (6)	19 (8)	21 (10)	0.078
	Pronation	-77 (11)	-74 (12)	-74 (9)	0.218
	Supination	72 (13)	67 (15)	69 (13)	0.260
Secondary to DRF	Wrist extension	-51 (15)	-57 (14)	-65 (10)	**0.002**
	Wrist flexion	46 (18)	51 (13)	59 (12)	**0.021**
	Ulnar deviation	-21 (8)	-22 (6)	-27 (9)	**0.035**
	Radial deviation	16 (6)	15 (6)	20 (9)	**0.003**
	Pronation	-69 (15)	-68 (14)	-72 (15)	0.682
	Supination	63 (20)	63 (16)	73 (13)	0.151

DRF: Distal radius fracture. The number of patients preoperatively was 104 (idiopathic= 61; DRF= 43), at 3 months was 67 (idiopathic= 37; DRF= 30), and at 12 months was 29 (idiopathic= 19; DRF= 10).
*The *p*-values indicate significance over time, i.e., whether differences between baseline and follow-up were significant.

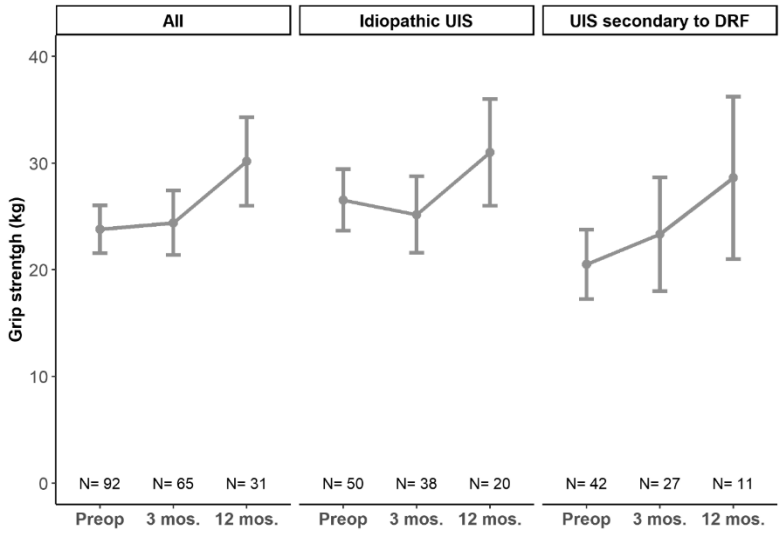

Figure 4: The mean grip strength (Kg) before ulna shortening osteotomy and at 3 and 12 months postoperatively. The error bars indicate standard errors.

Complications

Table 2 shows all complications. Of all patients, 64% experienced at least one complication. Of the 80 complications in total, 50 were directly related to hardware; 50 patients (47%) had complaints of hardware irritation of whom 34 (32%) had their hardware removed. There were no refractures after plate removal. Six patients (6%) needed refixation because of nonunion; characteristics of these patients are presented in Table 4. Five patients (5%) had subsequent therapy for persistent ulnar-sided wrist pain; 2 underwent hand therapy and/or splinting; 1 underwent TFCC reinsertion; 1 underwent pisiformectomy, and 1 underwent neurolysis.

Table 2: Complications and reoperations within twelve months after ulna shortening osteotomy.

Complication	**n**
No complication	38 (36% had no complications)
Grade I	29 complications in 29 patients (27% had a Grade I complication)
Postoperative bleeding	1
Scar tenderness	1
Hardware irritation	16
Hand therapy	
• ECU luxation	1
• DRUJ instability	1
• Midcarpal laxity	1
• Radial tunnel syndrome	1
• Persistent ulnar sided wrist pain	1
Splinting	
• ECU tendinitis	1
• Impaired pronation	1
• Persistent ulnar sided wrist pain	2
Delayed union needing bone stimulation	2
Grade II	3 complications in 3 patients (3% of the patients had a Grade II complication)
Corticosteroid injection	
• Trigger finger	3
Grade IIIA	0 complications (% had a Grade IIIA complication)
Grade IIIB	48 complications in 39 patients (37% had a Grade IIIC complication)
Refixation after nonunion	6
Hardware removal	34
Persistent ulnar sided wrist pain	
• TFCC reinsertion	1
• Pisiformectomy	1
• Neurolysis	1
3-LT tenodesis	1
Tenolysis	4
Grade IIIC	0 complications

TFCC: Triangular Fibrocartilage Complex

Table 4: Patient and surgical characteristics of the patients that required bone stimulation and/or refixation for delayed union/nonunion.

Characteristic	**Pt.1**	**Pt.2**	**Pt.3**	**Pt.4**	**Pt.5**	**Pt.6**	**Pt.7**	**Pt.8**
Age	46	71	35	48	63	53	41	46
Sex	Female	Female	Male	Female	Male	Male	Female	Female
Duration of symptoms (months)	5	12	10	60	5	24	18	9
Type of work	Heavy	None	Heavy	Medium	None	Heavy	Medium	Medium
Side	Dominant	Non-dominant	Dominant	Dominant	Dominant	Non-dominant	Dominant	Dominant
Smoking status	No	No	No	No	No	No	No	No
Etiology	DRF	DRF	DRF	Idiopathic	Idiopathic	Idiopathic	Idiopathic	Idiopathic
Plate	Acumed	AO	AO	Acumed	AO	Acumed	Acumed	Acumed
Mm shortening	3,5	4	4,5	3	4	3	3	*
Traumatic injury after USO	No	No	No	No	No	No	Yes	Yes
Bone stimulator (IGEA) used	No	No	No	No	No	Yes	Yes	Yes
Time to revisions surgery (days)	126	119	233 (****)	143	173	221	NA**	NA**
Experience level of surgeon***	III	IV	III	III	III	III	IV	III

USO: Ulna Shortening Osteotomy; DRF: Distal Radius Fracture.

*= Missing

**NA: Not Applicable; union achieved with bone stimulation and refixation not needed.

***Patient was too busy with work.

****According to the classification by Tang and Giddins.

DISCUSSION

Ulnar impaction syndrome (UIS) is a condition at the ulnar side of the wrist that occurs because of chronic excessive loading across the ulnocarpal joint [1]. Ulna shortening osteotomy (USO) is a frequently used surgical treatment for patients with UIS [4,5]. In this study we report on the outcomes of USO using prospectively gathered and reliable patient-reported outcome measures (PROMs) in a relatively large sample size [6–9]. We found that patients with UIS reported less pain and improved function at 12 months after USO. However, there was a large variance in the outcome and a relatively high number of complications, ranging from minor to severe (which includes plate removal). Results of this study may be used in preoperative counselling and shared decision making when considering USO.

Our study had several limitations. First, there were missing data in the patient and clinician-reported outcomes, making our findings not generalizable to the entire cohort. However, the data were missing at random and there were no baseline differences between responders and non-responders. Thus, we are confident that the missing data did not influence our findings. A second limitation is that in several electronic patient dossiers, the indication for USO was not explicitly stated. Therefore, we had to categorize these patients retrospectively. Third, the study sample was not homogenous regarding some factors that may influence the outcome of surgery. While all USOs were performed at the level of the diaphysis using an oblique cut, there was variation in the manner of the osteotomy (freehand vs. specific USO devices), the type and position of the fixation plate, which may have influenced the outcomes during follow-up. Although, previous research did not find a difference in pain relief or return to work between freehand USO and specific USO devices [23, 40]. Fourth, some patients underwent concomitant surgery during the USO, this could have induced some co-treatment bias.

Previous studies have reported an overall improvement in patient-reported pain and function after USO in patients with UIS [6–9]. Our data are in line with previous studies and demonstrate improvement following USO in a relatively large sample size. USO can be considered an effective treatment for patients with UIS in general, but it should be noted that we observed a large variation in the patient-reported outcome at 12 months. Some patients remained impaired, and a large prevalence of complications occurred, ranging from minor to severe. The reason for the variation in the patient-reported outcome will be a focus of future research. We found mean improvement for various measures of range

of motion over time. This improvement will probably not be clinically relevant as it is of the same magnitude as the measurement error of the goniometer [32]. However, the gain in patient-reported outcomes was not at the cost of the range of motion. This finding is in line with previous research [9,33,34]. The grip strength also improved over time.

New is the scoring of complications after USO following the International Consortium for Health Outcome Measurement Complications in Hand and Wrist conditions (ICHAW). This system with well-described definitions of complications was designed to improve the standardization and transparency of complication registration after hand and wrist surgery. Six percent of the patients required refixation with bone graft for radiographically established nonunion. This finding is similar to the results of the meta-analysis reporting nonunion rates after oblique USO [35]. Little is known on the risk factors for nonunion after USO, as the complication is relatively infrequent and most studies on USO (including this one) lack power for statistical inference. Cha found that smoking, low bone density, and decreased range of motion were independently associated with nonunion after USO [36]. Interestingly, all our patients did not smoke at the time of the USO. Many other factors, such as the type of osteosynthesis material, experience of the surgeon, and comorbidities, may lead to an increased risk of nonunion. Our descriptive data may contribute to future meta-analyses on this topic.

Furthermore, thirty-two percent of the patients underwent subsequent surgery to remove the plate within 12 months after surgery. This number is expected to increase when applying longer follow-up durations. Previous studies have also reported high rates of plate removal of e.g. 19-43% [12,37], and in other studies, the plate is routinely removed [38,39]. Patients should therefore be informed that they might require subsequent surgery to remove the plate. Future research should identify which factors are associated with hardware removal.

In this study, we compared patients with UIS based on etiology. In line with de Runz et al., we found a larger ulna positive variance in patients with secondary UIS had than in patients with primary UIS [40]. Despite these differences between the subgroups before surgery, we did not find differences in postoperative patient-reported pain and function. This was also previously reported by Nunez et al. [41]. Based on our findings, there is no need to inform patients differently based on the etiology of UIS regarding potential pain relief and gain of function after USO.

It should be noted that the patients in this study who underwent USO for UIS secondary to a distal radius malunion did not have considerable angulation in the distal radius. Patients with a clinically relevant radial head displacement undergo corrective osteotomy of the distal radius in our clinics. This in is line with other institutions who recommend a corrective osteotomy of the distal radius instead of USO in case of 10° palmar inclination or >20° dorsal inclination from the normal tilt [9,42,43]. Stirling et al. investigated the patient-reported outcome following corrective osteotomy of the distal radius and also reported favourable results [44]. For patients with severe concomitant wrist instability, other treatment modalities may be necessary; however, this was outside the scope of this study.

This study concerned a relatively large number of patients with UIS who underwent USO that was evaluated using a standardized set of prospectively collected patient-reported and clinician-reported outcome measures. The routinely collected data provide valuable insights into the performance of the USO of our daily practice. Also, this study reflects the results from multiple surgeons performing diaphyseal oblique USO, which makes the outcomes more generalizable. We found beneficial outcomes in patients with primary UIS or secondary to distal radius malunion, however, patients should be informed that plate removal is often required, and residual complaints might remain.

LIST of ABBREVIATIONS

ECU: Extensor Carpi Ulnaris
ICHAW: International Consortium for Health Outcome Measurement Complications in Hand and Wrist conditions
IQR: Inter quartile range
MCID: Minimal clinically important difference
MRI: Magnetic resonance imaging
NSAID: Non-steroidal anti-inflammatory drug
PROM: Patient-reported outcome measure
PRWHE: Patient Rated Wrist/Hand Evaluation
ROM: Range of motion
SD: Standard deviation
STROBE: Strengthening the Reporting of Observational Studies in Epidemiology
TFCC: Triangular Fibrocartilage Complex
UIS: Ulnar impaction syndrome
USO: Ulna shortening osteotomy

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SUPPLEMENTARY MATERIALS

Table S1: Postoperative therapeutic regime after ulna shortening osteotomy.

Time	Postoperative regime
Day 0	A plaster cast is applied after surgery (including wrist and/or elbow); Tendon gliding exercises fingers and thumb; Sling
Day 10-16 (2012 - 2015)	Removal of bandage and plaster cast;
Day 3-5 (2012 – present day)	Thermoplastic wrist orthosis (day and night) or sugar-tong (surgical preference); Tendon-gliding exercises; Start hand therapy 2-3 times weekly
Week 2-4	Suture removal; Start scar management; On indication edema control (Coban); Optimization range of motion fingers and thumb (tendon gliding exercises); Start active range of motion palmar flexion and dorsal flexion; Warning: no exercises for pronation and supination; Warning: no heavy load bearing.
Week 5-6	Intensifying active range of motion palmar flexion and dorsal flexion; If applicable, replace sugar-tong with thermoplastic wrist orthosis; Warning: no exercises for pronation and supination; Warning: no heavy load bearing.
Week 7-13	Start pronation and supination exercises; Warning: no intensive mobilization in maximal wrist positions; Start wrist exercises for coordination, strength, and stability; Increase load bearing and functionality; Phase-out orthosis; Warning: no heavy load bearing.
Month 3-6	Intensify range of motion wrist/forearm. Phase-out orthosis during load-bearing activities. Power training, stability training;
Month 7-12	On indication optimization of function

Table S2: ICHOM Complications in Hand and Wrist conditions (ICHAW), modified and derived from Clavien-Dindo 2009.

Grade	Definition, to occur within the final time point of the relevant track
Grade I:	Any deviation from the normal treatment course without the need for surgical, endoscopic, and radiological interventions. Acceptable therapeutic regimens are extra analgesics and additional hand therapy/ splinting/ cast. This grade includes e.g.: tendinitis, scar tenderness, temporary sensory disturbances, etc. Complex Regional Pain Syndrome is excluded from this grade (see Grade III-C).
Grade II:	Any deviation from the normal treatment course requiring antibiotics, steroid injections, or other pharmacological treatment not listed in Grade I. Also included are wound infections and hematoma's not needing anaesthesia. Complex Regional Pain Syndrome is excluded from this grade (see Grade III-C).
Grade III:	Any deviation from the normal treatment course requiring surgical, endoscopic, or radiological intervention. Also, this includes tendinitis, scar tenderness, persistent pain, etc. not responding to conservative therapy, drugs, or injections.
A:	Minor surgical intervention under local anaesthesia (e.g., irritating K wire, suture removal subcutaneously)
B:	Major surgical intervention under regional or general anaesthesia (e.g., repeat surgery, tenolysis, neurolysis, nerve repair or surgery for tendon rupture, breaking of the plate, non-union, initial prosthesis failure)
C:	Complex Regional Pain Syndrome, diagnosed using Budapest criteria, independent of the initiated treatment

Table S3: Differences in demographic data and patient-reported outcomes between responders and non-responders.

Characteristic	Responders	Non-responders	*p*-value
n	106	46	
Age, mean (SD)	50 (11)	48 (16)	0.506
Sex = Males, n (%)	32 (30)	14 (30)	1.000
Duration of symptoms, median [IQR]	12 [8, 30]	12 [6, 24]	0.341
Type of work, n (%)			0.757
None	32 (30)	17 (37)	
Light	24 (23)	8 (17)	
Medium	32 (30)	12 (26)	
Heavy	18 (17)	9 (20)	
Dominant side affected = No, n (%)	47 (44)	23 (50)	0.641
Etiology = Secondary to DRF, n (%)	44 (42)	15 (33)	0.393
Preoperative PRWHE, mean (SD)			
Total score	64 (18)	66 (18)	0.502
Pain score	34 (9)	35 (8)	0.409
Function score	61 (21)	62 (21)	0.636
3 months PRWHE*, mean (SD)			
Total score	40 (22)	40 (24)	0.972
Pain score	22 (11)	22 (13)	0.919
Function score	37 (24)	36 (26)	0.871

SD: Standard Deviation; IQR: Inter Quartile Range; DRF: Distal radius fracture; PRWHE: Patient Rated Wrist/Hand Questionnaire; ROM: Range of Motion. The *p*-value is calculated between the groups based on etiology.

*18% missing data

CHAPTER 3

Long-term outcomes after ulna shortening osteotomy: a mean follow-up of 6 years

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ABSTRACT

Aims: The primary aim of this study was to describe long-term patient-reported outcomes after ulna shortening osteotomy for ulna impaction syndrome.

Methods: Overall, 89 patients treated between July 2011 and November 2017 who had previously taken part in a routine outcome evaluation up to 12 months postoperatively were sent an additional questionnaire in February 2021. The primary outcome was the Patient-Rated Wrist and Hand Evaluation (PRWHE) total score. Secondary outcomes included patient satisfaction with treatment results, complications, and subsequent treatment for ulnar-sided wrist pain. Linear mixed models were used to compare preoperative, 12 months, and late follow-up (ranging from four to nine years) PRWHE scores.

Results: Long-term outcomes were available in 66 patients (74%) after a mean follow-up of six years (SD 1). The mean PRWHE total score improved from 63 before surgery to 19 at late follow-up (difference in means (Δ) 44; 95% confidence interval (CI) 39 to 50; $p<0.001$). Between 12 months and late follow-up, the PRWHE total score also improved (Δ 12; 95% CI 6 to 18; $p<0.001$). At late follow-up, 14/66 of patients (21%) reported a PRWHE total score of zero, whereas this was 3/51 patients (6%) at 12 months ($p=0.039$). In all, 58/66 patients (88%) would undergo the same treatment again under similar circumstances. Subsequent treatment (total n = 66; surgical n = 57) for complications or recurrent symptoms were performed in 50/66 patients (76%). The most prevalent type of reoperation was hardware removal in 42/66 (64%), and nonunion occurred in 8/66 (12%).

Conclusion: Ulna shortening osteotomy improves patient-reported pain and function that seems to sustain at late follow-up. While satisfaction levels are generally high, reoperations such as hardware removal are common.

Level of Evidence: Therapeutic II

INTRODUCTION

Ulna shortening osteotomy (USO) is an established treatment option for patients with ulnar impaction syndrome (UIS).[1–3] Previous studies reported good results, but mainly focused on radiological outcomes or clinician-reported outcome measures.[4–7] However, these studies often lacked patient-reported outcome measures (PROMs), preoperative measurements[5], or had a small sample size.[8–10]

Our previous study on 106 patients found beneficial outcomes in patient-reported pain and function 12 months after USO, measured with the Patient Rated Wrist Hand Evaluation (PRWHE).[11,12] While short-term outcomes are favourable, long-term PROMs beyond one year after USO are barely reported. However, we need to know whether short-term outcomes are sustainable at late follow-up as USO realigns the distal radioulnar joint (DRUJ) and changes the multidirectional status of the joint[13], and multiple studies have reported osteoarthritic changes at long-term follow-up.[4,5,14,15] For example, De Runz et al. found that 63% of the patients had worsening or developing distal radioulnar joint osteoarthritis (DRUJ OA) at a mean follow-up of five years (1 to 10) after USO.[5] As DRUJ OA can result in symptoms that might require subsequent treatment (such as DRUJ arthroplasty), it is crucial to know whether patients still benefit from USO after long-term follow-up or whether outcomes decline.

This follow-up study aimed to investigate the late postoperative patient-reported pain and functional status in patients undergoing ulna shortening osteotomy for ulna impaction syndrome using the PRWHE. Secondary outcomes included patient satisfaction with the treatment result, complications, and additional treatment for persistent/recurrent ulnar-sided wrist pain.

PATIENTS and METHODS

This was an observational prospective cohort study, reported according to the Strengthening the Reporting of Observational Studies in Epidemiology statement.[16] Data were collected at Xpert Clinics, a multicentre institution specialising in hand surgery and hand therapy in The Netherlands. The local Medical Research Ethical Committee approved the study (NL/sl/MEC-2019-0486). All patients provided written informed consent for their data to be anonymously used for this study.

Patients who underwent USO between July 2011 and February 2017 were contacted again for a late follow-up extension of our routine outcome measurement system.[17] After consultation with a hand surgeon, patients visiting our institution were invited to be part of a quality registry using GemsTracker (The Netherlands) electronic data capture tools. Upon agreement, they received secure web-based questionnaires before and at defined timepoints up to 12 months after treatment. Comprehensive details about the research setup, patient assessment, and follow-up regiment of the Hand and Wrist Cohort have been described previously.[17,18]

Participant selection

We identified 126 patients with a treatment code of USO in the Hand and Wrist cohort between July 2011 and February 2017 (minimally four years before initiating this study). We excluded three patients younger than 18 years and 17 patients who did not complete the PRWHE before surgery. We reviewed electronic patient records to confirm that the USO was performed for UIS, as USO may also be used for other indications. As in our previous study[12], at least one of the following criteria needed to be met to be included in the study: 1) the surgeons explicitly diagnosed the patients with UIS in the electronic patient records; 2) wrist arthroscopy showed signs of type 2 lesions, such as Triangular Fibrocartilage Complex (TFCC) degeneration and lunate chondropathy, according to Palmer[19]; 3) magnetic resonance imaging (MRI) showed signs of focal abnormal signal intensity in the lunate, triquetrum, and ulnar head[20]; and 4) there was evident static or dynamic ulnar positive variance on standard posterior-anterior wrist radiographs in a neutral position.[21] This definition excluded three patients that underwent USO for other indications. A total of 14 patients who underwent simultaneous ligament reconstruction for instability (Extensor Carpi Ulnaris (ECU) loop, three-ligament tenodesis, and TFCC reinsertion) were also excluded. This left 89 patients contacted in February 2021 to fill in questionnaires on pain, hand function, satisfaction, and complications.

Surgical procedure

The USOs were performed by ten Federation of European Societies for Surgery of the Hand (FESSH)- certified hand surgeons with experience levels three (n=4), four (n=5), and five (n=1).[22] Surgery was performed under general or regional anaesthesia. All USOs

were performed at the level of the distal diaphysis using an oblique osteotomy that was made freehand or with an external cutting device based on surgical preference. The median amount of shortening was 4 mm (interquartile range (IQR) 3 to 4) and was based on preoperative ulnar variance. The ulna was fixed using a compression plate and screws (LCP/LC-DCP, Synthes, Switzerland) or an ulna specific system (Acumed, USA; Zimmer Biomet, The Netherlands; LCP Ulna Shortening System, Synthes).

Rehabilitation

The routine postoperative immobilisation protocol has been described before.[12] The entire postoperative protocol is shown in Table S1. Our hand surgery and therapy centre are fully integrated, and postoperative hand therapy was closely monitored. Standard radiographs were taken at three and 12 months postoperatively to assess bony union. Additional radiographs were made on indication (e.g., in case of delayed union, nonunion, or trauma). Hardware removal was considered when patients experienced irritation from the plate and when complete bone union was confirmed on the radiograph, which is considered a valid reason in the Netherlands.[23,24]

Variables and data Sources/measurements

Age, sex, type of work, symptom duration, treatment side, hand dominance, and the smoking status at the time of surgery were routinely registered. We reviewed the medical records to collect data on treatment of the initial injury, operative variables, and the occurrence of complications and subsequent treatment.

Patients were sent the Dutch-language version of the PRWHE to evaluate surgical outcomes.[11,25] The PRWHE is a validated questionnaire, and previous research found that it is a very responsive patient-derived questionnaire to evaluate the treatment outcomes of USO.[26–28] It consists of 15 questions relating to pain and function, with a total score ranging from zero (no pain or dysfunction) to 100 (maximum pain and dysfunction). The minimal clinically important difference (MCID) in the PRWHE total score for patients who underwent USO for idiopathic UIS is 17.[26]

We used the satisfaction with treatment results questionnaire to assess patient satisfaction, which has good test-retest reliability and construct validity in patients with

hand and wrist conditions.[29] Patients were asked to score how satisfied they were with the treatment outcome on a five-point Likert scale: "poor", "moderate", "fair", "good", and "excellent". Furthermore, patients were asked about their willingness to undergo treatment again: "yes" or "no".

Additionally, patients were asked if they had had a complication and whether they had undergone subsequent treatment for persisting/recurrent complaints (both "yes" or "no"). If patients answered with "yes", they were asked when and what kind of additional treatment ("pain killers", "hand therapy", "immobilisation therapy", "surgery", or "other") they underwent.

Patients who did not respond to the questionnaires (non-responders) received two rounds of reminders with two weeks in between. After the two reminders, patients who did not complete the questionnaire were contacted by phone to request participation.

The primary outcome of this study was the improvement in PRWHE total score after a minimum of four years of follow-up. Secondary outcomes were the PRWHE subdomains pain and function (0 to 50), satisfaction with the treatment result, complications, and subsequent treatment.

Statistical methods

The study size was determined by the number of patients treated within the study period that responded to all questionnaires. We performed a post hoc power analysis: with the sample size of 66 patients, we could detect a medium effect size (d) of 0.35, using an α error probability of 0.05 and power of 80%.[30] Continuous data were checked for normal distributions with histograms and quantile-quantile plots. Normally distributed data were displayed as mean values, including standard deviations (SD) and skewed data with median values and inter-quartile ranges (IQR). We compared demographic data and PRWHE scores between patients who completed the late follow-up assessment (responders) and patients who did not (non-responders) using independent samples t-tests, Mann-Whitney U tests, and chi-squared tests. We used linear mixed models (LMM) to compare the PRWHE total score between time points. We did not find any violation of the model assumptions: linearity, homoscedasticity, and normality of the residuals. Furthermore, we determined the percentage of patients who achieved the MCID of 17 between intake and 12 months, and late follow-up. A *p*-value smaller than 0.05 was

considered significant. All analyses were performed using R statistical software (R Project for Statistical Computing, Austria).

RESULTS

Of the 89 patients who were contacted for this study, 66 patients (74%) completed the questionnaires, one patient (1%) had passed away due to an unrelated cause, and 22 patients (25%) could not be reached. No differences in demographic variables and PRWHE scores at intake or 12 months between responders and non-responders were observed (Table S2). A total of 66 patients were included; characteristics are displayed in Table 1. The mean age was 46 years (SD 13; range 18 to 73), and 21/66 (32%) were males. The USO was performed freehand in 36/66 (55%) and using an ulna specific system in 30/66 (45%). The mean late follow-up after surgery was 6.3 years (SD 1.3; min 4.0; max 9.0). PRWHE scores were available for all 66 patients before surgery and at late follow-up, while 51 patients also provided PRWHE scores after 12 months.

Patient-reported pain and hand function

To justify pooling late follow-up PRWHE scores as one timepoint in patients with variable follow-up (four to nine years), mean scores were compared between patients with a follow-up between four to six years (n=33) and patients with a follow-up between six to nine years (n=33). No difference was found between the two groups (18; 95% confidence interval (CI) 11 to 25 vs 19; 95%CI 13 to 26; p=0.775, linear mixed model), suggesting that pooling was justified.

The mean PRWHE total score improved from 63 before surgery to 19 at late follow-up (difference in means (Δ) 44; 95%CI 39 to 50; p<0.001, linear mixed model; Table 2). Between 12 months and late follow-up, the PRWHE total score also improved (Δ 12; 6 to 18; p<0.001, linear mixed model). Pain and function subscales showed similar improvement (Table II). At late follow-up, 14/66 (21%) reported a PRWHE total score of zero, whereas this was 3/51 (6%) at 12 months (p=0.039, two proportion Z-test).

Table 1: Characteristics of the study population at intake.

Characteristic	Overall
Total, n	66
Mean age, years (SD)	46 (13)
Male sex, n (%)	21 (32)
Duration of symptoms, median [IQR]	14 [7, 25]
Type of work, n (%)	
None	20 (30)
Light	11 (17)
Medium	19 (29)
Heavy	16 (24)
Dominant side affected, n (%)	34 (52)
Ulna shortening, mm, median [IQR]	4 [3, 4]
Aetiology, n (%)	
Idiopathic	43 (65)
Acquired (distal radius fracture)	23 (35)
Technique, n (%)	
Freehand, fixed with LCP/LC-DCP	36 (55)
Ulna specific system	30 (45)
Acumed	26
Biomet	1
Synthes	3

IQR, interquartile range; LC-DCP, limited contact dynamic compression plate; LCP, locking compression plate; SD, standard deviation.

Table 2: Mean Patient Rated Wrist/Hand Evaluation (PRWHE) scores including 95% confidence intervals before surgery, at 12 months and late follow-up (mean of 6 years) after ulna shortening osteotomy.

Category	Baseline (95%CI)	12 months (95%CI)	6 yrs. (95%CI)	Δ Before to 6 yrs.† (95%CI)	Δ 1y to 6 yrs.† (95%CI)
N patients	66	52	66		
PRWHE total score	63 [58-68]	31 [25-37]	19 [14-24]	44 [39-50]*	12 [6-18]*
PRWHE pain score	33 [30-36]	17 [14-20]	11 [8-14]	22 [19-25]*	6 [3-9]*
PRWHE function score	30 [27-33]	13 [11-16]	7 [5-10]	22 [20-25]*	6 [3-9]*

*$p<0.001$, pairwise testing from the linear mixed model.

†Difference between the defined time points.

CI, confidence interval.

Figure 1 shows a large variation between the individual longitudinal PRWHE scores. Overall, 56/66 of the patients (85%) improved beyond the MCID (17) at late follow-up, whereas this was 73% (37/51 at 12 months (p=0.161, two proportion Z-test). One patient who decreased beyond the MCID between intake and 12 months (29 points) underwent hardware removal as subsequent treatment and improved at late follow-up (32 points). Between 12 months and late follow-up, 16/51 (31%) improved, 2/51 (4%) became worse, and 33/51 (65%) showed no change in relation to the MCID range. Overall, 20 patients already had a PRWHE score ≤ 17 at 12 months and could not improve beyond the MCID.

Satisfaction with treatment

At late follow-up, 28/66 (42%) rated their satisfaction with treatment outcome as excellent, 24/66 (36%) as good, 10/66 (15%) as fair, 3/66 (5%) as moderate, and 0/66 (0%) as poor, and one patient (1%) did not respond. A total of 58/66 patients (88%) would undergo the same treatment again under similar circumstances, 7/66 (11%) would not, and one patient (1%) did not respond. The reasons for the seven patients that would not undergo USO again were a time-consuming rehabilitation period (n= 4); high levels of acute postoperative pain (n= 2), persistent ulnar sided wrist pain (n= 1). The two patients who had worse PRWHE scores late follow-up compared to their 12-month measurement rated their satisfaction as excellent and fair, and both would undergo USO again.

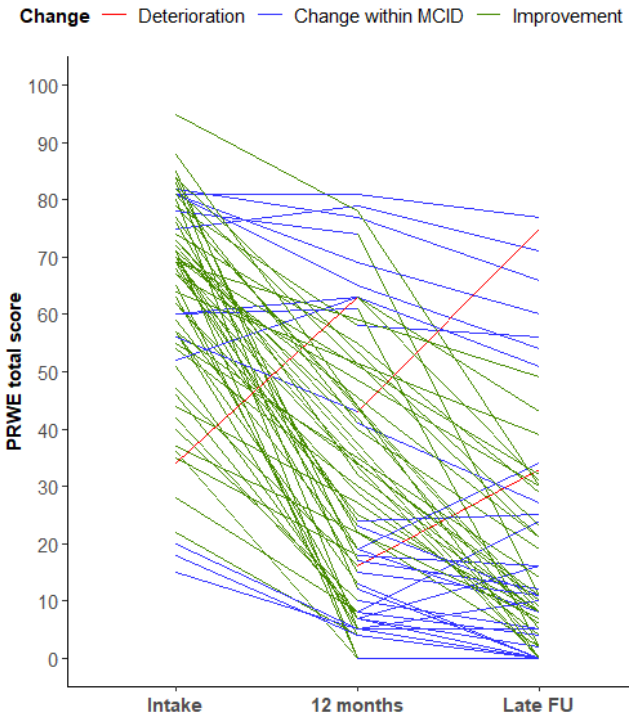

Figure 1: Longitudinal individual Patient Rated Wrist/(Hand) Questionnaire (PRWHE; range 0 to 100) total score before surgery and at 12 months and late follow-up (mean of six years) after surgery. Individual lines were code coloured between timepoints (intake to 12 months; 12 months to late follow-up; intake to late follow-up if the 12-month score was missing) based on their change score in relation to the minimal clinically important difference of 17 points.

Complications and additional treatments

A total of 13/66 patients (20%) reported having undergone subsequent therapy for a complication or persisting/recurrent ulnar-sided wrist pain. This was lower than the rate of subsequent therapy recorded in the patients' charts (50/66 (76%); $p<0.001$; two proportions Z-test). The specific patient-reported and clinician-reported subsequent therapies are displayed in Table 3. The most common type of subsequent surgical treatment was hardware removal (42/66 (64%)). Hardware removal was performed after a median of 11.2 months (IQR 7.5 to 13.4) since USO. In all, 8/66 patients (12%) had a nonunion; five patients after a freehand USO and three with an ulna specific system. Revision surgery was performed after a median of 5.4 months (IQR 4.6 to 6.7) since USO and bone union was subsequently achieved in all patients. Posthoc analyses showed that

patients who had experienced a nonunion had a worse PRWHE score than the other patients at 12 months (Δ -20; 95%CI -37 to -2; p=0.029, linear mixed model), but a similar score at late follow-up (Δ -8; 95%CI -24 to 8; p=0.327, linear mixed model) (Table 4).

Table 3: Subsequent treatment reported by the patient and clinician after ulna shortening osteotomy (USO) in 66 patients after late follow-up (mean of 6 years). Only the most invasive (surgical treatment) was registered if multiple treatments were required for the same indication.

Treatment (explanation)	N (patient - reported)	N (clinician – reported)
Subsequent treatment	13 patients	50 patients
Non-surgical treatment		
Pain killers	0	0
Antibiotics	0	0
Cortico steroid injection (ECU tendintis)	0	3
Hand therapy (improve ROM)	3	4
Splinting	0	0
Bone stimulation (ulna fracture after hardware removal)	1	1
Pain clinic	1	1
Surgical treatment		
Revision (nonunion)	4	8
Revision (additional shortening)	0	1
Hardware removal (hardware irritation)	4	42
TFCC reinsertion, dorsal capsulodesis (DRUJ instability)	2	2
PIN neurectomy	1	1
Pisiformectomy	0	2
Cubital tunnel release	0	1

ECU: Extensor Carpi Ulnaris; ROM: Range of Motion; TFCC: Triangular Fibrocartilage Complex; PIN: Posterior Interosseus Nerve.

Table 4: Posthoc comparison of the mean Patient Rated Wrist/Hand Evaluation total score at 12 months and late follow-up (mean of 6 years) after ulna shortening osteotomy between patients without (N=58) and with a nonunion (N= 8).

Timepoint	Nonunion= No		Nonunion= Yes		Δ Between groups	p-value†
	N	Mean [95%CI]	N	Mean [95%CI]		
Baseline	58	63 [57-68]	8	65 [50-80]	-2 [-18-14]	0.792
12 months	46	28 [22-35]	6	48 [32-65]	-20 [-37-2]	0.029
6 yrs.	58	18 [12-23]	8	26 [11-41]	-8 [-24-8]	0.327

Δ Difference between the defined time points

†Pairwise testing from the linear mixed model. An interaction term between time and group was included in the model to test for differences over time.

CI, confidence interval.

DISCUSSION

We found beneficial long-term patient-reported outcomes after USO in patients treated for ulna impaction syndrome. While most improvement was observed in the first 12 months, mean PRWHE scores improved further between 12 months and late follow-up. After a mean of six years, 85% of the patients had improved beyond the MCID, and 21% reported the best possible PRWHE score (score of zero). In all, 78% of the patients rated their satisfaction with treatment results as good or excellent, and 88% would undergo the same treatment again. Furthermore, 64% of the patients required reoperation for hardware removal.

In a previous study with a mean follow-up of five years after USO, 63% of the patients had developed or worsened DRUJ OA.[5] Therefore, the question raised whether long-term patient-reported outcomes still were favourable. Only limited long-term PROM data using the PRWHE after USO are available. We found a mean improvement of 44 points on a zero to 100 scale between preoperative and late-term patient-reported pain and hand function. Hassan et al. reported similar results in 20 patients with previous distal radius fractures who had an improvement of 53 points on the PRWHE after a mean follow-up of 24 months.[8] Our mean late-follow up PRWHE score (mean = 19) is comparable to results from Roulet et al.[7], who reported a mean PRWHE score of 22 points in 25 patients after a mean follow-up of 5.3 years, and seems better than the study from de Runz et al.[5], who reported a mean score of 33 in 46 patients after a mean follow-up of 5.2 years. In addition to showing that long-term outcomes were similar to previous reports, our study also revealed no signs of functional deterioration at long-term follow-up compared to short-term outcomes.

Despite the observed improvement after USO, the mean long-term PRWHE score (mean = 19) still was worse than the age-standardised reference ranges from the general Dutch population (mean = 8).[31] This finding was also observed after a late follow-up of patients who underwent corrective osteotomy of the distal radius [32] or patients who underwent open repair of the Triangular Fibrocartilage Complex (TFCC).[33] These data may be important for managing treatment expectations.

We observed a considerable variation in pain and hand function scores between patients at all timepoints. While a mean improvement of 44 points was observed, the improvement in PRWHE scores ranged from three to 88 points. Furthermore, one patient deteriorated with 19 points compared to preoperative scores. The reason for this

variation is still largely unknown. De Runz et al. found that patients with DRUJ osteoarthritis had worse PRWHE scores than patients without[5], and other studies suggested that the DRUJ morphology affected the outcome.[4,6,7] However, this study did not have radiological data at late follow-up, and DRUJ morphology could not reliably be assessed. Future prospective studies should further investigate predictors for the long-term patient-reported outcome after USO.

The difference in the rate of patient-reported and clinician-reported subsequent treatments for complications and persisting symptoms is interesting. This is in line with a previous study from our group on the long-term outcomes of open TFCC repair.[33] Even some of the more severe complications, such as nonunion, were not reported by some patients. We hypothesise that this may be due to adequate treatment of the complication. High rates of reoperations after USO have been described before.[34,35] The most common cause of reoperation after USO seems to be hardware removal.[35,36] In our institution, indications for hardware removal are mainly based on patient complaints such as pain and tenderness over the plate, impaired range of motion, paresthesia and cold intolerance. Some authors advocate that appropriate plate placement might avoid these symptoms and reduce hardware removal,[36–39] but there is no consensus on the best placement location yet. While the plate was removed in 42 patients, only four patients considered this a complication. This might be due to the adequate preoperative consultation in which patients were informed that reoperation to remove hardware was likely to occur. The nonunion rate in our study sample was relatively high compared to our previous study (12% vs 6%) and the pooled estimate from the meta-analysis by Owens (4%).[12,40] We could not find the cause for a higher incidence in our study as multiple prognostic factors for nonunion after USO, such as bone density and ROM, were not measured.[41] We observed that patients who experienced a nonunion (subsequently treated) had an impaired functional outcome at 12 months, but this difference disappeared at late follow-up. Next to hardware removal and nonunion, other subsequent procedures were performed for persistent/recurrent ulnar-sided wrist pain in some patients. This observation is also noted in other studies addressing surgical outcomes of ulnar-sided wrist pain.[33,35,42] and may result from coexisting pathology.[43] In our study, none of the patients underwent DRUJ arthroplasty for DRUJ OA. Future studies are needed to validate these results and investigate conversion rates after longer follow-up durations.

We have not been able to find other studies evaluating patient satisfaction after USO using the validated satisfaction with treatment results questionnaire. Stockton et al. performed a meta-analysis pooling different scoring systems for patient satisfaction and showed that 76% had a "good" to "excellent" outcome.[1] This is similar to our findings. Feitz et al. used the same questionnaire to evaluate long-term patient satisfaction after open TFCC repair, and found similar rates of patients with an excellent outcome (42% vs 40%) and patients who would undergo the same treatment again (88% vs 87%).[33]

This study has strengths and limitations. Strengths include the data collection using standardised PROMs, which occurred prospectively in daily practice. The availability of preoperative PRWHE scores enabled us to quantify the improvement in pain and hand function. Also, these outcomes reflect the results of multiple surgeons, again increasing the validity. A limitation of our study is the number of patients lost to follow-up (25%), making our results less generalisable to the entire patient cohort. However, the results from our responder analyses indicated that PRWHE scores between responders and non-responders before surgery and 12 months after surgery did not differ. Second, the inclusion of both freehand USOs and osteotomy guided USOs may be considered a limitation. One could argue, however, that our study results are more generalisable. Third, we did not have long-term radiographic and clinician-reported outcomes, such as DRUJ status, grip strength, and range of motion. While validated PROMs (such as the PRWHE) are recognised to assess functional outcomes, future studies should investigate long-term radiographic follow-up and relate these findings to PROMs and functional outcomes.

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SUPPLEMENTARY MATERIALS

Table S1: Postoperative therapeutic regime after ulna shortening osteotomy.

Time	Postoperative regime
Day 0	A plaster cast is applied after surgery (including wrist and/or elbow); Tendon gliding exercises; Sling
Day 10 to 12 (2012 to 2015)	Removal of bandage and plaster cast;
Day 3 to 5 (2015 to present day)	Thermoplastic wrist orthosis (day and night) or on indication sugar-tong; Tendon-gliding exercises; Start hand therapy 2-3 times weekly
Week 2 to 4	Suture removal; Start scar management; On indication edema control (Coban); Optimization range of motion fingers and thumb (tendon gliding exercises); Start active range of motion palmar flexion and dorsal flexion; Warning: no exercises for pronation and supination; Warning: no heavy load-bearing.
Week 5 to 6	Intensifying active range of motion palmar flexion and dorsal flexion; If applicable, replace sugar-tong with thermoplastic wrist orthosis; Warning: no exercises for pronation and supination; Warning: no heavy load-bearing.
Week 7 to 13	Start pronation and supination exercises; Warning: no intensive mobilization in maximal wrist positions; Start wrist exercises for coordination, strength, and stability; Increase load-bearing and functionality; Phase-out orthosis; Warning: no heavy load-bearing.
Month 3 to 6	Intensify range of motion wrist/forearm. Phase-out orthosis during load-bearing activities. Power training, stability training;
Month 7 to 12	On indication optimization of function

Table S2: Demographics and Patient Rated Wrist/Hand Evaluation (PRWHE) between responders and non-responders.

Variable	Responder	Non-responder	*p*-value
Total, n	66	23	
Mean age, years (SD)	46 (13)	47 (13)	0.548
Female sex, n (%)	21 (32)	6 (26)	0.801
Duration of symptoms, median (IQR)	14 [7, 25]	16 [7, 33]	0.899
Type of work, n (%)			0.251
None	20 (30)	11 (48)	
Light	11 (17)	5 (22)	
Medium	19 (29)	5 (22)	
Heavy	16 (24)	2 (9)	
Treatment side = dominant, n (%)	34 (52)	6 (26)	0.062
PRWHE, mean (SD)			
Preoperative total score	63 (19)	66 (16)	0.432
Preoperative pain score	33 (9)	35 (8)	0.420
Preop function score	30 (10)	32 (10)	0.477
12-month total score	30 (25)	36 (16)	0.423
12 months pain score	17 (14)	20 (12)	0.384
12 months function score	13 (12)	16 (15)	0.500

IQR, interquartile range.

CHAPTER 4

The association between plate location and hardware removal following ulna shortening osteotomy: a cohort study

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ABSTRACT

Hardware removal after ulna shortening osteotomy is common. We evaluated the association between plate location and hardware removal rate in 326 procedures in 321 patients with a median follow-up of 4.3 years (IQR 3.3) and corrected for confounding variables and did survival analyses. Complications were scored using the International Consortium for Health Outcome Measurement complications in Hand and Wrist Conditions tool. The 1-year and 5-year reoperation rates for hardware removal were 21% and 46% in the anterior group vs. 37% and 64% in the dorsal group. Anterior plate placement was independently associated with a decreased immediate risk of hardware removal. Higher age, male sex, and treatment on the dominant side were also associated with a reduced risk of hardware removal. We did not find a difference in hardware removal rates between freehand or jig-guided ulna shortening osteotomies. We noted perioperative problems in 3% of the procedures and complications in 20%.

Level of evidence: III

INTRODUCTION

Ulnar shortening osteotomy (USO) is frequently performed for various ulnar-sided wrist disorders, such as ulnar impaction syndrome, irreparable degenerative triangular fibrocartilage complex tears and mild distal radioulnar (DRU) joint instability.[1–4]

Despite good outcomes[1,3–5], previous studies have reported high reoperation rates after USO. Plate removal due to hardware irritation seems to be the most prevalent cause for reintervention.[6,7] The rate of hardware removal varies largely (0-71%) between studies.[8,9] Hardware removal is not without risk, as refractures and other complications may occur.[10,11]

There is ongoing debate about optimal plate location to decrease plate irritation and the need for removal.[8,12–14] Some authors advocate anterior placement of the plate[8,15], or dorsal placement[13], while others did not find a significant difference in complication rates between plate locations.[7,14]

Few retrospective studies have reported on predictors for hardware removal.[6,7,12,13,16] Factors other than plate location that are associated with an increased rate of hardware removal include heavy physical work[17] and older age.[7]

This study investigates whether the position of the fixation plate on the ulna influences the immediate risk of hardware removal after USO when adjusting for potential confounding variables, and what other factors are associated with an increased rate of hardware removal. Additionally, we report the peri- and postoperative complications associated with hardware removal.

METHODS

In this multicentre retrospective cohort, we studied patients who underwent USO between July 2011 and November 2019 at Xpert Clinics, The Netherlands. Our institution grew from one clinic with two hand surgeons to 18 clinics with 23 hand surgeons and over 150 hand therapists during the study period. Our study was conducted according to guidelines from the 'Strengthening the Reporting of Observational Studies in Epidemiology' statement.[18] The local medical research ethical committee of the Erasmus University Medical Centre approved the study. All patients provided written consent.

Participants

The patients included in this study were part of the Hand and Wrist Cohort, a routine measurement system for quality registration purposes.[19] We identified all patients with a treatment code of USO between 2011 and 2019, and the first authors (JST and SAS) manually checked these entries within the patient charts to avoid misclassification (e.g., when surgery was cancelled, or another procedure was performed). Bilateral procedures were included in the study since they do not introduce significant dependency problems in register studies.[20] We excluded patients when the plate position or plate type could not be retrieved from their charts or radiographs or when treatment codes were indexed wrongly in the database.

Variables and measurements

Age, sex, type of work, symptom duration, treatment side, and hand dominance were routinely registered by a certified hand therapist during admission. In addition, other patient characteristics, such as smoking status at the time of treatment (yes/no), weight and height, were self-reported by web-based secure questionnaires (GemsTracker©, Rotterdam, the Netherlands).

Electronic patient files and radiographs were evaluated for operative variables by the authors (JST, SAS, EPAvdH, and OTZ). Surgery was performed by 19 Federation of European Societies for Surgery of the Hand (FESSH) certified hand surgeons with experience levels 3 (n = 8), 4 (n = 9), and 5 (n=2).[21] All USOs were performed at the level of the distal diaphysis using a diagonal cut. Based on preoperative ulnar variance, the median amount of shortening was 4 mm (IQR 1). The total number of annual USOs increased over time due to clinic growth (Figure S1).[19] While both plate locations were used during the entire study period, we observed a decrease in dorsal placement and an increase in anterior placement since 2017. In earlier years, a freehand technique was mostly used (AO, Davos, Switzerland), whereas this was gradually replaced by jig-guided osteotomies (Acumed®, Hillsboro, OR, USA; Recos® KLS Martin, Tuttlingen, Germany, Trimed®, Santa Clarita, CA, USA, Medartis®, Basel, Switzerland). Generally, the fixation plates were placed 3 cm proximal to the ulnar head on the anterior or dorsal surface of the ulna.

The primary outcome was the rate of hardware removal, which is not routinely performed in The Netherlands, but may be indicated on clinician-based arguments or patient-based symptoms.[10] Patient-based symptoms are considered a valid reason for hardware removal.[22] We only considered hardware removal after careful clinical and radiographical affirmation of bone union and informed consent after shared decision making. The indication for hardware removal was subtracted from the patient records and classified, according to a review from Vos et al.[22], as (1) surgeon derived arguments (such as broken material, infection, or tendon rupture); (2) patient's requests (such as: "it does not belong to my body" and litigations); (3) patient's complaints (such as pain, swelling, paraesthesia, problems in daily living or cosmetic issues due to plate prominence).

Perioperative findings and complications after hardware removal were subtracted from the electronic patient files and scored following the International Consortium for Health Outcome Measurement Complications in Hand and Wrist Conditions (ICHAW).[23] This tool classifies surgical complications into different grades (I-III; a higher grade is more severe) based on the treatment required (Table S1).

Statistical methods

Time-to-event (hardware removal) was calculated in weeks. In patients who did not undergo hardware removal, we calculated event-free time by subtracting the date of USO and the last evaluation of their patient record (minimal 1.5 years after initial USO). Patients who did not undergo hardware removal during the study period were censored after their recorded event-free time had surpassed to account for variations in follow-up time and minimise bias.[24] Kaplan-Meier survival analyses were performed to evaluate the cumulative incidence of hardware removal, including 95% confidence intervals (CI) at 1, 2, and 5 years after initial USO. Differences between groups were tested using a log-rank test. The weeks in which participants were censored are marked with a '+' in the Kaplan-Meier curve.

We used a Cox proportional hazards model to estimate adjusted hazard ratios (HRs) of hardware removal with 95%CI for each variable in the model. The following variables were included in the model: sex, age, body mass index (BMI), smoking, type of work, treatment side, plate location, surgeon expertise level, and plate type. Plate type was used instead of osteotomy technique (freehand vs. jig) since plates from different

manufacturers have distinct profiles. An HR larger than one was interpreted as an increased hazard of hardware removal, and an HR smaller than one as a decreased hardware removal hazard.[25] The hazard is the immediate risk of experiencing an event at time *t*.[26] We tested the proportional hazards assumption using the Schoenfeld residuals.

The number of patients treated during the study period determined the sample size. Sample size calculations for Cox models primarily depend on simulation studies.[27] We adhered to the recommended minimum of ten events per variable.[28,29]

To investigate whether a difference in hardware removal rates could be explained by healthcare-avoiding behaviour during the COVID-19 lockdown, we conducted a sensitivity analysis by only including patients treated before March 2018, which was two years before the lockdown.[30] For all analyses, a p-value < 0.05 was considered statistically significant.

RESULTS

We identified 351 USO records in the database and excluded 25 wrongly indexed ones (e.g., the patient underwent a treatment other than USO). The study population included 326 procedures (performed in 231 patients). Characteristics are displayed in Table 1. The median patient age was 46 (IQR 22.8), and 67% were female. The median time between USO and last electronic patient files check was 4.3 years (IQR 3.3).

USO plate was removed in 181 patients. In 179 (99%), the indication for hardware removal was based on patient complaints (painful/irritating hardware n= 174; wrist motion limitation n=34; paresthesias n= 6; cold intolerance n= 1). In two patients, the decision was not based on complaints: one patient had radiological bone atrophy of the ulna, and the other was less than 18 years old and was beginning a professional sports career.

Table 1: Characteristics of the 326 procedures (321 patients).

Variable	All (n=326)	Dorsal (n=199)	Anterior (n=127)
Age [years], median (IQR)	46 (23)	44 (22)	50 (21)
Female patients, n (%)	219 (67)	130 (65)	89 (70)
BMI, median (IQR)	26 (4)	26 (4)	26 (5)
Smoker, n (%)	81 (25)	43 (22)	38 (30)
Treatment side, n (%)			
Dominant, Non-dominant	183 (56)	107 (54)	76 (60)
Non-dominant	143 (44)	92 (46)	51 (40)
Type of work, n (%)			
None	93 (28)	53 (27)	40 (31)
Light	67 (21)	42 (21)	25 (20)
Moderate	102 (31)	62 (31)	40 (31)
Heavy	64 (19)	42 (21)	22 (17)
Plate type, n (%)			
AO	113 (35)	85 (43)	28 (22)
Acumed	200 (61)	111 (56)	89 (70)
Medartis	3 (1)	2 (1)	1 (1)
KLS Martin	7 (2)	0 (0)	7 (6)
Trimed	3 (1)	1 (1)	2 (2)

IQR: Interquartile Range; BMI: Body Mass Index; n: number.

The timing of hardware removal varied from 15 to 372 weeks after USO, and 80% were performed between 29 and 103 weeks (Figure S2). The Kaplan-Meier curves stratified for plate location are shown in Figure 1. After 5 years, the cumulative hardware removal rate was 64% (CI 56 to 70%) in the dorsal group and 46% (CI 36 to 55%) in the anterior group (p=0.001). The hardware removal rate was also lower in the anterior group in the sensitivity analysis (p=0.034) and when excluding the Recos, Trimed, and Medartis plates (p<0.001). We found no difference based on the osteotomy technique (p=0.47; Figure S3). Event rates at other time points are shown in Table S2. The median time until hardware removal was 80 weeks in the dorsal group, meaning that at 80 weeks after the USO, 50% of the plates had been removed. The median time in the anterior group could not be calculated as only 46% of the plates had been removed by the end of the study period.

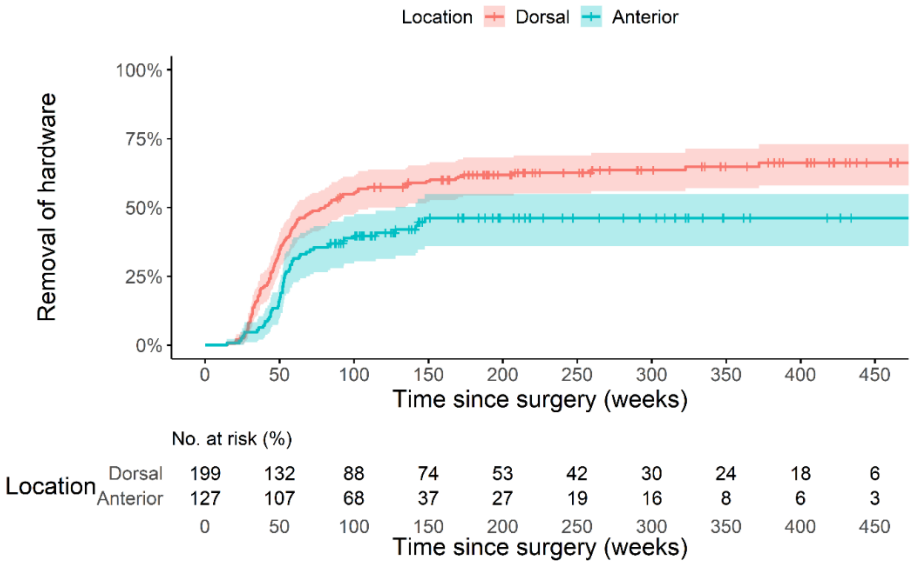

Figure 1. Kaplan–Meier curve including 95% for hardware removal after ulna shortening osteotomy based on plate location (anterior or dorsal). The number of patients at risk in each group is shown for every 50 weeks since USO.

Factors associated with hardware removal

The rate of hardware removal was lower in the anterior placement group with an adjusted HR of 0.62 (CI 0.44 to 0.89; p=0.008) (Table S3); This means that having an anterior fixation plate was associated with a 38% reduced hazard of hardware removal compared to dorsal fixation when correcting for confounding variables. Older age (HR 0.88; CI 0.78 to 0.97; p=0.015) was independently associated with a reduced hazard of hardware removal (12%/10 years) and male sex with a 32% reduced hazard compared with females (HR 0.68, CI 0.48 to 0.96; p=0.029). Treatment on the non-dominant side was associated with a 37% increased hazard of hardware removal compared to treatment on the dominant side (HR 1.37, CI 1.01 to 1.83; p=0.038).

Perioperative findings and complications

Perioperative problems were noted in six patients (3%) and complications in 37 patients (20%) (Table 2). Twenty (11%) had a Grade I, 11 (6%) a Grade II, four (2%) a Grade IIIA,

and three (1%) patients had a Grade IIIB complication. Based on plate location, we did not observe a difference in perioperative problems (p=0.54) and complications (p=0.48). Three patients (2%) had a refracture of the ulna after hardware removal; the time between USO and hardware removal in these patients was 31, 44, and 58 weeks (Table 3).

Table 2: Problems during hardware removal (181 procedures) after ulna shortening osteotomy and complications following ICHAW (stratified based on plate location (Dorsal n= 126; Anterior n= 55)).

	Overall	Dorsal	Anterior	*p*-value[a]
Perioperative problems				
None	175 (97%)	123 (98%)	52 (95%)	0.541
Difficulties with removal due to bone overgrowth	1	0	1	
Overturned screw	1	1	0	
Failing nerve block	1	1	0	
Ulnar nerve in scar tissue, neurolysis performed to get to the plate	1	0	1	
Larger incision is needed to remove the plate	2	1	1	
Complications				
None	144 (80%)	98 (78%)	46 (84%)	0.484
Grade I				
None	161 (89%)	110 (87%)	51 (93%)	0.416
(Unspecified) Pain:				
Hand therapy and splint	5	5	0	
Analgesics	1	1	0	
Acute postoperative pain: Analgesics	3	1	2	
EPL dysfunction (related to anaesthesia): Hand therapy and splint	1	1	0	
Ulnar nerve sensibility disturbances including numbness				
De-sensibilisation therapy	1	0	1	
Expectative	3	2	1	
Scar tenderness:				
Scar massage therapy	1	1	0	
Expectative	4	4	0	
Swelling: Coban glove	1	1	0	
Grade II				
None	170 (94%)	118 (94%)	52 (95%)	0.999
TVS: Corticosteroid injection	1	1	0	
Pain: Corticosteroid injection	4	3	1	
Wound infection: Antibiotics	1	1	0	
Postoperative bleeding: Bandages	2	1	1	
Hematoma: Analgesic	1	0	1	
Refracture: Cast	2	2	0	
Grade III				
None	174 (97%)	121 (96%)	53 (96%)	0.999
A				
Abscess: Drainage	2	1	1	
Skin irritation: Stitch removal	2	1	1	
B				
Hematoma: Drainage	1	1	0	
Postoperative bleeding: Exploration and coagulation.	1	1	0	
Refracture: Refixation with plate	1	1	0	

[a] The *p*-value was calculated between the volar and dorsal group, using a Chi-squared test. EPL: extensor pollicis longus; TVS: tendovaginitis stenosans; n: number.

Table 3: Characteristics of the three patients with a refracture after hardware removal.

Variable	Patient 1	Patient 2	Patient 3
Age	19 years	17 years	33 years
Sex	Male	Female	Male
BMI	25	25	26
Smoking status	Yes	No	No
Treatment side	Dominant	Non-dominant	Dominant
Type of work	None	None	Light
Plate position	Dorsal	Dorsal	Dorsal
Plate	Acumed	Acumed	AO
Removal after USO	44 weeks	31 weeks	58 weeks
Mechanism details	Unknown	Traffic accident	Heavy load-lifting

BMI = Body Mass Index; AO = Arbeitsgemeinschaft fur Osteosynthesefragen; USO =ulna shortening osteotomy.

DISCUSSION

An explanation for the difference in hardware removal rates based on plate location may be the anatomical advantage of anterior placement with thicker soft tissue coverage over the hardware.[12] Also, the extensor carpi ulnaris may be prone to subluxing over the dorsal plate, whereas this is unlikely for the flexor carpi ulnaris over an anterior plate.

Several studies have compared the rate of hardware removal for different plate locations and found contradictory results. Das De et al. found significantly lower reoperations in the dorsal group (1/16; 6%) compared with the anterior group (6/18; 50%).[13] Three other studies (n = 35 to 98) found no statistical differences based on plate location.[7,14,31] However, the results of previous studies should be interpreted with caution as they may have been underpowered to detect a statistical difference and did not adjust for potential confounders. Also, the follow-up duration should be considered when reporting the rate of hardware removal, as some patients opt for hardware removal even after more than 4 years of follow-up.

We did not find a difference in hardware removal rates based on different types of fixation plates, which is in line with the results of Verhiel et al.[7] Jungwirth-Weinberger et al. showed that the new locking 2.7 mm compression plate did not decrease the number of hardware removals due to hardware irritation and concluded that plate location is more important than its thickness, size, or design.[16]

Besides plate location, we identified some sociodemographic factors independently associated with hardware removal. First, younger age was associated with higher rates of hardware removal. The immediate risk of hardware removal decreased by 12% for every 10 years in age. A possible explanation is that younger patients have a more active lifestyle and experience more discomfort from the friction of the plate. A previous study also advocated plate removal in younger patients after bone union because of the prolonged exposure to metal corrosion and metal ions.[17] However, this should no longer be a relevant consideration with the newer alloys.[22] Also, surgeons might have had a lower threshold to remove the plate in younger patients; for example, one surgeon in our study recommended removing the plate in one asymptomatic patient younger than 18 years in anticipation of future sports-related injuries. Second, female patients had a 32% increased risk of hardware removal as compared with males. A possible cause for the higher incidence of hardware removal in women is that they experience more complaints from the hardware due to less robust soft tissue cover. Third, USO performed on the non-dominant side was associated with an increased instantaneous risk of 37% as compared with the dominant side. Some patient dossiers mention plate irritation when wearing watches or jewellery, which might be an explanation. We expected the BMI and the physical level of work to influence the reoperation rate; however, these factors were not significant. Verhiel et al. also investigated hardware removal rates (98 patients) for various sociodemographic variables using bivariate analyses.[7] In line with our findings, they found that patients undergoing hardware removal were younger but there were no differences according to the BMI or type of work. In addition, they did not report any differences based on sex and treatment side.

As the newly developed ICHAW classification was used in this study, comparisons with other studies should be made with caution as their complication scoring protocol may not be comparable with ICHAW. In our study, the bleeding rate was 3%, infection rate was 1%, and refracture rate was 2%. These rates do not differ from other commonly performed hand and wrist surgeries. Two of the three patients who had a refracture had their plate removed in the first year after USO. While 94 of the 96 plates that were removed in the first year after USO did not lead to refracture, early removal should be performed with caution. While a previous study reported that union is achieved after a mean of 4 to 5 months after USO, complete consolidation was only seen on radiographs after 16 to 20 months.[32] Therefore, the ulna may be still at greater risk of refracture in face of a new injury.

This study has limitations. First, some patients could have had their hardware removal elsewhere, leading to an underestimation of the true incidence. We considered using the last clinical note at the end of the follow-up, however, this would have resulted in selection bias as patients that returned to the clinic for hardware removal or other hand and wrist complaints were followed longer, whereas satisfied patients would have been excluded. Furthermore, we assumed that the plate locations were equally distributed in patients that underwent hardware removal elsewhere, thereby not affecting the HR. Second, there were no strict predefined indications justifying hardware removal. Third, the incidence of symptoms, such as wrist motion impairment, paresthesia, and cold tolerance should be interpreted with caution as they are likely underestimated due to underreporting in the patients' charts.

Future prospective studies could incorporate additional measurements (such as dynamic ultrasound) before hardware removal to investigate if patients' complaints relate to objective clinical signs. Furthermore, the role of psychosocial aspects such as pain catastrophizing, mental distress, and illness perception on hardware irritation, should be investigated, as these are known to influence the outcome in other types of musculoskeletal surgery.

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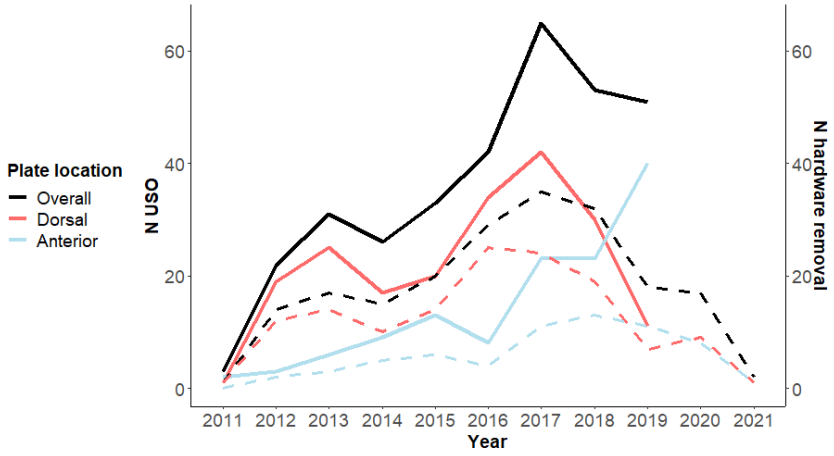
SUPPLEMENTARY MATERIALS



	2011	2012	2013	2014	2015	2016	2017	2018	2019
Freehand	3	22	29	14	17	9	7	8	4
Jig Assisted	0	0	2	12	16	33	58	45	47

Figure S1: Overview of the annual number of ulna shortening osteotomies (USOs) and reoperations for hardware removal. The solid lines represent the overall (black) number of ulna shortening osteotomy (N USO) performed between 2011 and 2019 and stratified based on plate location (anterior = blue line; dorsal = red line). The dotted lines represent the number of operations for hardware removal between 2011 and 2021 for the overall group (black) and stratified on plate location (anterior = blue line; dorsal = red line). The number of freehand and jig-guided USOs is displayed for each year.

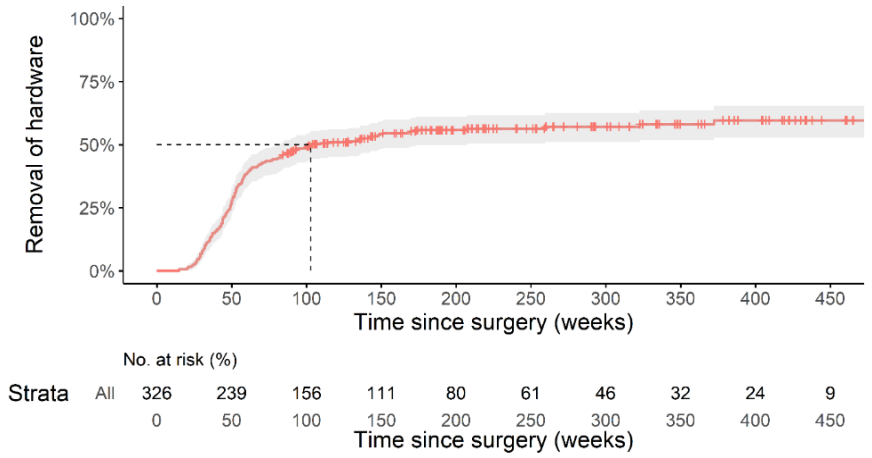


Figure S2: Kaplan-Meier curve including 95% confidence interval for hardware removal after ulna shortening osteotomy during a mean follow-up of 4.3 years. The number of patients at risk is displayed every 50 weeks since USO.

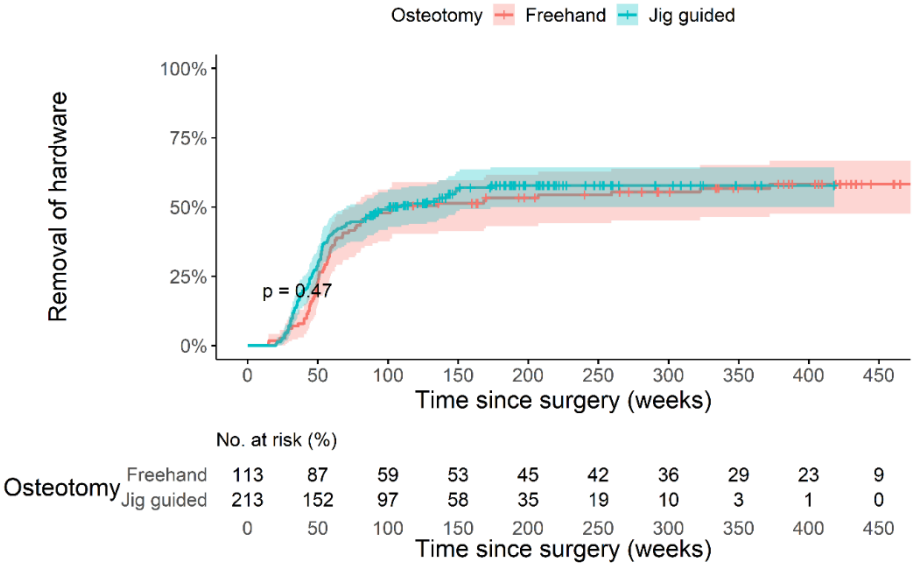


Figure S3: Kaplan-Meier curve including 95% for hardware removal after ulna shortening osteotomy based on osteotomy type (freehand of jig-guided). The number of patients at risk in each group is displayed every 50 weeks since USO.

Table S1: International Consortium for Health Outcomes Measurement classification of complications in hand and wrist conditions.

Grade	Definition, to occur within the final time point of the relevant track
Grade I:	Any deviation from the normal treatment course without the need for surgical, endoscopic, and radiological interventions. Acceptable therapeutic regimens are extra analgesics and additional hand therapy/ splinting/ cast. This grade includes e.g.: tendinitis, scar tenderness, temporary sensory disturbances, etc. Complex Regional Pain Syndrome is excluded from this grade (see Grade III-C).
Grade II:	Any deviation from the normal treatment course requiring antibiotics, steroid injections, or other pharmacological treatment not listed in Grade I. Also included are wound infections and hematoma's not needing anaesthesia. Complex Regional Pain Syndrome is excluded from this grade (see Grade III-C).
Grade III:	Any deviation from the normal treatment course requiring surgical, endoscopic, or radiological intervention. Also, this includes tendinitis, scar tenderness, persistent pain, etc. not responding to conservative therapy, drugs, or injections.
A:	Minor surgical intervention under local anaesthesia (e.g., irritating K wire, suture removal subcutaneously)
B:	Major surgical intervention under regional or general anaesthesia (e.g., repeat surgery, tenolysis, neurolysis, nerve repair or surgery for tendon rupture, breaking of the plate, non-union, initial prosthesis failure)
C:	Complex Regional Pain Syndrome, diagnosed using Budapest criteria, independent of the initiated treatment

Table S2: Descriptive results of the survival analyses for all procedures and stratified on plate location.

Variable	Overall (n= 326)	Dorsal n = 199)	Anterior (n = 127)
Number of events	181	126	55
Cumulative event rate			
1-year (CI)	31% (25 to 36%)	37% (30 to 43%)	21% (14 to 28%)
2-years (CI)	50% (44 to 55%)	57% (49 to 63%)	40% (30 to 48%)
5-years (CI)	57% (51 to 63%)	64% (56 to 70%)	46% (36 to 55%)

CI = 95% confidence interval

Table S3: Results of the multivariable Cox regression analysis.

Variable	Hazard Ratio	95%CI	*p*-value
Age (each 10 years)	0,88	[0,78 to 0,97]	**0,015**
Sex			
Females	Ref	Ref	
Males	0,68	[0,48 to 0,96]	**0,029**
BMI	1,02	[0,98 to 1,05]	0,424
Smoking			
Yes	Ref	Ref	
No	0,88	[0,62 to 1,25]	0,486
Type of work			
None	Ref	Ref	
Light	1,27	[0,8 to 2,01]	0,303
Moderate	1,3	[0,87 to 1,94]	0,196
Heavy	1,44	[0,89 to 2,31]	0,136
Treatment side			
Dominant	Ref	Ref	
Non-dominant	1,37	[1,01 to 1,83]	**0,038**
Duration of complaints (months)	1,00	[0,99 to 1]	0,614
Plate			
AO	Ref	Ref	
Acumed	1,25	[0,88 to 1,76]	0,213
KLS Martin	1,56	[0,45 to 5,36]	0,483
Medartis	1,58	[0,37 to 6,71]	0,537
Trimed	1,1	[0,25 to 4,84]	0,897
Expertise level[a]			
III	Ref	Ref	
IV	1,47	[0,89 to 2,43]	0,135
V	1,45	[0,76 to 2,79]	0,261
Location			
Dorsal	Ref	Ref	
Anterior	0,62	[0,44 to 0,89]	**0,008**

CI: Confidence Interval; BMI: Body Mass Index; Ref: reference

[a] According to Tang and Giddins (2016)

CHAPTER 5

Return to usual work following an ulnar shortening osteotomy: a sample of 111 patients

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ABSTRACT

Purpose: The primary aim of this study was to analyse the median time until patients performed their usual work following an ulnar shortening osteotomy (USO). The secondary aim was to identify factors influencing the median time until return to their usual work.

Methods: We used a retrospective cohort of patients with ongoing data collection from our institution in the Netherlands. Patients with paid employment who underwent USO were invited to complete a return-to-work questionnaire at 6 weeks, 3 months, 6 months, and 12 months after surgery. The probability of and median time until return to usual work were assessed using an inverted Kaplan-Meier analysis. Factors influencing the return to usual work were evaluated using multivariable Cox proportional hazard regression.

Results: In total, 111 patients who underwent USO were included, with a mean age of 46 years. The probability of returning to usual work in the first year was 92%, and the median time was 12 weeks. The type of work was independently associated with a return to work, with median times of 8, 12, and 14 weeks for light, moderate, and heavy physical work, respectively. We did not find differences in return to usual work based on age, sex, duration of complaints until surgery, treatment side, smoking status, the preoperative Patient Rated Wrist Evaluation score, or whether the osteotomy was performed freehand or with an external cutting device.

Conclusion: Half of the patients that underwent USO fully performed their usual work by 12 weeks following surgery. We found that 92% of the patients performed their usual work within 1 year after surgery. We found a large variation in time until a return to work based on the type of work. Surgeons can use this data to inform patients on the rehabilitation phase after USO.

Level of evidence: Prognostic IV

INTRODUCTION

Ulnar shortening osteotomy (USO) is a common treatment for ulna impaction syndrome (UIS).[1,2] Previous research on USO has predominantly focused on outcomes in terms of pain, function, and complications. Less information is available on whether and when patients can return to their usual work. For shared clinical decision-making, however, it is important that patients are counselled not only on the expected result of the treatment, but also about the time until return to work (RTW) following USO. Some studies reported on the time until patients returned to work following USO.[3–7] However, less is known about the prognostic factors for RTW.

For other types of hand surgery, several studies have investigated factors that are associated with RTW.[8–11] These studies reported that patient characteristics, such as sex, type of work, and pain before surgery, influence RTW in patients with hand disorders and injuries, but these factors may differ for different treatments and may therefore not generalize to USO.

Previous studies have shown that the time until RTW following trauma and upper extremity surgery is strongly influenced by whether the patients are receiving workers' compensation.[12,13] To compare our RTW data with those of other societies, some details of the Dutch social welfare system are required. In the Netherlands, employees get paid leave in case of illness, following law from June 5th 1913.[14] During the time this study was undertaken, the employer usually paid 100% of the full wages in the first year and 70% in the second year, and the wage cannot be lower than the minimum allowed wage as decided by the government. In addition, the employer is required to provide replacement activities and/or do as much as possible to allow the employee to RTW within these 2 years or risk a fine (1 year of salary costs) on top of paying the 2 years of wages.

The primary aim of this study was to describe the probability of performing usual work within the first year following USO. The secondary aim was to identify factors influencing the median time until return to work.

METHODS

Study design and setting

This is a retrospective study on a cohort of patients that underwent USO between June 2011 and November 2020, using longitudinally gathered data from Xpert Clinics (The Netherlands). Within this period, our institution grew from 1 clinic with 2 hand surgeons to 18 clinics with 23 hand surgeons and over 150 hand therapists.

Patients visiting our institution are invited to participate in a routine outcome measurement system after their first consultation with a hand surgeon. If the patient agrees, they receive secure web-based questionnaires at intake and at 6 weeks, 3 months, 6 months, and 12 months after surgery using GemsTracker (Generic Medical Survey Tracker) electronic data capture tools.[15] GemsTracker is a secure, web-based application for the distribution of questionnaires and forms during clinical research and quality registration. For each round of questionnaires, patients are sent 3 reminders when they had not completed all questionnaires. The setting of our study group has been reported previously.[16]

We report this study using the Strengthening the Reporting of Observational Studies in Epidemiology statement.[17] The study was approved by the ethics committee of the Erasmus University Medical Centre. All patients provided informed written consent for their data to be anonymously used for this study.

Patients

We evaluated all patients in our database who had a treatment code of USO during the study period. Patients were excluded from this study when they: (1) were younger than 18 years; (2) did not have paid work before surgery; (3) underwent concomitant stabilizing procedures; or (4) did not provide information about RTW. Indications for USO were ulnar-sided wrist pain associated with ulnar impaction syndrome. Clinical symptoms included tenderness around the ulnar head with exacerbation during forceful grip, repetitive pronation, and a positive ulnocarpal stress test. Standard posterior-anterior wrist radiographs in neutral wrist position were obtained to assess ulnar positive variance. If the ulnar positive variance was not present or when there was uncertainty on the diagnosis, posterior-anterior wrist radiographs with a firm grip, wrist arthroscopy, or

magnetic resonance imaging were performed.[18] If a diagnostic wrist arthroscopy was performed, the triangular fibrocartilage complex, lunate, and triquetrum were evaluated according to the classification of Palmer et al.[19] Magnetic resonance images were assessed for focal abnormal signal intensity in the lunate, triquetrum, and ulnar head.[20]

Surgical procedure

The USOs were performed by 17 hand surgeons, who were all fellowship-trained and Federation of European Societies for Surgery of the Hand-certified, with experience levels 3 to 5 according to the classification of Tang and Giddins.[21] Surgeons performed their preferred method of USO under general anaesthesia or a regional anaesthetic block (axillary or supraclavicular). A longitudinal incision was made on the ulnar surface of the forearm, and the ulna was exposed between the flexor carpi ulnaris and extensor carpi ulnaris. Care was taken not to damage the dorsal sensory branch of the ulna. An oblique osteotomy was made at the level of the distal diaphysis, and the ulna was shortened by several millimetres (median = 3 mm; interquartile range, 3-4 mm), depending on preoperative ulnar-positive variance. The surgical technique evolved over the study period, with some surgeons choosing to perform the USO using various systems with precise osteotomy-guided jigs (63 Acumed, 1 Biomet, 2 Medartis, 4 KLS Martin) instead of a freehand technique (42).

Rehabilitation

The general postoperative immobilization protocol consisted of plaster cast immobilization (including wrist and/or elbow) for 10-12 days (since 2015 this was reduced to 3-5 days), followed by a thermoplastic orthosis (including the wrist and, based on the surgeon's preference, also elbow immobilization) for 6 weeks after surgery, after which the orthosis was phased out within 6 weeks. Postoperative immobilization varied slightly based on the surgeons' preference and patients' needs. All patients were advised to follow an extensive rehabilitation program consisting of exercises under the direct supervision of a hand therapist: tendon gliding exercises for the fingers were initiated immediately following surgery, wrist flexion/extension exercises were initiated 2 weeks after surgery, and pronation/supination and strengthening exercises were initiated after 6 weeks after surgery.

Standard radiographs were taken at 3 and 12 months after surgery to assess bony union, and additional radiographs were made on indication (e.g., in cases of delayed union, nonunion, or trauma). Plate removal was considered when patients experienced irritation from the plate and when bone healing was confirmed with an x-ray.

The general instructions on physical activities and load bearing by the hand surgeons and hand therapists were to avoid pronation and supination in the first 5 to 6 weeks following surgery and to avoid forceful lifting in the first 7 to 13 weeks following surgery (Table S1). During daily practice, the hand surgeons' and hand therapists' instructions were patient-tailored based on radiographic signs and patients' symptoms. In the Netherlands, instructions on RTW and the type of work that can be performed are the sole responsibility of independent occupational physicians.

Variables, data sources/measurements

Baseline characteristics of all patients, including age, sex, occupational status, smoking status at the time of surgery, duration of complaints, and hand dominance, were collected before initiating treatment. To assess patient-reported pain and hand function at intake, the validated Dutch version of the Patient Rated Wrist Hand Evaluation (PRWHE) was used.[22] Pain during physical load was measured at baseline and at 6 weeks, 3 months, 6 months, and 12 months after surgery using a Visual Analogue Scale (0-100, where higher scores indicate more pain).[23] Three levels of the physical intensity of work were defined: light physical work (e.g., an office job), moderate physical work (e.g. working in a shop), and heavy physical work (e.g., working at a construction site). This information was recorded by a hand therapist after the diagnosis was made during the consultation.

Patients with paid employment were invited to complete an online questionnaire on RTW at 6 weeks and at 3, 6, and 12 months after treatment. Patients were asked whether they returned to work and were given the following answer options: (1) yes; (2) no, because of the hand/wrist problem I am currently being treated for; (3) no, because of something else. If answered with "yes", patients were asked the following 5 questions (translated from Dutch): (1) how many hours per week do you usually work?; (2) how many hours per week are you currently working?; (3) how many weeks after your initial surgery did you return to your work?; (4) are you currently doing your regular work or are (temporary) adjustments made to your work?; and (5) how many weeks after starting

your initial surgery did you return to your original work? If patients answered “no” to the initial question (option 2 and 3), no further questions were asked.

Return to work was defined as the first time that the patient reported having returned to work and performing the usual work for a minimum of 50% of the usual hours a week as stated in the patient’s contract. Patients performing adjusted work were classified as not returned to work. We chose 50% RTW as our primary outcome since Dutch labour laws require patients to be able to perform less than 50% of their usual work to be allowed any form of compensation.

Statistical methods

We used the inverted Kaplan-Meier method to estimate the cumulative RTW during the first year following surgery and to calculate the median time until RTW. We conducted a complete-case multivariable Cox proportional hazards model to identify characteristics that were independently associated with RTW. A hazard (HR) > 1 was interpreted as an increased probability to RTW, whereas an HR < 1 indicated a decreased probability to RTW. We made sure not to exceed the advised minimum of 10 events per included predictor variable.[24,25] We tested the proportional hazards assumption using Schoenfeld residuals. In all time-to-event analyses, we addressed loss to follow-up by censoring patients who reached retirement during follow-up or stopped providing information regarding RTW. This means that patients were included in the analysis for the time that they provided data, thus dealing with losses to follow-up and minimizing bias.[26] The weeks in which participants were censored are marked with a “+” in the Kaplan-Meier curve. The Visual Analog Scale was analysed using a linear mixed model with random intercepts.

For all tests, we considered a *p*-value equal to or smaller than .05 to be statistically significant.

Because data were collected during daily clinical practice, we had a substantial proportion of nonresponse at follow-up (Figure 1). A nonresponder was defined as a patient who did not fill in the RTW questionnaire, whereas a responder was defined as a participant who filled in the RTW questionnaire at least once. Demographic characteristics of responders and nonresponders are added as supplementary materials.

RESULTS

Patient selection and demographics

The database contained USO codes of 334 patients. Of these patients, 159 were confirmed as eligible, and 111 responded to the RTW questionnaire (response rate: 70%). The flowchart of the study is displayed in Figure 1.

The study sample consisted of 111 patients (71% was female) with a mean age of 46 years (SD, 12 years). The median number of hours of employment per week was 32 (Q1-Q3, 24-40). Most patients performed moderate physical work (40%), followed by light physical work (34%) and heavy physical work (26%). Other patient characteristics are shown in Table 1. The patients improved in pain during physical loading after surgery, with the most improvement in the first six weeks (Figure S1&S2; $p<0.05$).

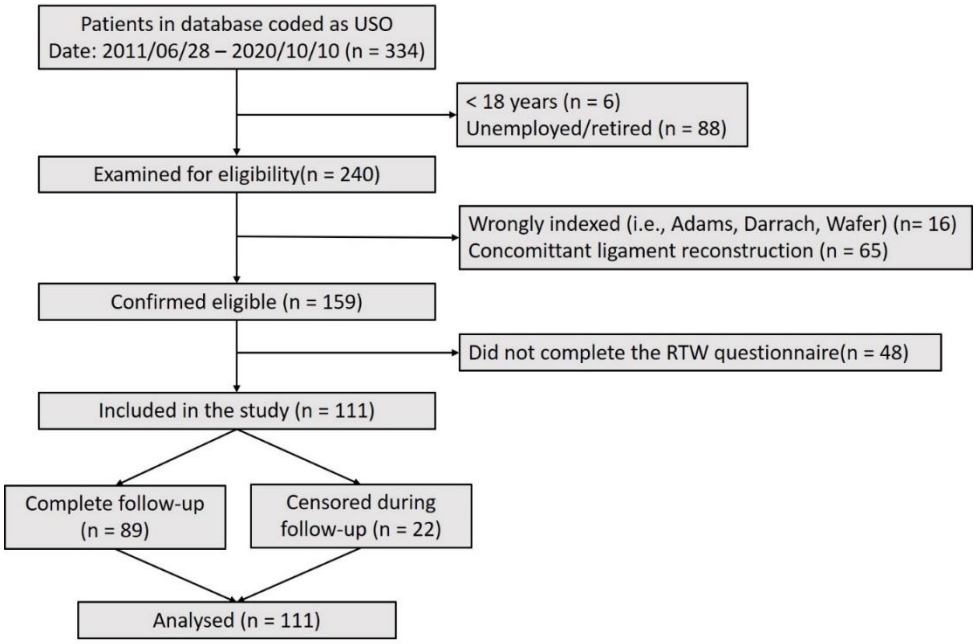

Figure 1: Flowchart of the study. USO = Ulnar Shortening Osteotomy (USO); TFCC= Triangular Fibrocartilage Complex; RTW= Return to Work.

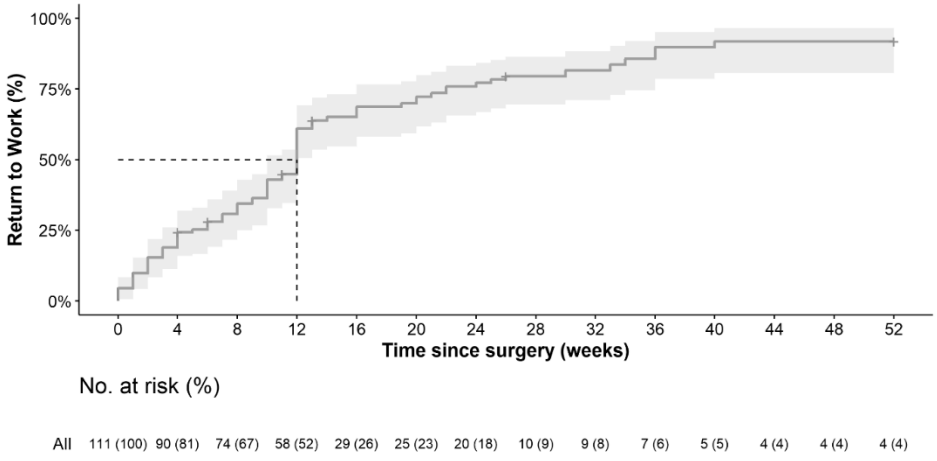

Figure 2: Kaplan-Meier curve for returning to work (RTW) after ulnar shortening osteotomy (USO) in weeks with 95% confidence intervals. The black dotted lines show the median time until return to work.

Table 1: Characteristics of the study population at baseline (N=111).

Characteristic	Level	Value
Age, mean (SD)		46 (12)
Sex, n (%)	Female	79 (71)
Contractual hours, median [IQR]		32 [24, 40]
Duration of complaints in months, median [IQR]		13 [8, 29]
Treatment side, n (%)	Dominant	57 (51)
Preoperative PRWHE* total score, median [IQR]		67 [56, 77]
Physical occupational intensity**, n (%)	Light Moderate Heavy	38 (34) 44 (40) 29 (26)
Second opinion, n (%)	Yes	20 (18)
Osteotomy technique, n (%)	Freehand External cutting device	41 (37) 70 (63)
Combined surgery***	Yes	19 (17)
Cigarette smoker, n (%)	No Yes Unknown	84 (76) 19 (17) 8 (7)

*PRWHE: Patient Rated Wrist/Hand Evaluation, 11% missing

**Physical occupational intensity: Light: e.g. office; Moderate: e.g. working in a store; Heavy: e.g. construction work

***Hardware removal of the distal radius (6), pisiformectomy (4), posterior interosseus nerve neurectomy (3), trigger finger release (2), carpal tunnel release (1), wafer (1), excision styloid process radius (1), excision mucoid cyst in the second distal phalanx (1).

Table 2: Sociodemographic characteristics of patients who provided data on the return to work questionnaire (responders) and patients who did not (non-responders).

Characteristic	Level	Responders	Non-Responders
n		111	48
Age, mean (SD)		46 (12)	44 (14)
Sex, n (%)	Female	79 (71)	28 (58)
	Male	32 (29)	20 (42)
Duration of complaints in months, median [IQR]		13 [8, 29]	12 [8, 24]
Treatment side	Dominant	57 (51)	28 (58)
	Non-dominant	54 (49)	20 (42)
Preoperative PRWHE total score, median [IQR]		67 [56, 77]	73 [59, 82]
Type of work, n (%)	Light	38 (34)	15 (32)
	Moderate	44 (40)	20 (42)
	Heavy	29 (26)	13 (27)
Second opinion, n (%)	Yes	20 (18)	8 (17)
	No	91 (82)	40 (84)

*PRWHE: Patient Rated Wrist Hand Evaluation

**Physical occupational intensity: Light: e.g. office; Moderate: e.g. working in a store; Heavy: e.g. construction work

Return to Work

The cumulative RTW during the first year following surgery was 92%. The median time until RTW was 12 (95% confidence interval, 10-12 weeks; Figure 2). The sensitivity analysis showed that the median time until RTW for 100% of the original contractual working hours was also 12 weeks (p=0.7). During the twelfth week following surgery, there was a peak in which 16% of the patients returned to work. Eighteen patients were censored before the 1-year follow-up. Four patients (1 female with moderate work, 1 female with heavy work, and 2 males with moderate work) reported not returning to usual work after 1 year but performed adjusted work between 80% and 100% of their usual contract hours.

During the first year, 31 patients (28%) underwent subsequent surgery to remove the plate. Return to usual work preceded hardware removal in all but 3 patients: 1 patient

returned to work the week after the hardware was removed and 2 patients did not return to usual after 1 year.

In the multivariable regression, the type of work was independently associated with RTW (Figure 3). Patients with moderate or heavy work returned later than patients with light work (HR = 0.50-0.51). The cumulative RTW after 1 year following surgery was 100% for light work, 86% for moderate work, and 91% for heavy work. The median times until RTW was 8, 12, and 14 weeks, respectively (Figure 4). Descriptive data on RTWs for other subgroups are shown in Table 3.

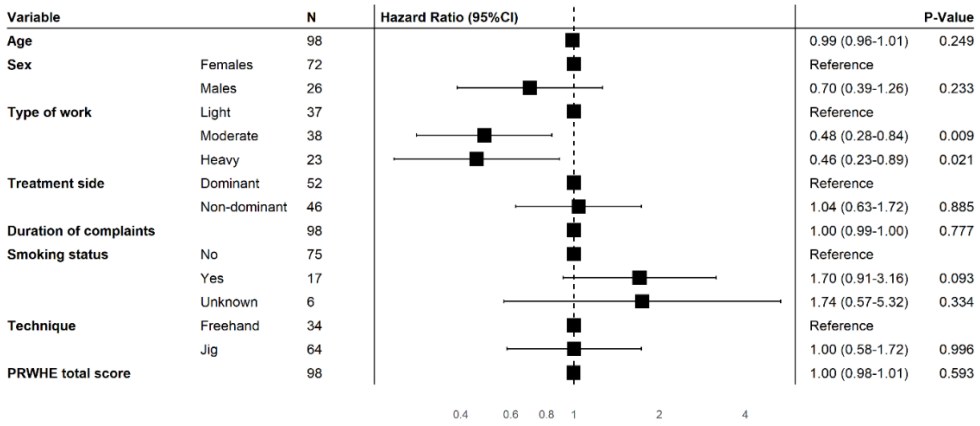

Figure 3: Results from the multivariable COX regression analysis for return to usual work for >50% of the usual contract hours using patient characteristics, surgical technique, and preoperative Patient Rated Wrist/Hand Evaluation (PRWHE) scores as covariates. A hazard ratio (HR) > 1 indicates a higher likelihood to return to work, whereas an HR <1 indicated a smaller likelihood to return to work in comparison to the reference group. Patients without preoperative PRWHE scores were excluded from this analysis (N=13).

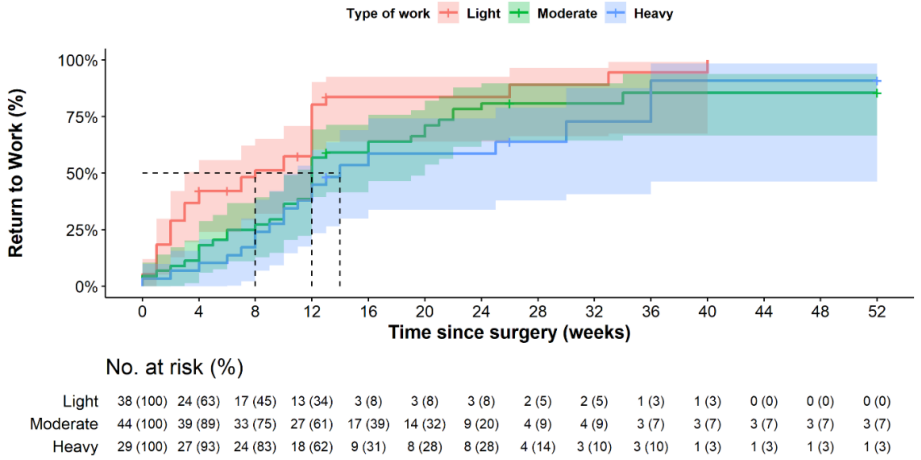

Figure 4: Kaplan-Meier curve for returning to work (RTW) after ulnar shortening osteotomy (USO) in weeks, with 95% confidence intervals stratified by type of work (red = Light; green = Moderate; blue = Heavy).

Table 3: Median time until return to usual work for > 50% of the usual contract hours for subgroups. Continuous variables were categorized based on the median value.

Variable	Median Time to RTW (95%CI)	1-year cumulative RTW
Age		
<49 years (n = 51)	12 (10-20)	96%
=> 49 years (n = 60)	12(10-12)	81%
Sex		
Females (n = 79)	12 (10-12)	95%
Males (n = 32)	13 (12-NA)	81%
Type of work		
Light (n = 38)	8 (3-12)	100%
Moderate (n = 44)	12 (11-20)	86%
Heavy (n = 29)	14 (11-NA)	92%
Treatment side		
Dominant (n = 57)	12 (10-16)	89%
Non-dominant (n = 54)	12 (10-13)	96%
Smoking status		
No (n = 84)	12 (7-13)	96%
Yes (n = 16)	12 (10-16)	92%
Unknown (n = 8)	7.5 (4-NA)	100%
Technique		
Freehand (n = 41)	12 (10-21)	92%
Assisted (n = 70)	12 (10-14)	91%
***PRWHE score**		
< 67 (n = 46)	12 (10-16)	92%
=> 67 (n= 53)	12 (9-14)	92%

*PRWHE: Patient Rated Wrist/Hand Evaluation.

DISCUSSION

In this study, we described the return to usual work in our cohort of patients who underwent USO. We found that 92% of the patients returned to usual work during the first year following USO. Half of the patients return to work within 12 weeks. We observed large variations in the timing of returning to usual work between different levels of work.

Previous studies reported descriptive data on RTW following USO. Sunil et al. found that 65% of the patients treated with a freehand USO returned to usual work in 14 weeks (range, 0-28 weeks) and 63% of the patients treated with an assisted osteotomy jig returned to usual work in 13 weeks (range, 0-50 weeks).[5] Luria et al. did not report on the time until return to usual work but reported 92% RTW rate in the freehand USO group and 94% RTW rate in the assisted osteotomy group. Minami and Kato reported that 92% of their patients returned to their usual work.[6,7] Auzias et al. reported an RTW time of 32 weeks.[27] Lastly, Papatheodorou et. al reported an average RTW of 16 weeks in all patients. From these findings, we conclude that most patients are capable of returning to their usual work[4]; however, the timing until RTW varies substantially between patients.

The type of work is a recurring predictor for the time until RTW following multiple hand injuries and surgeries.[10] A study from Moermans et al. investigated times until RTW following USO in a small sample of 10 and 18 patients with light and heavy physical work, respectively.[3] They found that 90% of the patient with light physical work returned after 3 months (range, 1 to 11 months), whereas 83% of the patients with heavy work returned after a mean of 8.3 months (range, 0.5 to 30 months). In our study, we found shorter durations until RTW of 8 and 14 weeks for light and heavy physical work, respectively. Moermans et al. acknowledge that their reported duration until osteotomy union was longer than those of other studies, which could have prolonged the RTW.[3] In our study, the median times until RTW for light and heavy work is in line with the general instructions of the postoperative regimen to avoid pronation and supination in the first 5 to 6 weeks and to avoid forceful load bearing in the first 7 to 13 weeks. However, it should be noted that some patients, including some in the heavy work category, were able to RTW sooner than the general instructions.

We did not find large differences between subgroups other than the type of work. Neutel et al.[10] reported that females had a longer time until RTW compared to males, which we were not able to confirm. Opsteegh et al.[28] reported that pain at baseline was a

determinant of RTW in patients with hand injuries; our study did not find this effect. We did not find a difference in the RTW between freehand USOs and USO guided by an external cutting device, which is in line with previous research.[5,6]

Our study has some strengths and limitations. The strengths include the comparison between different levels of physical workload and the survival analysis allowing time-dependent estimates of RTW while dealing with loss to follow-up and minimizing bias. The first limitation was that we could not determine from the data to what extent the decision to RTW was externally guided. In the Netherlands, independent occupational physicians are responsible for instructions concerning RTW and the type of work that can be done. While surgeons should not interfere with these instructions, their advice on the type of tasks and load bearing allowed could have influenced the decision to RTW. In future studies on RTW, we are incorporating a question on whether or when patients felt confident to return to their usual work following surgery, to compare these estimates with the actual RTW times. Second, we estimated the RTW with subjective questionnaires. Databases with information from public services could have provided a clearer picture, but these were not accessible. Third, the sample size was relatively small because of the exclusion all patients that did not have paid work before surgery, as well as nonresponses on the RTW questionnaires. The amount of missing data could potentially have led to selection bias. We adhered to the proposed rule of 10 events per independent predictor in the COX regression analysis.[23] A larger sample size would have allowed more variables into the model, as well as HRs with smaller confidence intervals. Lastly, the postsurgical rehabilitation protocol may have deviated from treatment protocols, thereby introducing possible bias. Therefore, the outcomes of this study are not specific to a certain postoperative treatment regime. However, our observational study design is representative of actual daily practice and reflects the results of multiple surgeons and hand therapists, and thereby has practical validity.

While we found that there was a large variation in time until RTW between different levels of the physical intensity of work, we also found large variations within these subgroups. Work-related factors, such as working relationships, accommodations, practical and physical limitations, are known to influence RTW outcomes in patients with musculoskeletal conditions and could have explained the variation within different levels of work.[29] Future research should incorporate when patients feel confident about RTW and how this is influenced by the type of work and psychosocial factors, such as pain

catastrophizing. Finding psychosocial factors that contribute to a longer time to RTW can provide a focus for psychosocial interventions to reduce the time until RTW.

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SUPPLEMENTARY MATERIALS

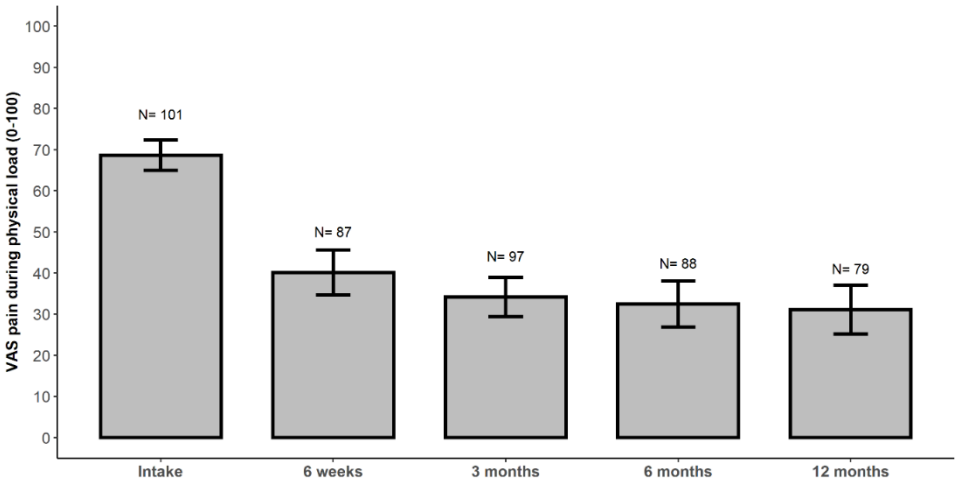

Figure S1: Pain during physical load as measured with a Visual Analogue Scale (VAS) for patients that underwent ulnar shortening osteotomy. Mean and 95% confidence intervals are plotted. The linear mixed model analysis demonstrated a significant improvement over time (p<0.001).

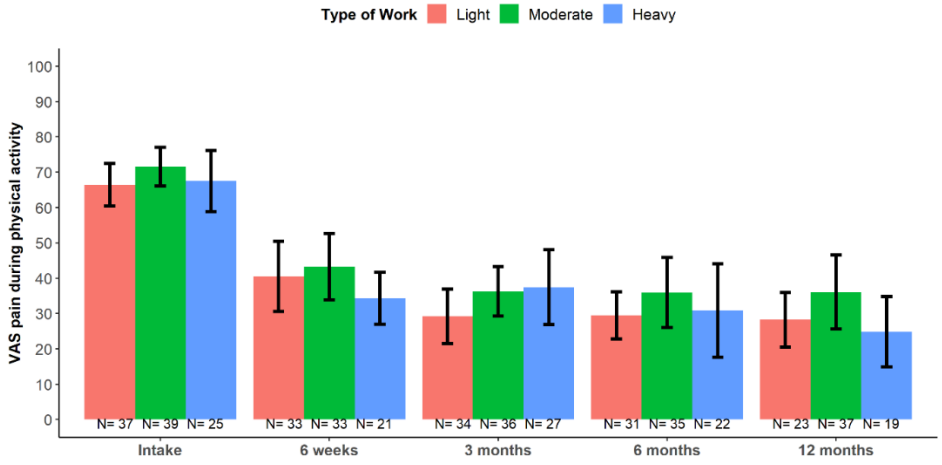

Figure S2: Pain during physical load as measured with a Visual Analogue Scale (VAS) for patients that underwent ulnar shortening osteotomy stratified for the type of work (red = Light; green = Moderate; blue = Heavy). Mean and 95% confidence intervals are plotted. The linear mixed model analysis demonstrated a significant improvement over time for all types of work (each p<0.001).

Table S1: Postoperative therapeutic regime after ulnar shortening osteotomy since 2015.

Time	Postoperative regime
Day 0	Plaster cast is applied after surgery (including wrist and/or elbow); Tendon gliding exercises; Sling
Day 10-12 (2012-2015)/ Day 3-5 (2015 -present day)	Removal of bandage and plaster cast; Thermoplastic wrist orthosis (day and night) or sugar-tong (surgical preference); Tendon-gliding exercises; Start hand therapy 2-3 times weekly
Week 2-4	Suture removal; Start scar management; On indication edema control (Coban); Optimization range of motion fingers and thumb (tendon gliding exercises); Start active range of motion palmar flexion and dorsal flexion; Warning: no exercises for pronation and supination; Warning: no heavy load-bearing.
Week 5-6	Intensifying active range of motion palmar flexion and dorsal flexion; If applicable, replace sugar-tong with thermoplastic wrist orthosis; Warning: no exercises for pronation and supination; Warning: no heavy load-bearing.
Week 7-13	Start pronation and supination exercises; Warning: no intensive mobilization in maximal wrist positions; Start wrist exercises for coordination, strength, and stability; Increase load-bearing and functionality; Phase-out orthosis; Warning: no heavy load-bearing.
Month 3-6	Intensify range of motion wrist/forearm. Phase-out orthosis during load-bearing activities. Power training, stability training;
Month 7-12	On indication optimization of function

CHAPTER 6

Factors associated with return to work after open reinsertion of the triangular fibrocartilage

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ABSTRACT

The aim of this study was to assess return to work (RTW) after open Triangular Fibrocartilage Complex (TFCC) reinsertion. RTW after open surgery for TFCC injury was assessed by questionnaires at 6 weeks, 3 months, 6 months, and 12 months post-operatively. Median RTW time was assessed on inverted Kaplan-Meier curves and hazard ratios were calculated with Cox regression models. 310 patients with a mean age of 38 years were included. By 1 year, 91% of the patients had returned to work, at a median 12 weeks (25%-75%: 6-20 weeks). Light physical labour (HR 3.74) was associated with RTW within the first 15 weeks; this association altered from 23 weeks onward: light (HR 0.59) or moderate physical labour (HR 0.25) was associated with lower RTW rates. Patients with poorer preoperative Patient-Rated Wrist Evaluation (PRWE) total score returned to work later (HR 0.91 per 10 points). Overall cost of loss of productivity per patient was €13,588. In the first year after open TFCC reinsertion, 91% of the patients returned to work, including 50% within 12 weeks. Factors associated with RTW were age, gender, work intensity, and PRWE score at baseline.

Level of evidence: Therapeutic III.

INTRODUCTION

Ulnar-sided wrist problems can interfere with ability to work and may lead to productivity loss. Triangular Fibrocartilage Complex (TFCC, see Figure 1) injuries are a frequent cause of ulnar-sided wrist pain. The surgical technique for TFCC reinsertion is well described. However, factors associated with the time to return to work (RTW) are less well-known. Bernstein et al. reported time to RTW in patients after an arthroscopic wafer procedure (21 weeks) and an ulnar shortening procedure (24 weeks).[1] Ruch et al. reported on arthroscopic repair of TFCC injury and found that 11 out of 13 patients returned to their original occupation at a mean 9 weeks.[2] Van der Molen et al. reported a median RTW time of 14 weeks after wrist fracture and ligament instability, and of 14 weeks after ulnar shortening.[3] Data on RTW after TFCC injury are scarce.

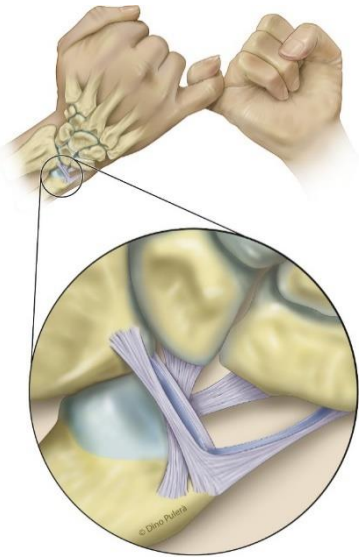

Figure 1. The triangular fibrocartilage complex (© Dino Pulerà).

Since productivity loss has substantial economic consequences, it is important to understand what factors are involved.[4] The Netherlands is renowned for its social welfare system. Paid leave in case of illness was introduced in 1929, following a previous law as early as June 5th, 1913.[5] To enable comparison with other societies, it is important to be aware of some of the details of this system. At the time of the present study, the system was as follows:

- The employer usually pays 100% of the full wages for year 1 and 70% for year 2, and the wage cannot be lower than the official minimum wage.
- The employer is required to provide replacement activities and/or do as much as possible to enable the employee to return to work within these 2 years, or else risk a fine (1-year salary costs) on top of paying the 2 years' wages.

Therefore, the aims of the present study were firstly to describe RTW after open TFCC repair, secondly to identify factors influencing time to RTW after open TFCC repair, and thirdly to calculate the costs of productivity loss.

PATIENTS and METHODS

The Erasmus University Medical Center, Rotterdam, the Netherlands' review board approved our study protocol (NL/sl/MEC-2018-1088). All patients provided written consent for their data to be used in this study. Our institution comprises 18 clinics with 23 surgeons certified by the Federation of European Societies for Surgery of the Hand (FESSH) and has over 150 hand therapists.

Patients

We included patients in paid employment, who underwent open TFCC surgery, and who provided RTW information at least once. Patients who failed to complete questionnaires at baseline were excluded. This study reports prospectively gathered data in a consecutive cohort of patients treated in daily hand surgery practice.

Usually, the indication for open TFCC reinsertion is a foveal tear with instability of the distal radioulnar joint (DRUJ).[6] Management of ulnar-sided wrist problems followed specific steps. Briefly, conservative treatment was initiated by short immobilization, followed by a rigorous program of wrist exercise. If symptoms persisted longer than 3 months, and instability of the DRUJ was evident, and if clinical symptoms and/or radiographs with a flake or non-union of the ulnar styloid process were present, direct open repair of the TFCC was considered. In all other cases, arthroscopy or magnetic resonance imaging (MRI) of the wrist was performed to confirm a TFCC injury. Arthroscopy findings were scored using the Palmer classification.[7]

Data collection was part of routine outcome measurement using GemsTracker electronic data capture tools.[8] Patients were invited after their first consultation with a surgeon.

GemsTracker (Generic Medical Survey Tracker) is a secure web-based application for the distribution of questionnaires and forms in clinical research and quality registrations. The clinical and research setting of our study group is described in more detail elsewhere.[9] Data were collected at Xpert Clinics, the Netherlands, between December 2013 and December 2018.

Data collection

Baseline characteristics (age, gender, occupational status, duration of complaints, Patient-Rated Wrist Evaluation (PRWE) total score and hand dominance) were collected before initiating treatment.[10] Three levels of physical intensity of work were defined: light (e.g., office job), moderate (e.g., shop), and heavy (e.g., construction site). A hand therapist entered this information after the diagnosis was made during the consultation. Patients in paid employment were invited to complete a 'return to work'-questionnaire at 6 weeks, 3 months, 6 months, and 12 months after treatment (Table 1).

Table 1: Return-to-work questionnaire.

Patients were asked if they returned to work and were given the following answer options:
1. Yes.
2. No, because of the hand/wrist problem I am currently being treated for.
3. No, because of something else.
If 'Yes', patients were asked the following five questions (translated from Dutch):
- How many hours per week do you usually work (according to your work contract)?
- How many hours per week are you currently working?
- How many weeks after starting your treatment did you return to your work?
- Are you currently doing your usual work or are (temporary) adjustments made to your work?
- How many weeks after starting your treatment did you return to your usual work?
If patients answered the initial question with 'No, …' (options 2 and 3), no further questions were asked.

Open TFCC reinsertion procedure

Surgeons performed their preferred method of open TFCC reinsertion. Most surgeons use a technique derived from the method of Garcia-Elias et al.[11] All surgeons were hand surgery fellowship trained and FESSH accredited: training level 3–5 according to Tang and Giddins.[12]

Rehabilitation

The general postoperative immobilization protocol consisted of a double-slab plaster of Paris cast for 3–5 days, followed by a forearm volar wrist splint for 6 weeks. Patients were offered an extensive program of hand rehabilitation comprising 6 weeks' active mobilization followed by 6 weeks' strengthening exercises. Immobilization varied slightly in the first week, based on surgeon preference: some chose a sugar-tong or upper-arm cast instead. Patients were followed up by a hand therapist in an outpatient clinic within 1 week after surgery. The cast was removed and a removable long-arm (below-elbow) thermoplastic splint with free motion of the elbow joint was applied. Immobilization was short, as suggested by Garcia-Elias et al.[11] Hand therapists started early active extension and flexion of the wrist 2 weeks after surgery. Our centres for hand surgery and therapy are fully integrated, and postoperative hand therapy was closely monitored and standardized.

Return to work

RTW was defined as the first time a patient reported returning to their original job for a minimum of 50% of the original hours per week as stated in their contract. This excluded adjusted duties as a criterion of RTW. We chose 50% RTW as our primary outcome since Dutch labour laws require patients to be able to perform less than 50% of their original work to be allowed any form of compensation. Surgeons and hand therapists can instruct their patients on type of activity and workload for the upper limb, but not on RTW itself, as this decision is by law the sole responsibility of an independent occupational physician.

Costs of productivity loss

The costs of productivity loss can be defined as "Costs associated with production loss and replacement costs due to illness, disability and death of productive persons, both paid and unpaid".[13] In other words, these are the costs for the employer related to the employee being less productive due to health problems. The human capital method was used to calculate the costs of productivity loss. In this method, any hour that the patient does not work is considered as an hour of lost productivity. The human capital method

multiplies the total working hours lost due to health problems and treatment by the average costs of lost productivity per hour. Total working hours lost due to health problems and treatment was calculated by multiplying the median time to RTW by the patient population's average working hours per week. The average hourly cost of productivity loss was calculated as a weighted mean of the cost of hourly productivity loss for women (32) and for men (38) in the Netherlands[14,15], resulting in 33.80 per hour for our patients. In formula form:

*Total cost of productivity loss per patient = median time to RTW (weeks) * average working hours per week * 33.26.*

To estimate the costs of productivity loss for patients with specific characteristics, additive costs for subgroup compared to costs in the entire cohort were calculated. Median survival was estimated using Kaplan–Meier estimates. Continuous variables were split at the median to create categories for the Kaplan–Meier estimates. To calculate the annual costs of productivity loss for the Dutch population, we used historical data on the prevalence of TFCC surgery. An average of 450 patients per year are surgically treated by TFCC reinsertion in the Netherlands (www.opendisdata.nl). We multiplied the cost of productivity loss by the total number of procedures to get costs at national level.

Statistical analysis

Survival analysis used a Cox proportional hazard model. The dependent variable was time to RTW. The hazard ratio is a comparison between the probability of an event (here, RTW) between two groups. As independent variables, we included age, gender, duration of complaints, dominant side, work intensity and whether surgery was performed in second line. All variables were first plotted in a Kaplan–Meier curve to estimate proportional hazard (i.e., if the hazard lines do not cross). If the hazard lines crossed (i.e., the hazard was not proportional), time-dependent variables were used. For PRWE baseline score, HR was calculated per 10 points. Patients were excluded from further analysis when they reached the age for retirement or reported not returning to work but not completing any additional questionnaires; these patients were included in the analysis until the time they stopped providing RTW information. Computation used R v3.3.4 (R Project for Statistical Computing, Vienna, Austria). A p-value < 0.05 was considered significant.

RESULTS

We performed open TFCC reinsertion in 584 patients. PRWE total score at baseline was obtained in 486 patients, of whom 385 (79%) reported being gainfully employed. We included 310 (81%) patients who responded to the RTW questionnaire (Figure 2). The mean age of the population was 38 years; most patients did light physical work (40%), followed by moderate (35%) and heavy physical work (25%) (Table 2).

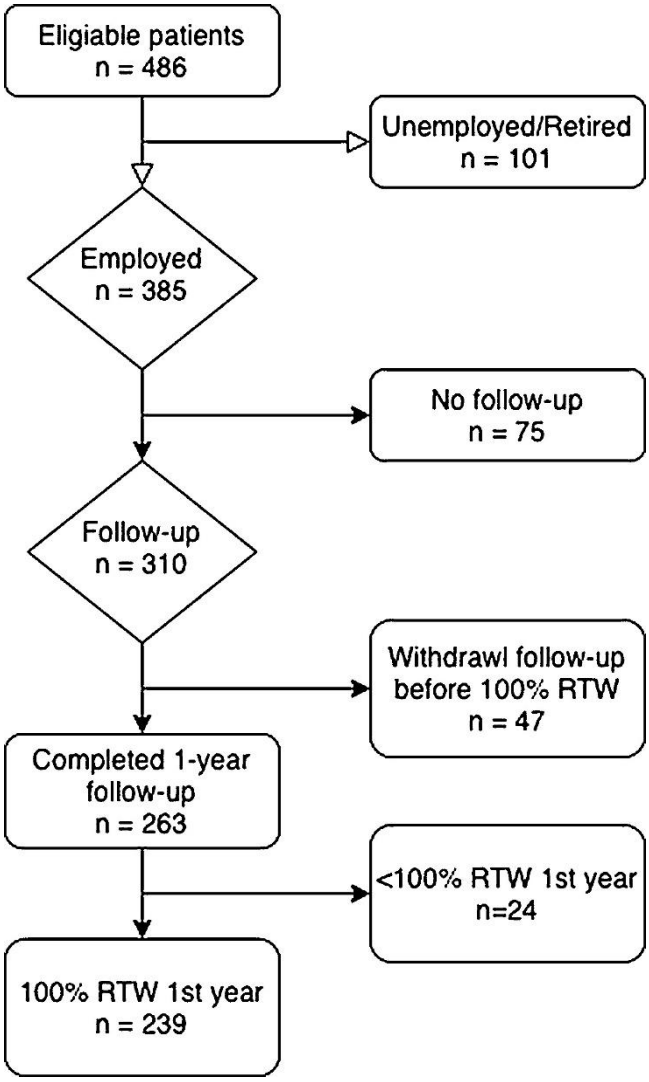

Figure 2. Flowchart: 584 patients underwent open TFCC repair, of whom 486 reported information about their employment; 385 (79%) patients had paid employment at inclusion. 310 completed the return to work (RTW) questionnaire. 47 patients were censored due to withdrawal from follow-up before they returned to work. Return to work is here defined as ≥50% of the original number of hours.

Table2: Demographic details for the 310 included patients.

Included patients	310
Age (mean (SD))	38 (12)
Gender, male (%)	93 (30%)
Dominant side operated on (%)	194 (63%)
Duration of symptoms (months) median (IQR)	9 (4-14)
Body Mass Index (kg/m²) (mean (SD)), n=286	25,3 (3,7)
Non-smoking (%), n=217	172 (79%)
Occupation (%)	
Light physical work (e.g., office work)	125 (40%)
Moderate physical work (e.g., working in a store)	107 (35%)
Heavy physical work (e.g., construction or road work)	78 (25%)

Median RTW time was 12 weeks. 91% of the initial 310 patients returned to work within 12 months. 47 patients were excluded for failing to provide additional information about RTW time. The patients (9%) who did not return to their original job mostly appeared to work a number of hours near the 50% RTW threshold or had work that was adjusted to their residual post-surgery limitations.

Women returned to their jobs later than men, irrespective of work intensity. Median RTW time for men was 8 weeks, versus 13 weeks for females (Fig. 3) (hazard ratio females: 1.58 CI [1.18–2.12], *p*-value = 0.00). Younger patients returned to work sooner than older patients (0.98 CI [0.97–0.99], *p*-value = 0.00). The patients with heavy work (n = 78) took longer to return to their jobs, but overtook all other groups by 12 months, with 95% RTW (Figure 4). At 7 weeks, 50% of the light-work group had returned to their jobs compared to only 11% of heavy workers. At the 12-week mark, 75% of light workers (n = 125), 45% of medium-type workers (n = 107) and only 25% of the heavy workers (n = 78) had returned to their jobs. Patients with a worse preoperative PRWE total score returned to work later (HR 0.91 per 10 points) (Table 3).

The overall annual cost of productivity loss was 13,588 (25%–75%: 6794–22,646) per patient and 6.1 million at Dutch population level (average productivity loss cost times total number of patients in the Netherlands (n = 450). In terms of work intensity, productivity loss cost was 7926 for light work, 16,984 for medium work and 18,116 for heavy work. Average productivity loss cost for males was 9058, compared to 14,719 for females (Table 4).

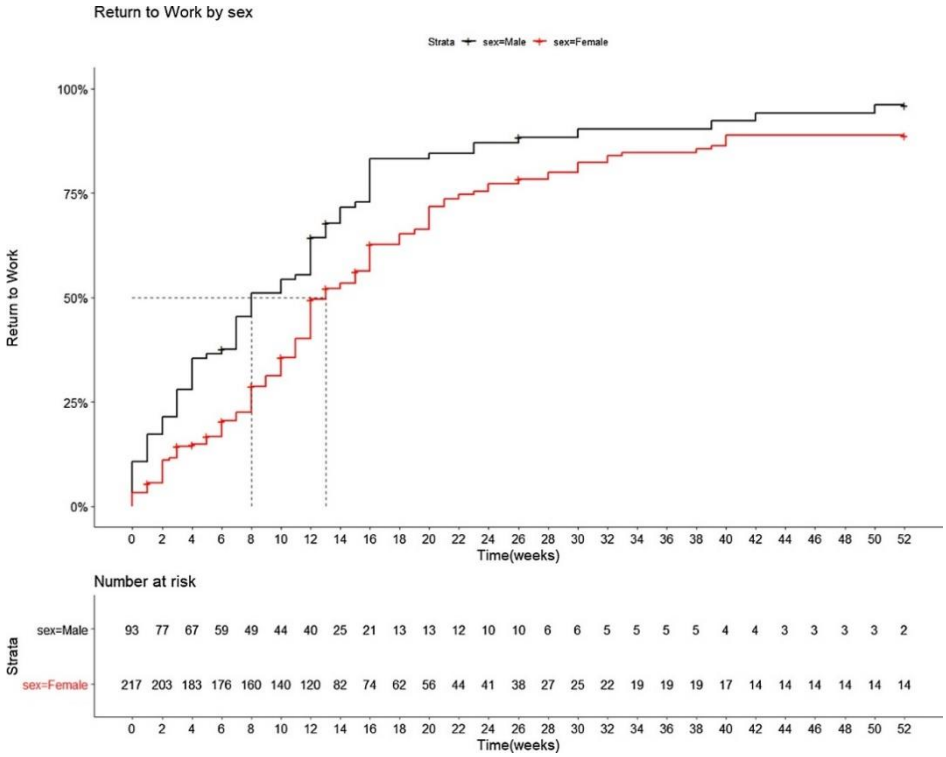

Figure 3. Kaplan–Meier survival plot for return to work after TFCC reinsertion by gender.

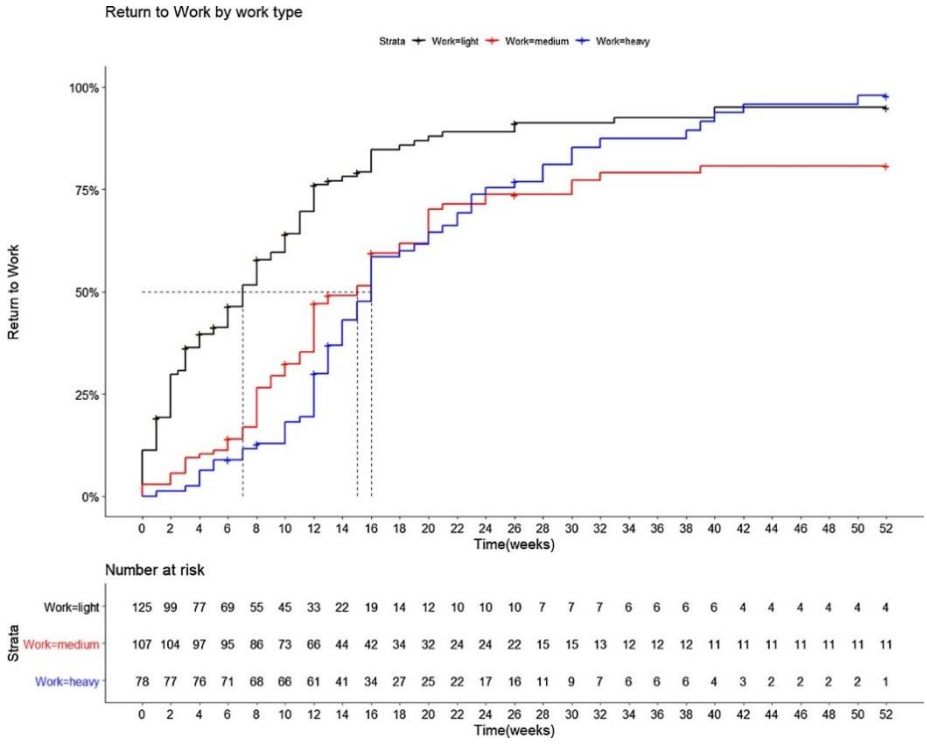

Figure 4. Kaplan–Meier plot for return to work after reinsertion of the TFCC according to work type.

Table 3. COX model for return to work for >50% of the original contract hours, using patient characteristics and hand function scores in PRWE total score [Range: 0–100] before surgery as covariates. A hazard ratio (HR) of 2.0 means that this group is twice as likely to return to work as compared to the other group in the same time period.

	HR	**95%CI**	***p*-value**
Male gender	1.58	[1.18–2.12]	<0.01
Age	0.98	[0.97–0.99]	<0.01
Duration of complaints, Months	1.00	[0.99–1]	0.86
Dominant side treated, Yes	1.00	[0.77–1.31]	0.98
PRWE Total score	0.91	[0.85–0.98]	0.01
Job type 0-15 weeks			
Light	3.74	[2.49–5.61]	<0.01
Moderate	1.44	[0.93-2.24]	0.10
Heavy	Ref	Ref	Ref
Job type 15-23 weeks			
Light	1.40	[0.61–3.18]	0.43
Moderate	0.96	[0.49-1.91]	0.92
Heavy	Ref	Ref	Ref
Job type 23-52 weeks			
Light	0.59	[0.2–1.71]	0.33
Moderate	0.25	[0.09-0.7]	0.01
Heavy	Ref	Ref	Ref

Table 4. Additional costs in euro for patient or disease characteristics. The table displays the costs for each subgroup. Median survival was estimated using Kaplan–Meier estimates. Continuous variables were split at the mean to create categories for the Kaplan–Meier estimates.

	Median RTW time (weeks)	**1y-costs (€)**
Overall	12	13,588
Work intensity		
Light physical labour	7	7926
Moderate physical labour	15	16,984
Heavy physical labour	16	18,116
Gender		
Male	8	9058
Female	13	14,719
PRWE, categorical		
Upper half (Mean = 74)	14	15,852
Lower half (Mean = 45)	11	12,455

DISCUSSION

The present study fills the knowledge gap with respect to RTW and productivity loss cost in a large cohort undergoing open TFCC surgery. We identified age, gender, work intensity and baseline PRWE score as factors for RTW time after open surgery of the TFCC. In addition, we estimated productivity loss cost at €13,588 (25%–75%: 6,794–22,646) per patient.

RTW has previously been studied in specific hand-trauma populations. After scaphoid or distal radius fracture, RTW time was 5 weeks according to Neutel et al.[16] To zoom in on elective hand surgery, ulnar shortening seems the most comparable diagnosis. According to Sunil et al., patients took 14 weeks to return to work after ulnar shortening.[17] The present median RTW time was 12 weeks, thus comparable to the time after ulnar shortening. We hypothesize that with modern plating techniques patients should return to work sooner than with ligament reinsertion, as repair requires more time to heal and to resist forces associated with loading and rotation.

In agreement with the paper by Neutel et al.[16], we found large differences between subgroups. The strongest predictor for RTW was type of work; light work showed a hazard ratio of 3.74 in the first 15 weeks. In the present study, females outnumbered males and took on average 60% longer to return to work. In Neutel et al.'s study of RTW after hand trauma[16], the hazard ratio for gender was 1.61; in the present study, it was 1.58. As this patient group comprised a wide range of types of hand injury, gender could be expected to be a prognostic factor for RTW, irrespective of type of hand surgery. The sex ratio was in line with the general gender distribution in our hand surgery practice, where only Dupuytren's disease is more common in males. In contrast with the findings of Neutel et al.[16], we did not find a significant hazard ratio for hand dominance or duration of symptoms. Age (hazard ratio 0.98) and baseline PRWE score (hazard risk 0.91 per 10 points) both proved to be significant prognostic factors. Thus, more self-reported pain and disability before treatment resulted in longer RTW times. Prognostic factors for RTW after an episode of lower back pain are diverse and include clinical, psychosocial, socioeconomic and claim-related factors according to a large review study.[18] Prognostic factors for RTW after wrist surgery could prove to be as various as for lower back pain.

Cost of productivity loss was another important endpoint in the present study. Unfortunately, the gender income gap is still present in the Netherlands; therefore, we used the actual average wage corrected for gender. The overall productivity loss cost per

patient was 13,588. Several studies reported costs related to return to work after elective hand surgery.[19,20] In earlier studies carried out by the Hand/Wrist Study Group, we determined that productivity loss cost per patient in partial fasciectomy in Dupuytren's disease was 2,638[21], and in surgical treatment of thumb base osteoarthritis was 11,574.[22] In comparison, productivity loss after open TFCC is costly and this should weigh in the decision-making process. The substantial costs associated with surgery should be weighed against alternative treatments where possible. The debate as to whether the TFCC should be performed by open or arthroscopic surgery is ongoing and a comparative review study failed to show significant differences in outcome.[6] Since there are no differences in outcome, it might be assumed that this rules out differences in productivity loss cost. However, abstention from surgery is also an option and is by default less costly, but this may be outweighed by continuing absenteeism due to persistent symptoms. It is important for both surgeon and patient to be aware of the consequences of the decision to operate. Apart from the consequences for an individual, society as a whole needs to be informed of the total costs involved. TFCC reinsertion in itself is an infrequent procedure, but we still estimated 6.1 million as the yearly cost for the Dutch population.

This study had some strengths and weaknesses. The strengths were the large sample size and comparison between different levels of work intensity. One limitation was that we were unaware of to what extent surgeons made recommendations on the sick leave to be given. Surgeons gave instructions to their patients on specific types of task and lifting and carrying, but gave no specific advice on return to work. The reason for this is that in our country independent occupational physicians are responsible for instructions allowing returning to and type of work. In addition, the estimated costs in this study may underestimate the actual economic burden because we included only absenteeism and did not take diminished functioning at work into account. Finally, the calculated costs are not easily comparable with other studies on productivity costs, since some used hourly wages as cost per hour instead of the total cost to the employer.[19] To make our results more easily comparable to other studies, we reported both costs and weeks of sick leave. Definitions of RTW vary, making results in other papers and other countries less suitable for comparison.

While we found several prognostic factors for RTW, many aspects are still unknown. For example, future research should focus on identifying psychosocial factors such as pain catastrophizing that may influence RTW. Identifying psychosocial factors that contribute to longer RTW time could guide psychosocial interventions to reduce the indirect costs

of surgery. Hand surgeons can use these results to optimize consultation. Determining optimal treatment timing might reduce the length of sick leave after surgery.

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CHAPTER 7

Outcomes of combined treatment of ulnar impaction syndrome and scapholunate dissociation using a single-stage procedure

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Submitted

ABSTRACT

Aims: To evaluate the outcomes of single-stage ulna shortening osteotomy and three-ligament tenodesis in patients with combined ulna impaction syndrome and scapholunate dissociation.

Methods: Fifty-three patients treated between 2012 and 2020 were included. Patients were monitored for 12 months after surgery using routine outcome measurements, including the Patient Rated Wrist Hand Evaluation (PRWHE), return to work, acute postoperative pain, grip strength, and range of motion. Furthermore, complications were scored.

Results: The PRWHE improved in the first 12 months after surgery (difference in means: 33; 95% confidence interval [25–41], $p<0.001$). After 12 months, the average grip strength was 90% of the contralateral side. The median return to work was 15 weeks, and the average acute postoperative pain score was 7 (range 0–10). There were no cases of infection, non-union, or complex regional pain syndrome. Hardware was removed in 19/53 patients (36%), and no other reoperations were performed in the study period.

Conclusion: Single-stage ulna shortening osteotomy and three-ligament tenodesis is safe and provides satisfactory outcomes in patients with ulna impaction syndrome and scapholunate dissociation.

Clinical relevance and take-home message

- The outcomes of single-stage ulna shortening osteotomy and three-ligament tenodesis in patients with combined ulna impaction syndrome and scapholunate dissociation are satisfactory.
- We propose to combine these procedures to avoid two subsequent surgeries.

INTRODUCTION

A dilemma arises when a patient presents with two common wrist disorders combined. What should we treat first, or should we combine two procedures into one surgical treatment? Ulna impaction syndrome (UIS) and scapholunate dissociation (SLD) are common causes of chronic wrist pain, and multiple treatment options exist for these pathologies. A common surgical procedure for UIS is an ulna shortening osteotomy (USO), while for SLD, a ligament reconstruction such as the three-ligament tenodesis (3LT) is the procedure of choice.[1] Studies regarding the treatment outcomes of USO and 3LT have mainly focused on isolated treatment of UIS or SLD, and generally demonstrated good mid- to long-term outcomes.[2–4]

UIS and SLD can coexist after upper extremity trauma, such as in a "fall on outstretched hand" (FOOSH) injury.[5] In this instance, surgeons are challenged with what pathology to treat first or whether both pathologies can be addressed in one procedure. Studies concerning the treatment of patients with coexisting UIS and SLD is scarce. We found one case report from 2020 reporting a successful single-stage USO and 3LT.[5] Combining these procedures might successfully address both pathologies, achieving a more satisfactory outcome, and avoid sequential procedures that might lead to extended rehabilitation and additional healthcare costs. On the other hand, safety risks should be considered; for example, a more extensive surgery might be associated with a higher incidence of complications or a more prolonged and painful recovery. Therefore, more data on the recovery phase of single-stage USO and 3LT for patients with coexisting UIS and SLD is needed.

We aimed to investigate whether a single-stage USO and 3LT procedure can improve patient-reported pain and function in patients with combined UIS and SLD, and to evaluate recovery in terms of complications, acute postoperative pain, return to work, grip strength, and range of motion.

PATIENTS AND METHODS

Study setting

This study used data from the Hand and Wrist Cohort that is routinely collected during daily practice at Xpert Clinics (The Netherlands).[6] Xpert Clinics is a multicentre institution in the Netherlands specialising in hand and wrist surgery. All patients who visit the institution are invited to be part of a routine outcome measurement registry after their first consultation with a hand surgeon. Upon agreement, they receive secure web-based questionnaires and undergo hand measurements before and at predefined timepoints after surgery using GemsTracker (Rotterdam, The Netherlands).[7] PROM collection was used for real-time patient monitoring, and this study makes secondary use of this data. The exact research setting, patient assessment, and follow-up regimens of the data collection have been reported previously.[6,8]

Study design

We conducted a multicentre retrospective analysis to evaluate the routine outcomes of single-stage USO and 3LT for patients who presented with coexisting UIS and SLD. This study is reported using the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.[9] All patients provided written informed consent for their data to be anonymously used in this study. The local Medical Research Ethical Committee approved the study protocol.

Patients

Based on treatment codes, we identified all patients who underwent single-stage USO and 3LT between February 2012 and July 2020 in the Hand and Wrist Cohort database. Fifty-three patients were identified. The diagnoses of UIS and SLD were based on clinical symptoms, X-ray, MRI, and/or wrist arthroscopy based on surgical preference. Radiographs of both wrists, in a neutral wrist position with a clenched fist, and PA views with the wrist in ulnar deviation, were evaluated for ulnar variance, subchondral cysts in the lunate or triquetrum, and SLD. An MRI was evaluated for focal abnormal signal intensity in the lunate, triquetrum, and ulnar head.[10,11] Wrist arthroscopy was performed to evaluate the status of the ulnar carpus and TFCC using the Palmer classification, and

the status of the SL ligament using the Geissler classification.[12,13] No exclusion criteria were applied for this study.

Surgical procedure

A total of eight surgeons performed the single-stage procedure; 37 of the 53 procedures (70%) were performed by a single surgeon (O.T.Z.). All hand surgeons were either hand fellowship-trained and/or certified by the Federation of European Societies for Surgery of the Hand. Surgeon experience levels ranged from level III to IV, according to Tang and Giddens.[14] Surgery was performed under a regional axillary or supraclavicular block.

The USO was performed using an oblique cut at the level of the diaphysis, and the plate was generally placed 3 cm distal to end of the ulna. The number of millimetres resected depended upon the preoperative ulnar variance. Surgeons used their preferred method for USO, which comprised dedicated osteotomy-guided jigs (Acumed®, Hillsboro, OR; or RECOS®, KLS Martin, Tuttlingen, Germany) or a freehand technique (AO, Davos, Switzerland).

The 3LT was performed according to the described technique by Garcia-Elias[1]; a full description can be found in the supplementary file (Supplementary file; Appendix A). All steps for the 3LT were prepared, the USO performed, and the ligament reconstruction subsequently finished. A volar cast with pronation and supination blockage was applied.

Postoperative pain control

For postoperative pain control, patients were prescribed paracetamol (1,000 mg), naproxen (500 mg), pantoprazole (40 mg), and oxycontin (10 mg). Patients who could not bear oxycontin were given tramadol (50 mg).

Rehabilitation

At our institution, hand therapy is fully integrated (Xpert Handtherapy). The postoperative immobilisation protocol consisted of plaster cast immobilisation for 3–5 days, followed by a thermoplastic orthosis until 5–6 postoperative weeks. For wrist flexion and extension, the 3LT protocol was used, whereas the USO protocol was followed for wrist supination and pronation. Standard radiographs were taken at 3 and 12 months postoperatively to assess bony union; additional radiographs were made on indication (e.g., in case of delayed union, non-union, or trauma). Plate removal was considered based on patient-based symptoms or clinician-based arguments following complete consolidation on the x-ray.[15–17] The postoperative protocol is shown in Table S1.

Variables and outcomes

Variables available in the database include age, sex, type of work, symptom duration, treatment side, and hand dominance. In addition, electronic patient files were screened for previous injury, diagnostic workup (X-ray, wrist arthroscopy, and/or MRI), operative variables (plate type and position, amount of ulna resected), and complications.

Patient-reported pain and hand function

Patients were asked to complete the Dutch-language version of the Patient Rated Wrist/Hand Evaluation (PRWHE) before and at 3 and 12 months after surgery, by email.[18] The PRWHE is a validated and responsive patient-derived questionnaire to evaluate the treatment outcomes of UIS.[19,20] The total score ranges from 0 (“no pain or dysfunction”) to 100 (“severe pain or dysfunction”). Patients were also asked to complete the Visual analogue scale (VAS; range 0–100; higher scores indicated more pain) to measure pain during load bearing at intake and at six weeks, three months, six months, and 12 months.[21] Furthermore, a nurse recorded the acute postoperative pain level 24 hours after surgery over the phone using the Numeric Pain Rating Scale (NPRS; range: 0–10; higher scores indicate more pain). The NPRS is a valid and reliable instrument for measuring pain intensity.[21]

Grip strength and range of motion

A hand therapist measured the active range of motion (ROM) and grip strength before and at three and 12 months after surgery. The ROM was measured in degrees from neutral using a goniometer according to the International Consortium for Health Outcome Measurement (ICHOM) guidelines.[22] Wrist flexion, radial deviation, and pronation were reported as positive values; wrist extension, ulnar deviation, and supination, as negative. Grip strength was measured using an E-LINK Jamar-Style dynamometer (Biometrics, Newport, UK) as per Mathiowetz et al.[23]

Return to work

Return to work (RTW) was measured at six weeks, three months, six months, and 12 months in a subgroup of patients who had paid work before surgery (Supplementary file; Appendix B). We defined RTW as the first time (in weeks) since surgery that the patient performed their original work for at least 50% of the contractual hours. We chose 50% RTW as our primary outcome, since Dutch labour laws require patients to be able to perform less than 50% of their usual work to be allowed any form of compensation.[24,25]

Complications

Complications were scored following the ICHOM Complications in Hand and Wrist conditions (ICHAW) classification (Table S2).[26] This tool classifies complications within 12 months after surgery into different grades (I–III) based on the treatment required. When a complication is not sufficiently relieved with minimally invasive treatment and more invasive treatment is given, only the highest-grade complication is reported. Complex regional pain syndrome (CRPS) was evaluated using the Budapest criteria.[27,28]

Sample size and statistical methods

The number of patients treated during the study period determined the sample size. Descriptive statistics were presented as mean values, including standard deviations (SD) or 95% confidence intervals (CI) for continuous data, and counts with percentages for

categorical data. Time-to-event data (RTW) were described using inverted Kaplan–Meier curves.

We used linear mixed models to evaluate the change of repeated measured outcomes (PRWHE, VAS pain, grip strength, and ROM) over time. The fixed effect in these models was the timepoint and the random effect was the patient. Only patients with baseline and at least one follow-up score were included in the models. Estimated marginalised means (EMMs), including 95% CI, were calculated for each time point, and compared post hoc. Missing data were not imputed, as this does not provide additional value to linear mixed models.[29] We investigated if a violation of the model following assumptions existed for all linear mixed models: linearity; homoscedasticity; and normality of residuals. For all analyses, a p-value ≤ 0.05 was considered significant. R statistical programming version 3.6.3 was used for all analyses.

RESULTS

The study population consisted of 53 patients (29 males, 54%) with a mean age ± SD of 45 ± 14 years. Symptoms had been present for a median of 9 months [IQR: 6, 24] before surgery. Demographic, diagnostic, and surgery-related characteristics are presented in Table 1.

Patient-reported pain and hand function

Thirty-eight patients (72%) provided PRWHE and VAS pain scores before and after surgery. The mean improvement in the PRWHE total score between intake and 12 months was 33 (CI [25–41], p<0.001); improvement was seen in both subscales of the PRWHE (p<0.001). The mean improvement in VAS pain under load bearing was 40 (CI [30–49], p<0.001). The EMMs, including CI, for every time point are shown in Table 2. Most improvement in patient-reported pain and function was found in the first three months after surgery. The NPRS score was recorded in 39/53 patients (74%). The median NPRS score at 24 hours after surgery was 7 (IQR [6–8]; min, 0; max, 10).

Active ROM and grip strength

ROM and grip strength were recorded in 25 patients (47%) before and after surgery. After an initial decrease in grip strength of the operated wrist from 32 kg ([26–37]) at intake to 26 kg ([20–31]; p=0.002) at three months, the grip strength improved to 35 kg ([29–41]; p=0.131; Table 2). At 12 months after surgery, the grip strength was 90% of the unoperated side (39 kg; [33–46]). Between intake and three months, decreases were seen in wrist flexion, wrist extension, ulnar deviation, radial deviation, and supination (Table 2). At 12 months after surgery, the ROM was similar to intake.

RTW

Forty patients (75%) had paid work prior to surgery and were eligible for the RTW analysis, of which 31 (78%) provided data. The cumulative incidence of RTW at 12 months was 65% (CI [42–80%]). The median time until RTW was 15 weeks (CI: 10–NA weeks; Figure 1). Twelve patients did not meet the RTW criteria at their last response: 10 patients performed adjusted work for a median of 100% of their contractual working hours (min, 63%; max, 100%); and two performed their original work for 5% and 32% of the working hours, respectively (Table 3).

Table 1. Characteristics of the study population.

Characteristics	Value
Patient-related	
n	53
Age, mean (SD)	45 (14)
Sex = Males, n (%)	29 (55%)
Duration of symptoms, median [IQR]	9 [6–24]
Type of work, n (%)	
None	13 (25%)
Light	12 (23%)
Medium	13 (25%)
Heavy	15 (28%)
Dominant side affected = Yes, n (%)	35 (66%)
Trauma documented = Yes, n (%)	50 (93%)
Diagnostic-related	
X-ray performed = Yes, n (%)	46 (87%)
Wrist arthroscopy performed = Yes, n (%)	50 (90%)
Palmer classification	
2A	13 (26%)
2B	18 (36%)
2C	14 (28%)
2D	1 (2%)
2E	4 (8%)
Geissler classification	
I	0 (0%)
II	0 (0%)
III	17 (34%)
IV	33 (66%)
MRI performed = Yes, n (%)	8 (15%)
Surgery-related	
Plate, n (%)	
Acumed	42 (79%)
Synthes	6 (11%)
Recos	5 (9%)
Bone anchor, n (%)	
JuggerKnot	20 (38%)
Mitek	20 (38%)
Parcus	10 (19%)
Unknown	3 (6%)
Plate position = Dorsal, n (%)	42 (80%)
Ulna shortening (mm), median [IQR]	4 [3–4]
Intervention = Concomitant, n (%)	
None	24 (45%)
ECU loop	26 (50%)
CTR and TFCC repair	1 (2%)
CMC-1 arthroplasty	1 (2%)
Pisiformectomy	1 (2%)

Abbreviations: SD, Standard deviation; IQR, Interquartile range; ECU, Extensor carpi ulnaris; CTR, Carpal tunnel release; TFCC, Triangular Fibrocartilage Complex; CMC-1, Carpometacarpal-1

Table 2. Estimated marginalised means including 95% CI at all timepoints.

	Intake	3 months	12 months	Δ intake – 3 months	Δ intake – 12 months
Patient-reported					
PRWHE total score	70 [63 to 77]	48 [41 to 55]	37 [29 to 44]	22 [14 to 29]	33 [26 to 41]
PRWHE function	34 [30 to 38]	24 [20 to 28]	18 [13 to 22]	10 [6 to 14]	16 [12 to 21]
PRWHE pain	36 [33 to 39]	24 [20 to 27]	19 [15 to 23]	12 [8 to 16]	17 [13 to 21]
VAS pain activity	75 [68 to 82]	49 [42 to 57]	35 [27 to 44]	26 [17 to 35]	40 [30 to 49]
Clinician-reported					
Grip strength operated wrist	32 [26 to 37]	26 [20 to 31]	35 [29 to 41]	-6 [-10 to -3]	4 [-1 to 8]
Grip strength contralateral wrist	37 [30 to 43]	39 [33 to 46]	39 [33 to 46]	3 [0 to 5]	3 [0 to 6]
Wrist flexion	50 [44 to 55]	35 [29 to 40]	49 [42 to 56]	-15 [-22 to -9]	-1 [-8 to 7]
Wrist extension	-54 [-58 to -50]	-45 [-49 to -41]	-57 [-62 to -52]	10 [4 to 14]	-2 [-8 to 3]
Supination	74 [70 to 78]	66 [62 to 71]	73 [67 to 78]	-7 [-11 to -3]	-1 [-6 to 4]
Pronation	-76 [-80 to -73]	-74 [-78 to -70]	-75 [-80 to -71]	2 [-2 to 7]	1 [-5 to 6]
Radial deviation	20 [17 to 22]	15 [12 to 17]	16 [13 to 19]	-5 [-7 to -2]	-3 [-7 to 0]
Ulnar deviation	-26 [-28 to -23]	-20 [-23 to -18]	-25 [-28 to -21]	5 [1 to 9]	1 [-3 to 5]

Abbreviations: PRWHE, Patient Rated Wrist/Hand Evaluation; VAS, Visual analogue scale.

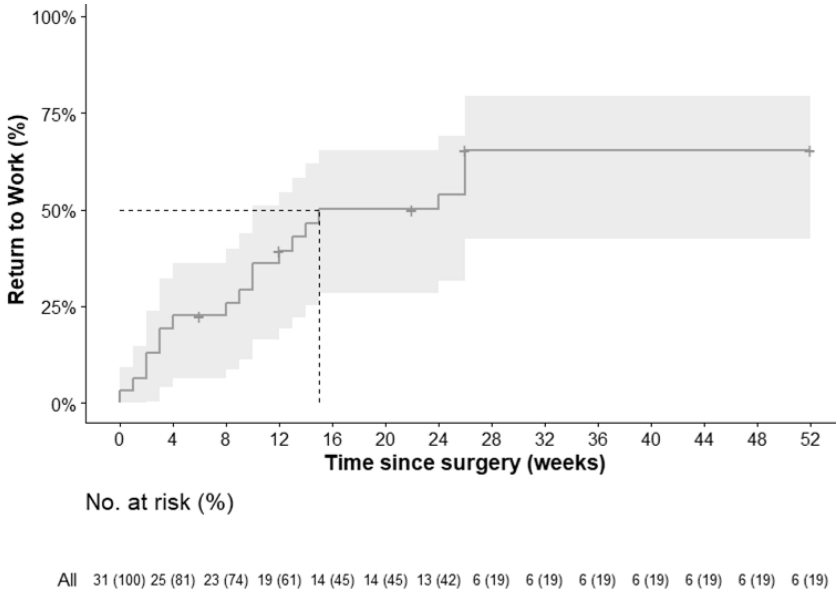

Figure 1. Kaplan–Meier curve for the return to usual work (RTW) after ulna shortening osteotomy and three-ligament tenodesis, including 95% confidence interval. The "+" denote the time points where patients were censored. The median RTW was 15 weeks, and the cumulative incidence after 12 months was 65%.

Table 4. Complications after single-stage ulna shortening osteotomy and three-ligament tenodesis graded following the International Consortium for Health Outcomes Measurement (ICHOM) guidelines.

Complication	Value
No complication	24 (45%)
Grade I	
Scar adhesion	1 (2%)
Hardware irritation	2 (4%)
Hand therapy for ECU tendinitis	3 (6%)
Persistent wrist pain	1 (2%)
Opioids, prednisone, and hand therapy for a polytendinitis	1 (2%)
Expectative treatment after for 3LT failure after FOOSH with proximal humerus fracture (treated elsewhere)	1 (2%)
Grade II	
Corticosteroid injections for tendinitis dig III and dig IV	1 (2%)
Grade IIIB	
Hardware removal due to patient-reported irritation	19 (36%)

Abbreviations: ECU, Extensor carpi ulnaris; 3LT, three-ligament tenodesis; FOOSH, fall on outstretched hand

Table 3. Details of patients who had not returned to their original work (RTW) for at least 50% of their original working hours at their last response after surgery.

Patient	Sex	Age	Type of work	Last response to RTW questionnaire (weeks)*	Type of work	Original working hours	Current working hours	Percentage of original working hours
1	M	28	Heavy	52	Adjusted	60	60	100%
2	M	49	Moderate	52	Adjusted	40	40	100%
3	M	24	Moderate	52	Adjusted	24	24	100%
4	M	49	Heavy	52	Adjusted	33	33	100%
5	F	47	Heavy	26	Adjusted	40	40	100%
6	M	60	Heavy	26	Adjusted	36	36	100%
7	M	27	Light	6	Adjusted	40	40	100%
8	M	56	Light	52	Adjusted	40	30	75%
9	M	61	Light	26	Adjusted	28	20	71%
10	F	45	Moderate	52	Adjusted	32	20	63%
11	F	51	Light	12	Original	38	12	32%
12	F	48	Light	22	Original	40	2	5%

*The RTW questionnaires were sent at six weeks, three months, six months, and 12 months after surgery.

Complications

Complications in the first 12 months after surgery were noted in 29 patients (55%): 9 patients had a grade I complication; one patient, grade II; and 19 patients, grade IIIB (all hardware removal was due to irritation; 3/11 volar plates and 16/42 dorsal plates) (Table 4). There were no reports of infection, postoperative bleeding, non-union, or CRPS.

DISCUSSION

Some patients present with coexisting UIS and scapholunate dissociation (SLD). There is a paucity in the literature concerning the optimal treatment strategy and subsequent outcomes for these patients. In this study, we investigated the outcomes of 53 patients with this combined pathology who were treated by a single-stage procedure of USO and

three-ligament tenodesis (3LT). We found that a single-stage procedure of USO and 3LT can result in favourable outcomes for patients with UIS and SLD.

We found improved patient-reported pain and hand function in the first 12 months after surgery. Using the PRWHE, the mean improvement was 33 points on a scale from 0 to 100. This is comparable to the improvement after USO for UIS or 3LT for chronic scapholunate injury (mean improvement of 32 and 31 points, respectively).[2,4] While the improvement after surgery is comparable, patients with combined pathology seemed to have slightly more pain and dysfunction before surgery and at 12 months after surgery than patients who underwent USO or 3LT in the absence of the other (Table 5). The median acute postoperative pain score 24 hours after surgery was 7 (possible range 0–100). This is comparable to other hand and wrist procedures, such as metacarpophalangeal arthroplasty (score of 6), hand resection arthroplasty (6), and arthroscopic surgery of the wrist (6).[30] We conclude that the median acute postoperative pain is acceptable; however, adequate pain monitoring and management is advised.

Grip strength initially decreased in the first three months after surgery and was similar to preoperative levels after 12 months. The same pattern was seen for active ROM, in which most impairments were found in wrist flexion and extension at three months after surgery. This reflected the rehabilitation regime patients followed with the hand therapist and improved between three and 12 months after surgery.

All patients were able to perform either their original or adjusted work within the 12 months after surgery. The median time until RTW after single-stage USO and 3LT was 15 weeks. The duration until RTW appears longer than in previous studies on USO and open TFCC repair [24,25] which both had a median of 12 weeks. However, when considering that these patients would undergo a USO and 3LT sequentially (24 weeks in total), combining the two procedures in a single-stage procedure might prove the more cost-effective option.

Using the newly developed ICHAW classification system,[26] we noted that complications occurred in 55% of patients. This complication rate might seem quite high; however, we argue that this might be due to the transparent classification system, originally adapted from the Clavien–Dindo classification in general surgery,[31] which also considers milder complications that might otherwise be overlooked. In a previous study, for example,[2] a 64% complication rate was found in patients who underwent USO without additional ligament reconstruction using the ICHAW classification. To the best of our knowledge,

the complication rate of solitary 3LT has not yet been reported using the ICHAW. No reoperations, other than hardware removal due to patient-reported irritation, occurred on the affected wrist within 12 months after surgery. Hardware removal seems to be the most common reoperation after surgery.[2,3,32,33] A previous study found that volar plate placement was associated with a reduced instantaneous risk of 38% compared to dorsal placement.[17] Using a volar approach might reduce the future reoperation rate. When we regard hardware irritation and subsequent removal as a common part of the treatment instead of a complication, the complication rate drops to 8%. Also, there were no cases of infection, non-union, or CRPS in our cohort. We conclude that single-stage USO and 3LT does not seem to increase the complication rate compared to USO alone.

Our study has some limitations. First, while all patients remained in regular follow-up, there were missing data in both the patient-reported and clinician-reported outcomes, which might have made our findings less generalisable to the entire patient cohort. To avoid missing any patients with a complicated treatment course, we also evaluated the records of patients who did not respond to the questionnaires for complications. Second, we could not identify patients who had coexisting UIS and SLD and either received USO or 3LT alone. The Hand and Wrist Cohort is based on treatment rather than diagnosis.[6] Therefore, we could not determine whether a single-stage procedure was required for every patient presenting with coexisting UIS and SLD, or whether starting with either USO or 3LT is adequate for some patients. With the recent implementation of ICHOM in our registry, comparing different treatment regimens based on surgical preference might be possible and will be a focus of future research.

In conclusion, single-stage USO and 3LT is safe to perform and provides favourable outcomes in patients with UIS and SLD; therefore, we advise combining treatment into a single-stage surgery as opposed to two subsequent surgeries.

Table 5. Mean patient rated wrist/hand evaluation scores of patients who single-stage underwent ulna shortening osteotomy (USO) and three-ligament tenodesis (3LT) compared with patients who underwent either USO or 3LT.

Study	Pathology	Intervention	Mean PRWHE total score (standard deviation)	
			Intake	12 months
Current	Ulna impaction syndrome with scapholunate dissociation	USO + 3LT	70 (22)	37 (24)
Teunissen et al.[2]	Ulna impaction syndrome	USO	64 (18)	32 (23)
Blackburn et al.[4]	Chronic scapholunate injuries	3LT	57 (10)	26 (21)

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SUPPLEMENTARY MATERIALS

APPENDIX A

Description of the 3LT procedure

The extensor retinaculum was divided over the third compartment, and a dorsal capsulotomy was made following Berger and Bishop.[34] A posterior interosseus nerve neurectomy was performed as a standard proximal to the joint. The proximal row was exposed, and the SL joint was inspected. A preliminary K-wire was over drilled with a 2.7-mm drill burr entering the proximal and dorsal scaphoid. The tunnel follows the longitudinal axis of the scaphoid, aimed at the palmar tuberosity. A longitudinal strip of the FCR was then passed through the scaphoid from volar to dorsal, and fixed to the lunate with a bone anchor (Mitek, Raynham, MA; JuggerKnot Soft Anchor, Zimmer Biomet, Warshaw, IN; Parcus, Anika Therapeutics, Bedford, MA). We did not use K-wires to protect the reconstruction. The capsule was closed with Vycril 3.0/4.0, and the skin with Monocril 3.0/4.0.

APPENDIX B

Return to work questionnaire

Patients were asked whether they had returned to work, and were given the following answer options: (1) Yes; (2) No, because of the hand/wrist problem I am currently being treated for; (3) No, because of something else.

If they answered "Yes," patients were asked the following five questions (translated from Dutch):

1) How many hours per week do you usually work?
2) How many hours per week are you currently working?
3) How many weeks after your initial surgery did you return to your work?
4) Are you currently doing your regular work or are (temporary) adjustments made to your work?
5) How many weeks after starting your initial surgery did you return to your original work?

If patients answered "No" to the initial question (option 2 or 3), no further questions were asked.

APPENDIX C

List of abbreviations

3LT	Three-ligament tenodesis
FCR	Flexor carpi radialis
ICHOM	International Consortium for Health Outcome Measurement
IQR	Interquartile range
PRWHE	Patient rated wrist/hand evaluation
NPRS	Numeric pain rating scale
ROM	Range of motion
RTW	Return to work
SD	Standard deviation
SLD	Scapholunate dissociation
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
TFCC	Triangular fibrocartilage complex
UIS	Ulna impaction syndrome
USO	Ulna shortening osteotomy
VAS	Visual analogue scale

Table S1. Postoperative therapeutic regime after single-stage ulna shortening osteotomy and three-ligament tenodesis.

Time	Postoperative regime
Day 0	A plaster cast is applied after surgery (including wrist and/or elbow) Start tendon gliding exercises fingers and thumb Sling Day 3-5 consult with hand therapist for removal of bandage and plaster cast and wound inspection Thermoplastic wrist orthosis (day and night) or sugar-tong (surgical preference)
Week 1–2	Start AROM fingers and thumb Start AROM wrist extension (maximum of 40 degrees) Start AROM supination and pronation (maximum of 30 degrees) On indication oedema control (Coban) Day 10-14 suture removal Start hand therapy 2-3 times weekly Warning: no maximal wrist positions and no heavy load bearing Start scar management
Week 3–4	Optimisation AROM fingers and thumb (tendon gliding exercises) Start AROM palmar flexion (maximum of 20 degrees) Optimisation AROM supination and pronation Warning: no maximal wrist positions and no heavy load bearing Intensify AROM wrist
Week 5–6	Start exercises on coordination and stability Phase-out orthosis Warning: no maximal wrist positions and no heavy load bearing Intensify AROM wrist
Week 7–12	Start exercises on coordination, stability, and strength Increase load bearing and functionality Phase-out orthosis; Intensify range of motion wrist/forearm
Month 3–6	Phase-out orthosis during load bearing activities Power training, stability training
Month 7–12	On indication optimisation of function

Abbreviations: AROM, Active range of motion

Supplementary REFERENCE

1. Berger RA, Bishop AT, Bettinger PC. New dorsal capsulotomy for the surgical exposure of the wrist. Ann Plast Surg 1995;35(1):54–59.

CHAPTER 8

The impact of psychosocial variables on initial presentation and surgical outcome for ulnar-sided wrist pathology: a cohort study with 1-year follow-up

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ABSTRACT

Aims: Ulnar-sided wrist pain has historically been equated to lower-back pain of wrist surgery. Little is known about the relationship between psychosocial profile and the manifestation of ulnar-sided wrist pathology and their treatment outcomes. This study aimed to determine the impact of pain catastrophising, psychological distress, illness perception, and patients 'outcome expectations on patient-reported pain and hand function before and one year after surgery for ulnar-sided wrist pathology.

Patients and Methods: We included patients who underwent surgical treatment for ulnar-sided wrist pathology. Before surgery, patients completed the Pain Catastrophising Scale (PCS), Patient Health Questionnaire (PHQ), Brief-Illness Perception Questionnaire (B-IPQ), and Credibility/Expectancy Questionnaire (CEQ). Pain and dysfunction were assessed before (n= 423) and one year after surgery (n= 253) using the Patient Rated Wrist/Hand Evaluation (PRWHE). Hierarchical linear regression was used to assess the relationship between psychosocial factors and the preoperative PRWHE score, postoperative PRWHE score, and change in PRWHE.

Results: Psychosocial variables explained an additional 35% of the variance in preoperative PRWHE scores and 18% on postoperative scores. A more negative psychosocial profile was associated with higher (worse) preoperative PRWHE scores (PCS: B= 0.19, CI= [0.02-0.36]; B-IPQ Consequences: B= 3.26, CI= 2.36-4.15; and B-IPQ Identity, B= 1.88 [1.09-2.67]) and postoperative PRWHE scores (PCS: B= 0.44, CI= [0.08-0.81]) but not with the change in PRWHE after surgery. Higher treatment expectations were associated with a lower (better) postoperative PRWHE score (CEQ expectancy: B= -1.63, CI= [-2.43;-0.83]) and a larger change in PRWHE scores (B= |1.62|, CI= [|0.77; 2.47|]).

Conclusion: A more negative psychosocial profile was associated with higher pain levels and dysfunction preoperatively and postoperatively. However, these patients showed similar improvement as patients with a more feasible psychosocial profile. Therefore, patients should not be withheld from surgical treatment based on their preoperative psychosocial profile alone. Boosting treatment expectations might further improve treatment outcomes.

Level of evidence: III (Cohort study)

INTRODUCTION

Chronic conditions of the wrist can be challenging to manage. Especially ulnar-sided wrist pain is playfully equated to the "lower back pain" or "black-box" of the wrist due to the diverse nature of chronic complaints, insidious appearance and resulting frustration as well as the anatomical complexity.[1–4]

The anatomy of the ulnar-sided wrist, the diagnosis and treatment options have recently been summarised in a comprehensive review.[4] In short, treatment often starts with nonoperative modalities, including anti-inflammatory drugs, splinting, corticoid steroid injection, and hand therapy.[4] Subsequent surgical treatment may be needed to reduce symptoms further and improve function. The Four-Leaf Clover treatment algorithm proposed by Kakar and Garcia-Elias recommends surgical treatment based on the status of 4 main structures related to ulnar-sided wrist pain[5]: A) bone deformity (e.g. ulnar impaction syndrome), B) cartilage defects (e.g. distal radioulnar joint osteoarthritis and pisotriquetral osteoarthritis), C) TFCC injury, and D) unstable Extensor Carpi Ulnaris. Treatment should mainly be directed to the type of pathological structure(s) focussing on the reconstruction of the anatomy by A) corrective osteotomy (e.g. ulnar shortening osteotomy), B) DRUJ arthroplasty (e.g. u-head) / Pisiformectomy, C) ligament reconstruction (e.g. Adams or TFCC reinsertion), and D) ECU stabilisation.

While effort has been put into understanding ulnar-sided wrist pathology based on the anatomy and biomechanics[1,4,5], psychosocial factors (e.g. pain catastrophising, anxiety and depression, and illness perception) have been scarcely investigated in these patients. However, this may be equally important as previous studies have shown that anatomical findings during diagnostic workup only partly relate to the amount of ulnar-sided wrist pain.[6–8]

The relationship between psychosocial profile and patient-reported pain and dysfunction is becoming well recognised for common musculoskeletal pathology. For example, pain catastrophising and depression were associated with higher scores of pain and dysfunction at presentation in patients with hip[9], thumb[10], or spine pathology.[11] Furthermore, illness perception was also associated with higher pain and dysfunction in patients with Quervain's tenosynovitis[12], thumb base osteoarthritis[10], and carpal tunnel syndrome.[13] Some studies found that the patients' psychosocial profile was even more associated with their pain and dysfunction than the severity of their pathology.[10,14]

Next to the potentially better understanding of patient-reported pain and dysfunction in patients with ulnar-sided wrist pathology, psychosocial factors may be determinants for the outcome of surgery. A meta-analysis on the outcome of total knee replacement reported that a more negative psychosocial profile was associated with worse outcomes.[15] However, other studies on spinal surgery or carpal tunnel release found that a more negative preoperative psychosocial profile did not compromise the outcome of surgery.[11,16]

The association between psychosocial variables and patient-reported pain and dysfunction have been scarcely investigated in patients with ulnar-sided wrist pathology. Also, their effect on the outcome of surgery is unclear. Therefore, this study aimed to determine the impact of pain catastrophising, psychological distress, illness perception, and patients' outcome expectations on patient-reported pain and hand function both before and at one year after surgery for ulnar-sided wrist pathology.

PATIENTS and METHODS

Study design and setting

We studied prospectively gathered data on a consecutive cohort of patients that underwent surgical treatment of ulnar-sided wrist pathology between September 2017 and June 2020 at Xpert Clinics, The Netherlands. All surgeons at our institution are certified by the Federation of European Societies for Surgery of the Hand and/or fellowship trained.

After their first consultation with a hand surgeon, all our patients were invited to be included in the Hand and Wrist Cohort, a routine outcome measurement system. Upon agreement, they received secure web-based questionnaires using GemsTracker.[17] Three reminders were sent to the patients for each round of questionnaires. The exact research setting of our study group has been reported previously.[18]

We report this study using the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.[19] International Review Board approval was obtained from the ethics committee of the Erasmus Medical Center Rotterdam (NL/sl/MEC-2018-1088). All patients provided written informed consent for their data to be anonymously used in this study.

Participants

We identified adult patients in the Hand and Wrist Cohort scheduled for surgical treatment for ulnar-sided wrist pathology by the treatment codes: USO; TFCC reinsertion; pisiformectomy; u-head implant; and Adams procedure. Generally, conservative treatment was initiated by a short period of immobilisation, followed by a rigorous program of wrist exercises. After careful anamnesis, physical examination, and imaging (e.g. MRI, CT, or wrist arthroscopy), surgical treatment was considered if symptoms persisted for more than three months or if patients did not want further nonoperative management. Surgical treatment was directed to the type of pathological structure(s) focussing on the reconstruction of the anatomy.[5] Exclusion criteria for this study were: 1) patients younger than 18 years; 2) patients with incomplete demographic and psychosocial data; 3) patients who underwent surgical procedures that were less prevalent than 30 in the dataset after applying exclusion criteria 1 and 2.

Baseline demographics

After the first consultation with a hand surgeon, sociodemographic characteristics were routinely collected. The variables evaluated in this study were age, sex, type of work, symptom duration, and whether the dominant side was affected.

Psychosocial variables

The Pain Catastrophising Scale (PCS) was used to measure pain catastrophising.[20,21] We evaluated the PCS total score, ranging from 0–52 (0 = no catastrophising behaviour; 52 = severe catastrophising behaviour). A PCS total score ≥30 is considered a clinically relevant level of catastrophising.

The Patient Health Questionnaire-4 (PHQ), a combination of the PHQ-2 and Generalised Anxiety Disorder (GAD)-2, measured psychological distress (anxiety and depression).[22] We evaluated the PHQ total score, ranging from 0-12 (0 = no psychological distress; 12 = severe psychological distress). A PHQ total score of 6-8 is considered a “yellow flag”, and ≥9 a “red flag”.

The Brief Illness Perception Questionnaire(B-IPQ) was used to measure how patients perceive their illness.[23,24] As recommended[23], we evaluated the subscales (range 0-10) separately. For the items Personal control (how much control patients feel they have over their illness), Treatment control (how much patients think their treatment will help their illness), and Comprehension (how well patients understand their illness), a higher score is better. For all other items: Consequences (how much the illness affects the patients' life), Timeline (how long patients expect their illness to last), Identity (how much patients contribute symptoms to their hand condition), Concern (How concerned patients are), and Emotion (how much the patients are emotionally affected by the illness) a lower score is better.

The Credibility/Expectations Questionnaire (CEQ) measured the patients' expectations and credibility of the treatment outcomes.[25] It consists of 6 questions, and the scores range from 3-27 (3 = low expectations and credibility; 27 = high expectations and credibility). In this study, we only evaluated the Expectancy subscale. Due to collinearity concerns, the Treament control subscale was not evaluated. We used the validated Dutch language versions (DLV) for all questionnaires.[21,24,26,27]

Outcome measure

The Patient Rated Wrist/Hand Evaluation-DLV (PRWHE) measured patient-reported pain and dysfunction before surgery and one year after surgery.[28,29] The 1-year follow-up duration was chosen based on the alignment of clinical follow-up, the pathophysiology of the condition and expected treatment effect[18]. This was in line with international recommendations.[30] We evaluated the PRWHE total score, ranging from 0-100 (0= no pain and dysfunction; 100= severe pain and dysfunction). Outcomes from some of the included patients in this study have been evaluated before.[31,32]

Sample size

For a fixed regression model with an R^2 deviation from zero with an effect size F^2 of 0.10, α of 0.05, 16 predictors and a sample size of 423, we reached a power of 99,5%. For the model at follow-up with the same effect size, α, 18 predictors, and 253 patients, we reached a power of 87,9%.

Statistical analysis

We checked continuous data for normal distributions with histograms and quantile-quantile plots. Normally distributed data were displayed as mean values with standard deviations (SD), and skewed data were displayed as mean values with inter-quartile ranges (IQR).

We performed a hierarchical multivariable linear regression to investigate the relative contribution of different variables to the explained variance in the amount of pain and dysfunction before surgery (PRWHE total score; model 1) and after surgery (model 2). For model 1, we consecutively added sociodemographics, scheduled surgical procedure, PCS + PHQ scores, and B-IPQ scores. For model 2, we also stepwise added the CEQ expectation subscale and the preoperative PRHWE score. For model 3, the outcome was the change score in PRWHE before and after surgery. Similar to other studies, PCS and PHQ scores were added simultaneously but separately from B-IPQ since pain catastrophising and psychological distress have been studied more extensively.[10,12,13] Outcome expectations were only evaluated in the outcome models (model 2).[33] The variable treatment was added in the models as an instrumental variable for diagnosis/pathology.

Regression coefficients (B) with corresponding 95% confidence intervals and standardised coefficients (β) are reported for all variables. To illustrate the explained variance of different models, R^2, adjusted R^2, and significance of F change are reported per step. All linear regression model assumptions were checked and satisfied.

We calculated Pearson correlation coefficients and variance inflation factors (VIF) to investigate whether the correlation between psychosocial variables did not bias our estimates. We interpreted the Pearson correlation coefficients as suggested by Hinkle et al. and VIF by Gareth.[34,35]

Because data were collected during daily clinical practice, and participation in the routine outcome measurement was voluntary, missing data were expected. We tested for significant differences in demographic characteristics and, when available, preoperative questionnaire scores between patients who completed all questionnaires (complete responders) versus patients who completed none or only some (non/partial responders) using analysis of variance or Chi^2 tests.

The sample size was calculated using GPower 3.1.[36] All other analyses were performed in software package R, version 3.6.1. For all tests, a *p*-value smaller than 0.05 was considered statistically significant.

RESULTS

A total of 603 patients with ulnar-sided wrist pathology were scheduled for surgical treatment during the study period. We excluded eight patients younger than 18 years, one patient with incomplete demographic data, and 12 patients who underwent a surgical procedure less prevalent than 30 times in the dataset.

Of the 582 eligible patients, 423 (initial response rate: 73%) completed all questionnaires before surgery (103 USO, 206 TFCC reinsertion, 114 Pisiformectomy) and were enrolled in the study. Of these patients, 253 (retention rate is 60%) also completed the follow-up assessment. This subgroup of patients was used for models 2 and 3 (Figure 1).

Patient characteristics

The sociodemographic characteristics, treatment, and psychosocial scores of the 423 included patients are displayed in Table 1. The mean age was 44 (SD 14), and 25% of the patients were males. Clinically significant levels of pain catastrophizing were found in 7% of the patients and psychological distress in 10%. There was no difference in the prevalence of abnormal levels of pain catastrophizing (USO: 7%; TFFC reinsertion: 7%; Pisiformectomy: 8%; p=0.952) and psychological distress (USO: 12%; TFFC reinsertion: 10%; Pisiformectomy: 9%; p=0.770) based on treatment.

Non/partial responders more often males than complete responders (p=0.007). There were no differences between these groups in other demographics or PRWHE, PCS, PHQ, IPQ, and CEQ scores (Table 1).

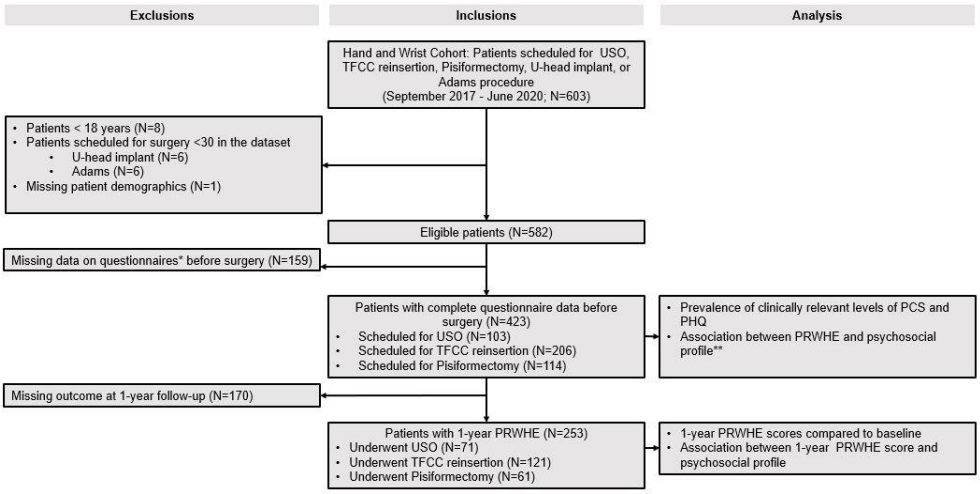

Figure 1: Flowchart of the study. Abbreviations: USO= Ulnar Shortening Osteotomy; TFCC= Triangular Fibrocartilaginous Complex; PRWHE= Patient Rated Wrist/Hand Evaluation. *PCS= Pain Catastrophising Scale; PHQ= Patient Health Questionnaire; B- IPQ= Brief-Illness Perception Questionnaire; CEQ= Credibility Expectancy Questionnaire. **PCS, PHQ, B-IPQ.

Table 1: Study population characteristics. Values indicate means with standard deviations unless stated otherwise.

Characteristic	All	Complete baseline	Complete baseline + 1-year PRWHE	*p*-value*	Range of possible values
N	582	423	253		
Age (years)	43 (15)	44 (14)	45 (14)	0.305	
Sex = Females, N (%)	405 (70)	316 (75)	202 (80)	*0.007*	
Duration of symptoms (mos.), median [IQR]	12 [6, 24]	12 [6, 18]	12 [6, 18]	0.626	
Type of work, N (%)				0.997	
None	118 (20)	83 (20)	54 (21)		
Light	182 (31)	136 (32)	77 (30)		
Medium	182 (31)	135 (32)	81 (32)		
Heavy	100 (17)	69 (16)	41 (16)		
Dominant side affected = No, N (%)	255 (44)	182 (43)	111 (44)	0.963	
Second opinion = No, N (%)	515 (88)	373 (88)	225 (89)	0.957	
Treatment, N (%)				0.742	
Ulnar shortening osteotomy	144 (25)	103 (24)	71 (28)		
TFCC reinsertion	294 (51)	206 (49)	121 (48)		
Pisiformectomy	144 (25)	114 (27)	61 (24)		
Preoperative PRWHE total score	63 (18)	63 (17)	65 (17)	0.495	0-100
Postoperative PRWHE total score	32 (24)	NA (NA)	30 (24)	0.489	0-100
PCS score	13 (10)	13 (10)	13 (10)	0.997	0-52
PHQ score	2 (3)	2 (3)	2 (3)	0.980	0-12
B-IPQ Consequences	8 (2)	7 (2)	7 (2)	0.906	0-10
B-IPQ Timeline	6 (2)	6 (2)	6 (2)	0.307	0-10
B-IPQ Personal Control	4 (2)	4 (2)	4 (2)	0.975	0-10
B-IPQ Identity	7 (2)	7 (2)	7 (2)	0.794	0-10
B-IPQ Concern	6 (2)	6 (2)	6 (2)	0.988	0-10
B-IPQ Understanding	8 (2)	8 (2)	8 (2)	0.973	0-10
B-IPQ Emotional Response	5 (3)	5 (3)	5 (3)	0.972	0-10
CEQ Expectancy	22 (4)	22 (4)	22 (3)	0.404	3-27

Abbreviations: SD= standard deviation; IQR= interquartile range; TFCC: Triangular Fibrocartilaginous Complex; PRWHE= Patient Rated Wrist/Hand Evaluation. *PCS= Pain Catastrophising Scale; PHQ= Patient Health Questionnaire; B- IPQ= Brief-Illness Perception Questionnaire; CEQ= Credibility Expectancy Questionnaire. *P-values indicates the difference between the three groups.

Association between psychosocial variables and preoperative pain and dysfunction

The psychosocial factors increased the explained variance of preoperative PRHWE total score from 7% (sociodemographics and scheduled treatment only) to 42% (Table S1; Figure 2). Female sex (B= 4.92; β=0.12), higher age (B= 0.18; β=0.15), higher PCS score (B= 0.19; β=0.11), higher B-IPQ Consequence score (B= 3.26; β=0.36), and higher B-IPQ Identity (B=1.88; β=0.23) were independently associated with higher (worse) preoperative PRWHE total score (Table 2).

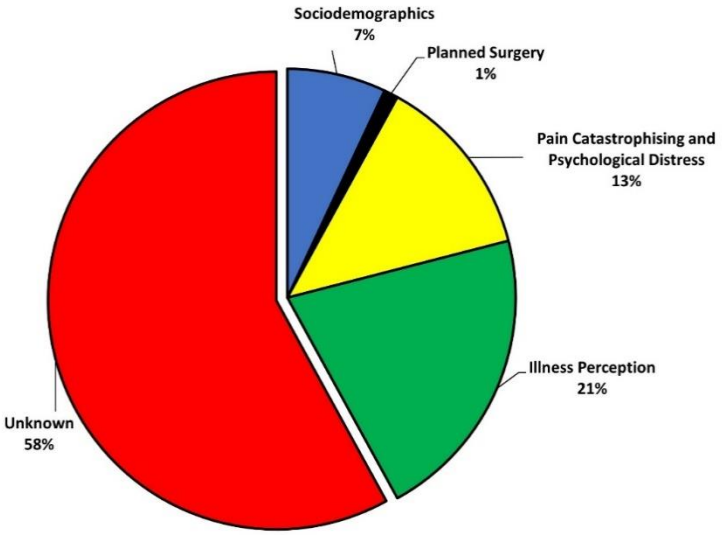

Figure 2: Pie chart on the increase in explained variance (R^2) of preoperative pain and function measured with the Patient Rated Wrist/Hand Evaluation (PRWHE). Each slice represents the added R^2 from a set of variables consecutively added to the linear regression models.

Table 2: Results from the final step of the multivariable linear regression model on the Patient Rated Wrist/Hand Evaluation (PRWHE) before surgery, one year after surgery, and the change score. Unadjusted beta's (B) with 95% confidence intervals (CI) and adjusted beta's (β) are reported.

	Preop. PRWHE		1-year postop. PRWHE		Change in PRWHE	
Variable	**B [95%CI]**	**β**	**B [95%CI]**	**β**	**B [95%CI]**	**β**
Sex = Females	*4.92 [1.79; 8.05]***	0,12	-1.46 [-8.42; 5.49]	-0,02	4.87 [-12.2; 2.47]	-0.08
Age (yrs.)	*0.18 [0.07; 0.28]**	0,15	0.02 [-0.21; 0.25]	0,01	-0.06 [-0.3; 0.18]	-0.04
Dominant side affected = No	1.89 [-0.78; 4.56]	0,05	3.78 [-1.72; 9.29]	0,08	2.64 [-3.24; 8.52]	0.06
Type of work = Light (ref = none)	2.33 [-1.51; 6.17]	0,06	-4.23 [-12.18; 3.71]	-0,08	-5.57 [-14.06; 2.92]	-0.11
Type of work = Medium (ref = none)	3.68 [-0.18; 7.54]	0,1	0.83 [-7.11; 8.76]	0,02	-0.39 [-8.87; 8.08]	-0.01
Type of work = Heavy (ref = none)	2.24 [-2.32; 6.8]	0,05	-5.29 [-14.76; 4.18]	-0,08	-5.83 [-15.96; 4.31]	-0.09
Second opinion = No	-2.72 [-6.93; 1.49]	-0,05	-2.36 [-11.45; 6.73]	-0,03	0 [-9.69; 9.69]	0.00
Duration of symptoms (mos.)	0 [-0.05; 0.05]	0	0.06 [-0.1; 0.22]	0,05	0.04 [-0.13; 0.22]	0.03
Treatment = TFCC reinsertion (ref = USO)	-1.05 [-4.49; 2.38]	-0,03	0.66 [-6.44; 7.76]	0,01	1.67 [-5.92; 9.25]	0.04
Treatment = Pisiformectomy (ref = USO)	-0.85 [-4.56; 2.86]	-0,02	-3.22 [-10.74; 4.3]	-0,06	-2.08 [-10.11; 5.96]	-0.04
PCS score	*0.19 [0.02; 0.36]**	0,11	*0.44 [0.08; 0.81]**	0,19	0.33 [-0.06; 0.72]	0.14
PHQ score	0.3 [-0.31; 0.9]	0,04	-0.02 [-1.29; 1.26]	0	-0.32 [-1.68; 1.04]	-0.04
B-IPQ Consequences	*3.26 [2.36; 4.15]****	0,36	0.31 [-1.73; 2.35]	0,02	*-2.15 [-4.15; -0.15]**	-0.17
B-IPQ Timeline	0.09 [-0.55; 0.73]	0,01	-0.33 [-1.77; 1.1]	-0,03	-0.22 [-1.75; 1.32]	-0.02
B-IPQ Personal Control	-0.23 [-0.83; 0.37]	-0,03	0.27 [-1; 1.55]	0,02	0.5 [-0.86; 1.86]	0.05
B-IPQ Identity	*1.88 [1.09; 2.67]****	0,23	0.53 [-1.23; 2.3]	0,04	-0.61 [-2.45; 1.23]	-0.05
B-IPQ Concern	-0.62 [-1.32; 0.08]	-0,09	-1.19 [-2.66; 0.29]	-0,12	-0.92 [-2.5; 0.66]	-0.10
B-IPQ Understanding	0.04 [-0.67; 0.74]	0	0.19 [-1.23; 1.61]	0,02	0.18 [-1.34; 1.69]	0.02
B-IPQ Emotional Response	0.58 [-0.09; 1.25]	0,09	1.08 [-0.33; 2.49]	0,13	0.84 [-0.67; 2.35]	0.10
CEQ Expectancy	NA	NA	*-1.63 [-2.43; -0.83]****	-0.25	*-1.62 [-2.47; -0.77]****	-0.25
Preop PRWHE total score	NA	NA	0.36 [0.15; 0.57]**	0.25	NA	NA
R^2	0.42		0.26		0.14	
Adjusted R^2	0.39		0.20		0.07	

Abbreviations: SD= standard deviation; IQR= interquartile range; TFCC: Triangular Fibrocartilaginous Complex; PRWHE= Patient Rated Wrist/Hand Evaluation. *PCS= Pain Catastrophising Scale; PHQ= Patient Health Questionnaire; B- IPQ= Brief-Illness Perception Questionnaire; CEQ= Credibility Expectancy Questionnaire.

*p<0.05; **p<0.01; ***p<0.001

Effect of psychosocial variables on postoperative pain and dysfunction

Mean PRWHE scores improved after treatment, irrespective of the type of surgery (each p<0.001; Table 3).

Table 3: Mean (SD) preoperative and 1-year postoperative Patient-Rated Wrist Hand Evaluation (PRWHE) total scores.

Treatment		**Preoperative**	**One year postoperative**	**Improvement**	***p*-value**
All		65 (17)	30 (24)	-35 (24)	<0.001
	USO	68 (16)	34 (25)	-34 (21)	<0.001
	TFCC reinsertion	62 (18)	28 (22)	-34 (24)	<0.001
	Pisiformectomy	66 (15)	29 (25)	-37 (25)	<0.001

Abbreviations: USO= ulnar shortening osteotomy, TFCC= triangular fibrocartilage complex.

The final model explained 26% of the variance in the 1-year postoperative PRWHE total score (Table S2). The consecutive relative contribution per set of variables is displayed in Figure 3. Higher PCS score (B=0.44; β=0.19) and a higher preoperative PRWHE total score (B=0.36; β=0.25) were independently associated with a higher (worse) 1-year postoperative PRWHE total score. A higher CEQ Expectancy score (B=-1.63; β=-0.25) was independently associated with a lower (better) 1-year postoperative PRWHE total score (Table 2).

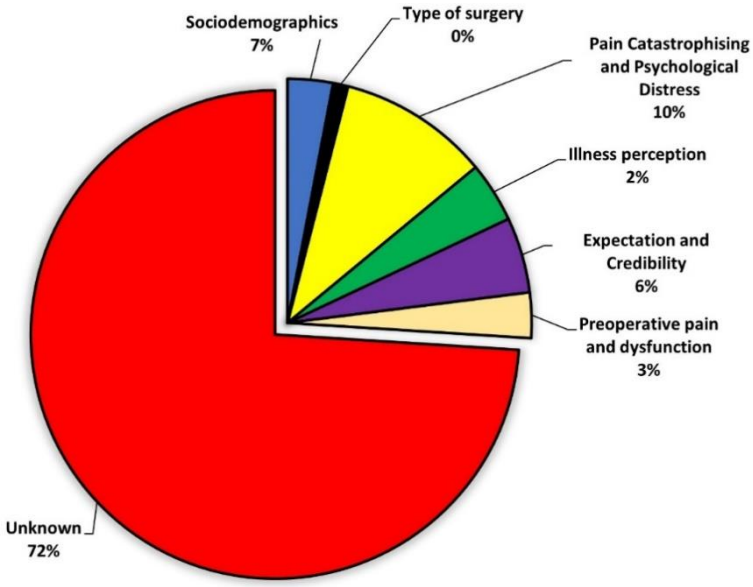

Figure 3: Pie chart on the increase in explained variance (R^2) of 1-year postoperative pain and function measured with the Patient Rated Wrist/Hand Evaluation (PRWHE). Each slice represents the added R^2 from a set of variables consecutively added to the linear regression models.

A posthoc analysis showed that a higher CEQ Expectancy score (B=-1.62; β=-0.25) and B-IPQ Consequence score (B=-2.15; β=-0.17) were independently associated with larger improvement in PRWHE score after one year (Table 2). All other variables did not influence the amount of improvement in this model.

There were no indications for multicollinearity in the models as Pearson correlation between psychosocial variables ranged from -0.21 to 0.57 (Table S3), and the VIF ranged from 1.05 to 2.15.

DISCUSSION

This study evaluated the impact of psychosocial factors on patient-reported pain and dysfunction both before and one year after surgery for ulnar-sided wrist pathology. Patients with more pain catastrophising behaviour or poor illness perception reported worse pain and dysfunction before surgery. Higher levels of pain catastrophising were associated with a worse 1-year outcome of surgery. In contrast, higher expectations of the treatment effect were associated with a better outcome. Higher expectations of treatment outcome increased the effectiveness of surgical treatment, while pain catastrophising and psychological distress did not seem to affect the effectiveness.

The first strength of our study is our routine longitudinal outcome management, including preoperative measurements, that allowed us to investigate the impact of psychosocial variables on treatment outcomes and change of scores. Second, we also evaluated the impact of illness perception and patients' expectations besides the more broadly studied factors such as pain catastrophising and depression. Third, the large sample size allowed for multivariable testing of all psychosocial concepts simultaneously with adequate power.

This study also has limitations. First, it was impossible to determine a causal effect between psychosocial factors and patient-reported pain and function. While we have confirmed a strong association between the two, the effect can be bidirectional. For example, a more negative psychosocial profile may lead to worse pain or vice versa. Future research should determine the direction of the association between psychosocial factors and patient-reported pain and function. Second, we only included patients with ulnar-sided wrist pathology who were scheduled for surgical treatment. From previous research on thumb base osteoarthritis, we know that patients scheduled for surgical treatment have a worse psychosocial profile than their nonsurgically treated counterparts.[37] Therefore, the results of this study may not be generalisable to nonsurgically treated patients with wrist pathology. A third limitation was the missing data. Participation in the routine outcome measurement system is voluntary, and we have found that the response rate drops to approximately 50% after one year.[18] Nonresponse was more common in males, which is a known risk factor in routine outcome measurement of elective surgery.[38] We did not observe differences in the pain, function, and psychosocial scores between full and partial/non-responders. Therefore, we think that the missing data does not jeopardise the conclusions of our study. Fourth, we could

not include the degree of anatomical abnormality in the models because there was no standardised workup protocol for patients with ulnar-sided wrist pain. For example, not all patients had a prior conventional x-ray, wrist arthroscopy, and MRI. Although previous research suggested that anatomical abnormalities were of limited value in explaining pain and dysfunction, incorporating them can better understand ulnar-sided wrist pain.

We showed that pain catastrophising behaviour and poorer illness perception were strongly associated with higher levels of patient-reported pain and dysfunction in patients with ulnar-sided wrist pathology. In our model, 35% of the explained variance could be attributed to pain catastrophising, anxiety and depression, and illness perception, which is in line with similar models from previous studies on carpal tunnel syndrome (20-25%)[13], Quervain's tenosynovitis (27%)[12], and thumb base osteoarthritis (42%).[10] In this study, higher levels of pain catastrophising were also independently associated with more pain and dysfunction one year after surgery. Teunis et al. also found poorer outcomes in patients with pain catastrophising behaviour after distal radius fracture surgery.[39] Another study found that pain catastrophising and anxiety and depression were associated with worse pain and function after three months of treatment in patients with degenerative wrist pathology (only 2% in their sample consisted of ulnar-sided wrist problems).[40] In contrast to pain catastrophising, higher treatment expectations were independently associated with a better 1-year outcome. This is in line with a previous study on the surgical outcome of Quervain's disease.[33] Interestingly, the mean improvement during the first year after surgery -although with a higher level of pain and dysfunction at intake- did not seem to differ based on pain catastrophising or anxiety and depression. A similar observation was reported by London et al.[40]

The relationship between psychosocial factors and pain and dysfunction in patients with ulnar-sided wrist pathology provides implications and recommendations for clinical practice. First, hand surgeons should be aware of the substantial relationship between patient-reported pain and dysfunction and psychosocial factors before surgery. A part of the complaints may stem from negative psychosocial factors, or the complaints may exhibit negative psychosocial factors. Second, operating patients with a more negative psychosocial profile report similar improvement than those with a more feasible psychosocial profile meaning that these should not be withheld from surgical treatment. However, considering the greater degree of complaints before surgery, patients with a more negative psychosocial profile before surgery still have worse 1-year treatment

outcomes than patients with a more positive psychosocial profile. Therefore, hand surgeons should question whether patients with a more negative psychosocial profile are sufficiently treated with surgical interventions alone. For example, patients may benefit from counselling on psychosocial factors. This is encouraged by Zale et al., who concluded that patients benefit from learning resiliency skills.[41] Another study successfully changed illness perceptions using an intervention targeting patients' perceptions of the consequences of myocardial infarction that resulted in accelerated patients' return to work.[42] Similarly, an intervention aiming to improve patients' psychosocial profile, such as illness perception in patients with ulnar-sided wrist pain, may improve treatment outcomes. Furthermore, we found that patients with higher outcome expectations had a greater improvement from surgical treatment. Thus, enhancing patient's expectations even further might increase the effectiveness of surgery. As hand surgeons, we are not trained to treat symptoms of pain catastrophising, anxiety, depression, and illness perception. Therefore, a consultation with a mental health provider might be used alongside nonsurgical interventions before proceeding to more invasive treatment options for ulnar-sided wrist pain.

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SUPPLEMENTARY FILE

Table s1: Preoperative hierarchical linear regression model. The table shows the unstandardised coefficients (B), corresponding 95% confidence intervals, and standardised coefficients (β) for the associations between each variable and the Patient Rated Wrist Evaluation (PRWHE) total score.

	Step 1 Sociodemographics		**Step 2 Planned surgery**		**Step 3 Pain catastrophising + psychological distress**		**Step 4 Illness perception**	
Variable	**B [95%CI]**	**β**	**B [95%CI]**	**β**	**B [95%CI]**	**β**	**B [95%CI]**	**β**
SexFemales	7.96 [4.13; 11.79]***	0,2	7.96 [4.14; 11.78]***	0,2	7.67 [4.11; 11.23]***	0,19	4.92 [1.79; 8.05]***	0,12
Age (yrs.)	0.13 [0.01; 0.24]*	0,1	0.1 [-0.02; 0.22]	0,08	0.18 [0.07; 0.3]**	0,15	0.18 [0.07; 0.28]**	0,15
Dominant side affected = No	1.05 [-2.23; 4.33]	0,03	0.81 [-2.48; 4.09]	0,02	0.78 [-2.28; 3.84]	0,02	1.89 [-0.78; 4.56]	0,05
Type of work = Light	1.81 [-2.89; 6.51]	0,05	2.13 [-2.6; 6.86]	0,06	3.54 [-0.88; 7.95]	0,1	2.33 [-1.51; 6.17]	0,06
Type of work = Medium	3.84 [-0.9; 8.58]	0,1	4.03 [-0.7; 8.76]	0,11	4.98 [0.56; 9.39]*	0,13	3.68 [-0.18; 7.54]	0,1
Type of work = Heavy	3.1 [-2.49; 8.69]	0,07	3.46 [-2.13; 9.05]	0,07	4.32 [-0.9; 9.53]	0,09	2.24 [-2.32; 6.8]	0,05
Second opinion = No	-4.98 [-10.01; 0.05]	-0,09	-5.33 [-10.39; -0.27]*	-0,1	-6.17 [-10.9; -1.44]*	-0,12	-2.72 [-6.93; 1.49]	-0,05
Duration of symptoms (mos.)	-0.01 [-0.07; 0.05]	-0,02	-0.02 [-0.09; 0.04]	-0,04	-0.03 [-0.09; 0.03]	-0,04	0 [-0.05; 0.05]	0
Treatment = TFCC reinsertion			-4.44 [-8.64; -0.24]*	-0,13	-2.72 [-6.65; 1.21]	-0,08	-1.05 [-4.49; 2.38]	-0,03
Treatment = Pisiformectomy			-2.82 [-7.39; 1.75]	-0,07	-2.3 [-6.55; 1.95]	-0,06	-0.85 [-4.56; 2.86]	-0,02
PCS score					0.5 [0.33; 0.67]***	0,29	0.19 [0.02; 0.36]*	0,11
PHQ score					0.88 [0.22; 1.53]**	0,13	0.3 [-0.31; 0.9]	0,04
B-IPQ Consequences							3.26 [2.36; 4.15]***	0,36
B-IPQ Timeline							0.09 [-0.55; 0.73]	0,01
B-IPQ Personal Control							-0.23 [-0.83; 0.37]	-0,03
B-IPQ Identity							1.88 [1.09; 2.67]***	0,23
B-IPQ Concern							-0.62 [-1.32; 0.08]	-0,09
B-IPQ Understanding							0.04 [-0.67; 0.74]	0
B-IPQ Emotional Response							0.58 [-0.09; 1.25]	0,09
R^2	0.07		0.08		0.21		0.42	
Adjusted R^2	0.05		0.06		0.18		0.39	
Sig. F-Change	<0.001		0.12		<0.001		<0.001	

Abbreviations: B= unstandardized beta coefficient; β= standardized beta; CI= Confidence Interval; Ref= reference level; USO= ulnar shortening osteotomy; TFCC= Triangular Fibrocartilaginous Complex; PCS= Pain Catastrophizing Scale; PHQ= Patient Health Questionnaire; B-IPQ= Brief Illness Perception Questionnaire

*p<0.05; **p<0.01; ***p<0.001

Table s2: Postoperative hierarchical linear regression model. The table shows the unstandardised coefficients (B), corresponding 95% confidence intervals, and standardised coefficients (β) for the associations between each variable and the Patient Rated Wrist Evaluation (PRWHE) total score.

	Step 1 Sociodemographics		**Step 2 Surgery**		**Step 3 Pain catastrophising + Psychological distress**		**Step 4 Illness perception**		**Step 5 Expectations from treatment**		**Step 6 Preop. Pain and dysfunction**	
Variable	**B [95%CI]**	**β**	**B [95%CI]**	**β**	**B [95%CI]**	**β**	**B [95%CI]**	**β**	**B [95%CI]**	**β**	**B [95%CI]**	**β**
Sex = Females	2.83 [-4.64; 10.3]	0,05	3.05 [-4.43; 10.53]	0,05	1.86 [-5.28; 9]	0,03	0.31 [-6.91; 7.52]	0,01	0.45 [-6.56; 7.45]	0,01	-1.46 [-8.42; 5.49]	-0,02
Age (yrs.)	-0.06 [-0.28; 0.16]	-0,04	-0.09 [-0.33; 0.15]	-0,05	0.02 [-0.21; 0.26]	0,01	0.03 [-0.21; 0.26]	0,02	0.07 [-0.16; 0.3]	0,04	0.02 [-0.21; 0.25]	0,01
Dominant side affected No	3.42 [-2.62; 9.46]	0,07	3.29 [-2.75; 9.34]	0,07	3.82 [-1.93; 9.58]	0,08	4.13 [-1.65; 9.91]	0,09	4.43 [-1.18; 10.04]	0,09	3.78 [-1.72; 9.29]	0,08
Type of work = Light	-5.95 [-14.52; 2.63]	-0,11	-6.12 [-14.74; 2.49]	-0,12	-4.89 [-13.1; 3.33]	-0,09	-6.04 [-14.29; 2.21]	-0,12	-3.48 [-11.59; 4.62]	-0,07	-4.23 [-12.18; 3.71]	-0,08
Type of work = Medium	0.38 [-8.15; 8.9]	0,01	0.2 [-8.32; 8.72]	0	0.81 [-7.33; 8.94]	0,02	-0.66 [-8.93; 7.6]	-0,01	1.51 [-6.58; 9.6]	0,03	0.83 [-7.11; 8.76]	0,02
Type of work = Heavy	-6.92 [-17.22; 3.38]	-0,11	-6.85 [-17.16; 3.46]	-0,11	-4.95 [-14.79; 4.89]	-0,08	-6.06 [-16.02; 3.89]	-0,09	-4.99 [-14.66; 4.68]	-0,08	-5.29 [-14.76; 4.18]	-0,08
Second opinion = No	-3.13 [-12.59; 6.34]	-0,04	-3.62 [-13.24; 6]	-0,05	-4.18 [-13.34; 4.98]	-0,05	-4.07 [-13.6; 5.46]	-0,05	-3.68 [-12.93; 5.56]	-0,05	-2.36 [-11.45; 6.73]	-0,03
Duration of symptoms (mos.)	0.13 [-0.03; 0.3]	0,1	0.11 [-0.06; 0.28]	0,08	0.09 [-0.07; 0.25]	0,07	0.09 [-0.08; 0.26]	0,07	0.07 [-0.1; 0.23]	0,05	0.06 [-0.1; 0.22]	0,05
Treatment = TFCC reinsertion			-5.62 [-13.28; 2.05]	-0,12	-2.05 [-9.46; 5.37]	-0,04	-1.39 [-8.82; 6.03]	-0,03	0.1 [-7.15; 7.34]	0	0.66 [-6.44; 7.76]	0,01
Treatment = Pisiformectomy			-5.73 [-13.99; 2.52]	-0,1	-5.36 [-13.22; 2.49]	-0,1	-5.58 [-13.43; 2.28]	-0,1	-3.86 [-11.53; 3.8]	-0,07	-3.22 [-10.74; 4.3]	-0,06
PCS score				#N/A	0.62 [0.3; 0.95]***	0,26	0.48 [0.1; 0.86]*	0,2	0.5 [0.14; 0.87]**	0,21	0.44 [0.08; 0.81]*	0,19
PHQ score				#N/A	0.94 [-0.27; 2.15]	0,1	0.48 [-0.85; 1.81]	0,05	0.15 [-1.15; 1.45]	0,02	-0.02 [-1.29; 1.26]	0
B-IPQ Consequences				#N/A	#N/A	#N/A	1.49 [-0.48; 3.45]	0,12	1.69 [-0.22; 3.6]	0,13	0.31 [-1.73; 2.35]	0,02
B-IPQ Timeline				#N/A	#N/A	#N/A	0.34 [-1.12; 1.8]	0,03	-0.4 [-1.86; 1.07]	-0,04	-0.33 [-1.77; 1.1]	-0,03
B-IPQ Personal Control				#N/A	#N/A	#N/A	0.36 [-0.97; 1.69]	0,03	0.14 [-1.16; 1.44]	0,01	0.27 [-1; 1.55]	0,02
B-IPQ Identity				#N/A	#N/A	#N/A	1.28 [-0.53; 3.1]	0,11	1.17 [-0.59; 2.93]	0,1	0.53 [-1.23; 2.3]	0,04
B-IPQ Concern				#N/A	#N/A	#N/A	-1.14 [-2.69; 0.41]	-0,12	-1.33 [-2.84; 0.18]	-0,14	-1.19 [-2.66; 0.29]	-0,12

B-IPQ Understanding				#N/A	#N/A	#N/A	-0.24 [-1.71; 1.24]	-0,02	0.2 [-1.25; 1.64]	0,02	0.19 [-1.23; 1.61]	0,02
B-IPQ Emotional Response				#N/A	#N/A	#N/A	0.86 [-0.62; 2.33]	0,1	1.21 [-0.22; 2.65]	0,14	1.08 [-0.33; 2.49]	0,13
CEQ Expectancy									-1.64 [-2.45; -0.82]***	-0.25	-1.63 [-2.43; -0.83]***	-0.25
Preop PRWHE total score											0.36 [0.15; 0.57]***	0.25
R^2	0.03		0.04		0.14		0.18		0.23		0.26	
Adjusted R^2	0.00		0.00		0.10		0.11		0.16		0.20	
Sig. F-Change	0.41		0.26		<0.001		0.19		<0.001		0.001	

Abbreviations: B= unstandardized beta coefficient; β= standardized beta; CI= Confidence Interval; Ref= reference level; USO= ulnar shortening osteotomy; TFCC= Triangular Fibrocartilaginous Complex; PCS= Pain Catastrophizing Scale; PHQ= Patient Health Questionnaire; B-IPQ= Brief Illness Perception Questionnaire
*p<0.05; **p<0.01; ***p<0.001

Table S3: Correlation matrix of psychosocial variables of all 423 patients.

Variable	1	2	3	4	5	6	7	8	9	10
1 PCS score	1									
2 PHQ score	0,45	1								
3 B-IPQ Consequences	0,36	0,30	1							
4 B-IPQ Timeline	0,31	0,13	0,24	1						
5 B-IPQ Personal Control	-0,06	0,04	-0,02	0,08	1					
6 B-IPQ Treatment Control	-0,13	-0,10	-0,01	-0,21	-0,05	1				
7 B-IPQ Identity	0,29	0,19	0,51	0,30	-0,03	-0,03	1			
8 B-IPQ Concern	0,44	0,32	0,46	0,34	0,03	-0,06	0,46	1		
9 B-IPQ Understanding	-0,10	-0,03	0,07	-0,02	0,06	0,23	0,07	-0,06	1	
10 B-IPQ Emotional Response	0,52	0,51	0,48	0,26	0,05	-0,06	0,42	0,57	-0,03	1

Abbreviations: PCS= Pain Catastrophizing Scale= PHQ: Patient Health Questionnaire= B-IPQ: Brief Illness Perception Questionnaire

CHAPTER 9

General discussion

OUTLINE

Ulnar-sided wrist pain has historically been equated to a "black box" due to its anatomical complexity, insidious appearance, and diverse nature of chronic complaints.[1–4] As such, the diagnosis and treatment of ulnar-sided wrist pain are considered challenging parts of hand- and wrist care. Evaluating treatment outcomes might facilitate informed decision-making and improve care. In this thesis, we investigated the outcomes of ulnar-sided wrist surgery in different domains, including patient-reported functional status, return to work, complications, and reoperations. We also investigated the patient-reported functional outcomes in a psychosocial context. The focus was on ulna shortening osteotomy (USO), a surgical procedure used to treat ulna impaction syndrome (UIS). Below, we reflect on the main findings and limitations of the studies performed. Furthermore, we provide a set of take-home messages for informing patients and considerations for surgeons. Lastly, we propose suggestions for future research.

REFLECTION ON THE MAIN FINDINGS

Patient-reported outcomes: pain and function

Although the USO is considered the "reference standard" treatment for patients with UIS[5,6], the quality of data on the effectiveness of surgery was moderate to low.[5] Limitations of previous studies include a lack of preoperative data[7,8], usage of unvalidated or unreliable measurement tools[9,10], or relatively low sample size.[8,11–13] Therefore, we aimed to investigate the effectiveness of USO in improving patient-reported functional status (relieving pain and improving hand function, as measured with the Patient Rated Wrist/Hand Evaluation[14,15]) in the first year after surgery while keeping these limitations in mind in **Chapter 2**. We found that the USO improved the functional status in patients with UIS compared to baseline. Most improvements in functional status were seen in the first three months after surgery, with continued improvement at twelve months. Similar effect sizes were seen in patients with idiopathic and secondary UIS due to distal radius malunion. Therefore, we conclude that USO is an effective treatment in improving patient-reported functional status for both groups. However, it should be noted that patients with secondary UIS due to distal radius malunion were carefully selected in terms of displacement of the distal radius. In patients with a palmer inclination >10 degrees or >20 degrees dorsal inclination of the distal radius, there is increasing evidence that a distal radius correction might be a more feasible alternative.[16–18]

While we found a large improvement in patient-reported functional outcomes within the first year after surgery in **Chapter 2**, we had concerns that the patient-reported functional outcomes might decline at long-term follow-up as several studies reported the development and worsening of DRUJ osteoarthritis after USO.[7,10,19,20] Long-term patient-reported functional outcomes after USO were scarce as previous research mainly focused on radiographic outcomes[7,10,20], had small sample sizes[8,21], or used self-designed scoring systems without evidence concerning reliability, validity, and responsiveness.[20] Therefore, we investigated the long-term patient-reported functional outcome after USO in **Chapter 3** and compared this outcome with baseline and twelve months results. We found further statistical improvement between the mean twelve months and long-term (a median follow-up of six years) patient-reported functional outcomes. When looking at the individual patient level, we found that 21% of the patients reported the best possible outcome (no pain and no difficulties with hand activities) at long-term follow-up compared to only 6% at twelve months. Also, we learned that most patients who still had

considerable complaints at twelve months showed further improvement at long-term follow-up.

While some studies have reported good long-term functional outcomes after USO before[8,21,22], we have added information by relating the long-term outcomes to baseline and twelve-month results. We can conclude that surgeons generally do not need to be afraid of deterioration in patient-reported functional outcomes at late follow-up after USO in patients with UIS. There are several possible explanations for the improvement seen between twelve months and long-term follow-up:

1. First, the wrist might have to adapt to the change in biomechanics and DRUJ remodelling and recover from the damage done by the impaction and surgery.[23,24] This might take longer than one year for some patients.
2. The rehabilitation phase might be more prolonged in patients who need subsequent surgery for complications. For example, we found that patients who underwent refixation for a nonunion had worse functional outcomes at twelve months than those without nonunion. However, these patients showed a substantial improvement between their twelve months and long-term functional outcome.
3. Several patients (76%) underwent subsequent treatment between twelve months and long-term follow-up, including reoperations for recurrent/persistent pain (e.g., TFCC repair). The bulk of reoperations was for hardware removal. The additional treatments could have contributed to a continued improvement in functional outcomes.
4. The patients' internal pain and hand function standards could have changed over time. This phenomenon is called response shift bias.[25,26] For example, patients could have adjusted to their functional outcomes after surgery and have internally accepted inconveniences.

The average long-term functional outcomes were still worse than the sex-and age-matched value in the general Dutch population.[27] This might suggest that the patient population did not completely recover to a healthy wrist following USO. Our hypotheses for this observation are:

1. Damage that has been done preoperatively (such as chondropathy of the lunate bone) cannot completely be undone.

2. Not all coexisting pathology has been treated. These can be coexisting wrist pathologies such as osteoarthritis or ligament issues (discussed in the sections below)[28], or other unrelated elbow and shoulder conditions that interfere with the PROM questionnaire.
3. The psychosocial profile of the patients, such as high levels of pain catastrophizing and worse illness perception, might negatively impact the long-term patient-reported surgical outcome (discussed further below).

Grip strength and range of motion

We also analysed changes in clinician-reported outcome measures in terms of grip strength and range of motion in the first year after surgery in **Chapter 2**. We stratified our analysis based on the etiology of UIS and found statistically significant improvement in several domains of active range of wrist motion and grip strength in both groups. The improvement in grip strength was in line with the previous research.[5] However, the clinical relevance of the improvement in range of motion seems limited as its magnitude was similar to the measurement error of the goniometer for most directions.[29] Nonetheless, we can conclude that the gain in PROMS was not at the cost of the active range of motion.

Return to work

As hand and wrist function is integral to one's ability to work, time until return to work (RTW) is a vital outcome domain in hand surgery for patients and policymakers.[30] Nevertheless, after major ulnar-sided wrist surgeries such as USO and open TFCC repair, only a few studies have investigated the return to work.[19,22,31–33] Little is known about the prognostic factors for a delayed RTW after these surgeries. For example, it is unknown if there is a difference in RTW between freehand USO and USO using a dedicated osteotomy system while controlling for potential confounders. Furthermore, previous studies showed that RTW after upper extremity surgery is strongly influenced by the healthcare setting, such as whether the patients receive workers' compensation.[34,35] Therefore, we aimed to study the RTW following USO and TFCC repair in **Chapters 5 and 6** in the Dutch healthcare setting (described in detail in Chapters 5 and 6)**.**

We defined RTW as the first time the patient reported having resumed their usual work for a minimum of 50% of their weekly working hours. We chose the 50% cut-off since Dutch labour laws require patients to be able to perform less than 50% of their usual work to be allowed any form of compensation.[36] We found that most patients (92%) were able to return to their usual work during the first year after USO. Patients who did not return to their usual work generally reported having adjusted work during their last follow-up. The median time until RTW was 12 weeks. Our results regarding the timing of RTW are also similar to or faster than previous studies on RTW after USO.[12,22,32] This might be due to the difference in definitions used for RTW between studies, as there is no international consensus. Concerning prognostic factors for RTW, we found that the physical workload was associated with the timing of RTW, which is in line with previous research on prognostic factors for delayed RTW in hand/wrist surgery.[37,38] Neutel et al. reported that females took a longer time until RTW than males after traumatic hand injury, which we could not confirm for USO.[39] In agreement with previous research[32,33], we did not observe a difference between freehand USO and jig-guided USO.

Interestingly, we found a peak in RTW in the twelfth week after USO, which is similar to other major hand/wrist surgeries within our institution, such as TFCC repair and trapeziectomy with ligament reconstruction and tendon interposition.[37,38] This peak might be due to the planned control consult with the hand surgeons, which is also around the twelfth week. In the Netherlands, independent occupational physicians are responsible for instructions concerning RTW and the type of work that can be done. While surgeons should not interfere with these instructions, their advice on the type of tasks and load bearing could have influenced the decision to RTW. We hypothesize that some patients may want to be ensured by their treating surgeon that it is safe to RTW. As the annual healthcare costs are gradually rising[40], it is important to study whether we can reduce the costs of lost productivity after surgery. For example, earlier control consults after USO for patients with light work (e.g., ten instead of twelve weeks) might also be enough to ensure patients can safely resume their original work.

From our findings, we conclude that most patients can return to their usual work within the first year. The timing until RTW varies substantially between patients. The type of work partly explained this variation, but a considerable amount of the variation remains unexplained. Possible explanations for the remaining variation could be patient-related factors such as employment status (freelancer versus on payroll), involvement in medical claims[41], and psychosocial profile.[42] For example, in carpal tunnel release, psychosocial

factors such as anxiety and depression play an important role[42]; this may also apply in patients undergoing ulnar-sided wrist surgery.

The return to work after open TFCC repair was similar to the USO, with a median return to work of 12 weeks and a probability of 91% returning to usual work after one year. The type of work was also associated with RTW in this study.

Complications and reoperations

While USO generally results in beneficial outcomes, it should be balanced against drawbacks such as its rehabilitation period and complications. In the literature, there is a considerable variation in the types of complications reported after USO and how often they occurred. This might be due to inconsistent reporting methods, such as the different definitions or the period evaluated for complications. However, because most papers do not provide a detailed description of how complications were scored, more research was needed.[43] Therefore, in **Chapter 2**, we aimed to investigate the complications after USO using a new classification system especially constructed for hand/wrist surgery by the ICHOM Hand and Wrist working group.[30] Using this transparent classification system, we found that 64% of the patients experienced some kind of complication. Although this might be due to the stricter complication scoring system (every deviation from the expected recovery course is seen as a complication), high complications and reoperation rates have been published before.[43,44]

Three main reoperation categories after USO could be separated:

1. Hardware removal for patient complications such as painful/irritating hardware, wrist motion limitations, paraesthesias, or cold intolerance. This was the most common type of reoperations in our cohort, which is in line with the previous reports.[43–45] Because of its high incidence, this reoperation was further investigated in **Chapter 4,** which is discussed below.
2. Refixation for nonunion. Depending on the study sample (**Chapters 2 and 5**), we found nonunion rates of 6% and 12%. A systematic review from 2019 found a range in nonunion rates after oblique USO between 0% and 18%.[46] Our nonunion rates are somewhat higher than the pooled estimate of 4% (standard deviation of 5) from the meta-analysis.[46] In the limitation section below, we explain why we could not identify risk factors for nonunion after USO. However,

an interesting observation was that nonunion occurred in dynamic compression and in ulna shortening-specific designed plates. The meta-analysis by Owens found similar nonunion rates for dynamic compression and ulna shortening-specific designed plates.[46]

3. Subsequent surgery for recurrent/persistent ulnar-sided wrist pain. We found reoperation rates of 3% for recurrent/subsequent ulnar-sided wrist pain in the first 12 months after surgery **(Chapter 2**) and 11% at long-term follow-up (**Chapter 5**). A possible explanation for the need for subsequent ulnar-sided wrist surgery might be that coexisting pathology was not diagnosed and adequately managed during the first operation. Kakar and Garcia-Elias observed that "many patients have suboptimal outcomes after treatment of ulnar-sided symptoms owing to contributing pathologies" and have published a guiding algorithm to ensure that different components of ulnar-sided wrist pain are addressed. They expect that using this treatment algorithm will improve clinical outcomes[28]; also, it might avoid the need for subsequent treatment. Other explanations might be a wrong indication for the initial USO or the development of subsequent pathology after the first operation.

There was no consensus in the literature on whether there was an association between hardware removal and plate location[44,47–50] as some advocated anterior placement of the plate[48,51], while others favoured dorsal placement[47], or did not find a difference based on plate location.[44,49] Therefore, we investigated the association between plate location and hardware removal in **Chapter 4**, while controlling for potential confounding variables identified in previous studies.[44,52] We found that an anterior plate placement was independently associated with a 38% decreased instantaneous risk of hardware removal. We conclude that anterior placement of the fixation plate is preferable in reducing subsequent hardware removal. This might be due to the anatomical advantage of anterior placement with thicker soft tissue coverage over the hardware.[50] Also, the extensor carpi ulnaris may be prone to subluxation over a dorsal plate, which is unlikely for the flexor carpi ulnaris over an anterior plate. Despite the decreased relative risk of hardware removal, the five-year reoperation rate in the anterior group was still high (46% versus 64% for dorsal plating).

In The Netherlands, hardware removal is not routinely performed, but generally, the threshold is low.[53,54] Few reports have investigated complications associated with hardware removal after USO. Furthermore, it was unknown whether there was a

difference in complication rate after hardware removal based on the initial plate location. Therefore, **Chapter 4** investigated the complications following hardware removal. Using the ICHOM's classification system, we found that 20% of the patients had complications after hardware removal. While most complications could be treated with nonsurgical modalities, some complications needed reoperations, such as drainage of abscesses or hematoma, stitch removal, or refixation for refracture. We did not find a difference in the complication rate between the removal of anterior and dorsal plates. We conclude that surgeons and patients should know that hardware removal after USO carries a definitive risk of complications. This is in line with a recent study regarding 13089 hardware removal procedures in the United States, where a 9.6% complication rate was found.[55]

One-stage USO and 3-ligament tenodesis

Some patients present with coexisting UIS and scapholunate dissociation (SLD). Except for one case report in 2020[56], we could not find any literature on treatment strategies for these patients. In our institution, some of these patients were treated with a single-stage USO and three-ligament tenodesis (3LT). Combining these procedures might successfully address both pathologies, achieving a more satisfactory outcome and avoiding sequential procedures that might lead to extended rehabilitation and additional healthcare costs. On the other hand, safety risks should be considered; for example, a more extensive surgery might be associated with a higher incidence of complications or a more prolonged and painful recovery. Therefore, we aimed to describe this treatment strategy and to report the patient-reported functional outcomes, grip strength, and range of motion, return to work, acute postoperative pain, complications in **Chapter 7**. We found that these patients showed improvement in functional status in the first year after surgery (that was similar to patients with isolated pathology who underwent USO or 3LT). Interestingly, there were no reports of infection, hematoma, nonunion, or complex regional pain syndrome. We concluded that single-stage USO and 3LT could achieve favourable outcomes in patients with coexisting UIS and SLD.

The role of psychosocial factors on pain and function in ulnar-sided wrist surgery

While effort has been put into understanding ulnar-sided wrist complaints based on the anatomy and biomechanics[1,4,28], previous studies have shown that anatomical findings during diagnostic workups only partly relate to the amount of ulnar-sided wrist pain.[57–59] Psychosocial factors (such as pain catastrophizing, psychological distress, and illness perception) have been scarcely investigated in patients with ulnar-sided wrist pain. However, the relation between musculoskeletal pathology and patient-reported pain and dysfunction has been well established in patients with hip[60], thumb[61], and spine pathology.[62] Therefore, we studied various psychosocial aspects in patients scheduled for ulnar-sided wrist surgery in **Chapter 8**.

We found that psychosocial factors could explain a considerable amount (35%) of the variance in patient-reported pain and dysfunction before surgery in patients with ulnar-sided wrist pathology. Pain catastrophizing and illness perception were strongly associated with higher pain and dysfunction. This is in line with previous reports on other hand and wrist pathologies such as thumb base osteoarthritis[61], carpal tunnel syndrome[63], and Quervain's tenosynovitis.[64] We also found that patients with higher levels of pain catastrophizing had higher levels of pain and dysfunction twelve months after surgery. However, the mean improvement during the first year after surgery - although with a higher level of pain and dysfunction at baseline- did not seem to differ based on pain catastrophizing or anxiety and depression. These observations align with a previous study on chronic atraumatic wrist pathology that evaluated functional outcomes three months after surgery.[65] We have added information by showing this also applies to ulnar-sided wrist pathologies and at a longer follow-up duration. Lastly, patients with the highest expectation from treatment results had the best outcome after surgery. Previous reports also found that higher expectations of treatment outcome were associated with better patient-reported outcomes in non-operative treatment for first carpometacarpal osteoarthritis and surgical decompression in de Quervain's tenosynovitis.[66,67]

We conclude that patients with ulnar-sided wrist pain and a more negative psychosocial profile should not be withheld from surgical treatment as they show similar improvement in patient-reported pain and function. However, they might benefit from additional

psychosocial interventions.[68] Also, boosting expectations may improve functional outcomes in future patients.

LIMITATIONS

Some limitations should be acknowledged concerning the studies in this thesis.

The Hand and Wrist Cohort database is categorized on treatment instead of diagnosis. Therefore, we had to review patient charts to retrieve the indication for which the patients underwent the USO. We had to diagnose some patients retrospectively as the indication was not always explicitly stated in the charts, and USO might be used for multiple indications. This posed a challenging task as there is no international consensus on the definition of UIS with clear criteria. Therefore, we classified patients with UIS based on a spectrum of self-designed criteria taking previous articles in retrospect as having either idiopathic UIS or secondary UIS due to a distal radius malunion.[69–71] We excluded all patients who did not meet our criteria for UIS (e.g., patients who underwent USO for isolated DRUJ instability). We transparently reported our criteria for having UIS to inform readers better if the patients described in our paper also apply to their practice. While we think that most readers will agree with our definitions, our findings may not be entirely generalizable to practices of readers with stricter (e.g., a cyst must be present in the lunate bone) or looser definitions of UIS. This definition problem will partly be solved with the implementation of ICHOM's hand and wrist set, in which a patient's diagnosis will also be explicitly added to the dataset. Still, a clear international description of UIS is needed to improve the generalisability of findings and to compare them between studies.

This thesis lacks radiographic data. The absence of this data is due to the setting in which routine outcome data is collected during daily practice. Also, follow-up radiographs were made using an uncalibrated mobile C-arm. It would have been interesting to evaluate the Tolat classification and the development/worsening of DRUJ OA in our cohort and relate this to functional outcomes.[72] However, radiographs were made three months after USO to assess union, and additional radiographs were made on indication only. Analysing these radiographs would therefore have resulted in selection bias.

As described in this thesis's general introduction, there are many approaches and techniques to choose from when considering ulna shortening. We only had access to data

regarding diaphyseal oblique USO. Therefore, we could not compare our diaphyseal USO outcomes with other techniques, such as metaphyseal USO and wafer procedures. Previous research found comparable results between metaphyseal and diaphyseal USO[73], and between USO and wafer.[74] However, these studies were mostly of low to moderate quality regarding outcome measurement and sample size. As there is a lot of practice variation for USO, it may be unfeasible and time-inefficient to compare all variations in separate randomized controlled trials. An alternative to potentially identify a best practice might be to compare outcomes between different institutions (each with their standard practice) using the ICHOM Hand and Wrist standard set.[30]

We encountered considerable variation between patients in every outcome domain that we investigated. For example, some patients remained functional impaired, had complications or reoperations, or could not return to their usual work. In contrast, others had an excellent outcome and an uncomplicated speedy recovery. Ideally, we would like to investigate this variation by identifying risk factors using sophisticated models. However, studying risk factors for a poor outcome or rare adverse events (such as nonunion) after USO can be challenging because of the generally low sample sizes and relatively few cases in the field. This is reflected by the low number of studies that try to study the variability of outcomes after USO.[44,58,75] Sharing anonymized patient-level data between institutions may facilitate future meta-analyses. Other types of collaborative research in hand surgery are also emerging.[76]

Lastly, as data were collected during daily practice and participation in the routine outcome measurement system is voluntary[77], we had missing data in patient-reported and clinician-reported outcomes. Missing data can potentially bias the results from analyses and decrease the generalisability of our findings. Therefore, we used more sophisticated tests, such as linear mixed models, to provide unbiased estimates. While previous research showed that multiple imputations do not add to linear mixed models[78], the missing data still had to be missing at random. In order to test this, we performed extensive missing data analyses for all our primary outcome measures using Little's test and comparing baseline data between patients with and without follow-up data.[79] As these analyses indicated that data were largely missing completely at random, we think our estimates are valid. However, future research would benefit from higher response rates, providing more precise measurements. We elaborate further on this in the future perspectives section of this chapter.

A LONG STORY SHORT: PUTTING IT TOGETHER

While ulna shortening osteotomy was performed as early as 1941 by Milch[80], substantial evidence on the outcomes after surgery using a standardized toolbox of high-quality measurement systems was lacking. The methodology used in this thesis has been similar to the Hand and Wrist standard set that was later introduced by the International Consortium for Health Outcomes Measurement (ICHOM).[30] This set of outcomes was agreed upon as essential in patients undergoing wrist treatment by a large international consortium of experts. Data were routinely collected during daily practice in a multicentre setting in the Netherlands[77,81], which added to the generalizability of our findings. All research proposals were checked by the Hand Wrist Study Group's management team and subsequently discussed in a multidisciplinary "lab meeting", including hand surgeons, hand therapists, and epidemiologists before conducting the study.

Informing patients during the shared decision-making process based on our data

- Generally, patients with ulna impaction syndrome can expect a relevant improvement in pain and hand function, which is already noticeable in the first three months after ulna shortening osteotomy and seems long-lasting at late follow-up.
- Patients must be aware of severe complications after ulna shortening osteotomy, such as nonunion (6-12%). Also, they need to be informed that plate irritation is common, and hardware removal is often performed (46%-64% based on plate location).
- The patient should know that hardware removal has a risk of complications, including infection (1%) and postoperative bleeding (3%). Besides the complications associated with surgery, the ulna may also be at greater risk of refracture (2%).
- More than 50% of the patients returned to their usual work within the first 12 weeks after surgery. The return to usual work within the first year was 92%.

Considerations for surgeons

- The reoperation rate for hardware removal was significantly lower in patients with anterior plating compared to dorsal plating. Anterior plating might reduce the risk of reoperations after ulna shortening osteotomy in future patients.
- The more expensive ulna shortening-specific designed plates were not superior to simple dynamic compression plates in terms of return to usual work and hardware removal rates. Furthermore, nonunion was observed in both techniques.
- Some patients present with ulna impaction syndrome and scapholunate dissociation. Single-stage treatment of ulna shortening osteotomy and three-ligament tenodesis can be an adequate treatment strategy for these patients.
- Patients with the highest treatment expectations had the best outcome from ulnar-sided wrist surgery. This indicates that boosting treatment expectations during the consultation might improve outcomes for future patients.

FUTURE PERSPECTIVES

We investigated treatment outcomes for USO, which is only one piece of the puzzle: the treatment of ulnar-sided wrist pathology. In the next couple of years, the Hand and Wrist Cohort dataset will continue to grow as all patients who visit Xpert Clinics will continue to be invited to participate in the routine outcome measurement system. Also, with the implementation of the ICHOM Hand and Wrist standard set, even more data (i.e., nonsurgical modalities) will become available. This data will offer exciting possibilities for further research in treating ulnar-sided wrist pathology.

Three research lines that are closely linked to each other could be investigated. First, additional analyses for USO could be performed when the amount of data grows. For example, we could build more complex models to investigate the variability in outcomes between patients. These models might identify risk factors for a poor clinical outcome or adverse events such as nonunion. Also, we might move toward individualized shared-decision making instead of providing information on a group level. Second, the outcomes of surgical alternatives treating UIS, such as the wafer procedure, can be investigated and compared. While previous studies have already compared outcomes between these two interventions, a recent systematic review concluded that only moderate-quality evidence was available.[74] Re-evaluating this comparison using high-quality outcome data might

provide new insights. Third, we will be able to evaluate ulnar-sided wrist pathology from a broader perspective. For example, by studying all patients with UIS who visit the clinic instead of the subgroup of patients who underwent USO, we can evaluate the diagnostic workup, the success rate of nonsurgical modalities, and conversion rates to major surgery. By comparing different workflows in terms of diagnostic modalities and subsequent treatment strategies, we hope to find a best practice. Eventually, we aim to develop a comprehensive guideline for managing ulnar-sided wrist pathology, as it is currently lacking in The Netherlands.

CLOSING REMARK

We are entering a new era of "big data research" in hand surgery, of which PROMs have become integral.[30] While randomized clinical trials will always have a place in the scientific landscape, academics and clinicians are starting to see the added value of routine outcome measurement registries. However, the quality of research that can be performed with registry data depends on the quality of data collection (the rubbish in = rubbish out principle). Using PROMs, patients are mainly responsible for the data quality we analyse. Response fatigue can be a serious problem, leading to incomplete or inaccurately completed forms.[82] Response fatigue might happen when it becomes too much of a burden for patients to fill in the questionnaires, which might be the case when questionnaires are long or when multiple questionnaires are administered as a battery. For example, six questionnaires are used in an extended ICHOM wrist track to evaluate treatment outcomes at multiple time points.[30] Therefore, reducing the number of items in a questionnaire might be a necessary step to take. Previous research has shown that this can be done successfully with hand surgery questionnaires.[83–85] By making shortened forms for the ICHOM hand questionnaires (together with the initial PROM developers), we can potentially tackle response fatigue. This might boost response rates, avoid incorrect responses, and achieve higher-quality routine outcome measurement data.

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CHAPTER 10

General summary

Ulnar-sided wrist pain has historically been equated to the "black box" of hand and wrist conditions due to its anatomical complexity, insidious appearance, and diverse nature of chronic complaints.[1–5] As such, the diagnosis and treatment of ulnar-sided wrist pain are considered challenging parts of hand- and wrist care. Evaluating treatment outcomes might facilitate informed decision-making and improve care.

In this thesis, we investigated the outcomes of ulnar-sided wrist surgery in different domains considered essential in hand and wrist surgery by an international consortium of experts (International Consortium for Health Outcomes Measurement; ICHOM).[6] Furthermore, the safety of combining two major wrist surgeries in a single-stage procedure was investigated. We also explored the relationship between ulnar-sided wrist symptoms and psychosocial parameters. The focus was on ulna shortening osteotomy (USO), a surgical procedure used to treat ulna impaction syndrome (UIS). Data for these studies were routinely collected at Xpert Clinics, a multicentre institution for hand and wrist surgery in the Netherlands. In the following sections, the main findings are summarised.

The effectiveness of USO in relieving pain and improving hand function has only been scarcely investigated using patient-reported outcome measures (PROMs). Studies comparing preoperative and predetermined postoperative scores are even more scarce. Also, it is unknown whether outcomes differ based on the etiology of UIS. Therefore, in **Chapter 2**, we studied the effectiveness of USO in patients with idiopathic and secondary UIS using the Patient Rated Wrist Hand Evaluation (PRWHE)[7], which is the recommended PROM for this treatment by ICHOM.[6] PROM scores, active range of motion, and grip strength were measured at baseline and 3 and 12 months after USO. In a sample of 106 patients with UIS, we found a significant improvement in the PRWHE total score after twelve months, with most improvements in the first three months. The mean improvement exceeded the minimal important change, meaning that the improvement was clinically relevant. Similar effect sizes were seen in patients with idiopathic UIS and with UIS secondary to a distal radius malunion. While no clinically relevant changes in the active range of motion were measured, grip strength improved after surgery. When analysing complications, we found that hardware-related problems were common: 47% experienced painful irritation or functional problems from the plate. Furthermore, 6% had a nonunion that healed after subsequent treatment. We concluded that USO is an effective treatment in relieving pain and increasing hand function in

patients with UIS; however, some residual symptoms remain, and hardware irritation is common.

Multiple studies highlight that osteoarthritis of the distal radioulnar joint may worsen or develop several years after USO.[8–11] Therefore, we were interested in whether the promising short-term PROMs found in **Chapter 2** were sustainable over time or worsened. We sent various questionnaires, including the PRWHE, to patients who underwent USO minimally four years ago. This prospective observational study on 66 patients with UIS is discussed in **Chapter 3**. We found that the PRWHE scores showed continued improvement from twelve months postoperatively to the (mean) six-year follow-up. 88% of the patients reported that they would undergo the same treatment again under similar circumstances. The long postoperative rehabilitation phase was the main reason some patients would not undergo the same treatment again. Furthermore, 78% of the patients underwent subsequent treatment due to complications or recurrent complaints, mainly for hardware irritation (64%). We concluded that USO improves patient-reported pain and function that seems sustainable at late follow-up. While satisfaction levels are generally high, reoperations such as hardware removal are common.

After taking note of the high incidence rates of hardware removal in **Chapter 2** and **Chapter 3**, we further investigated the cumulative incidence of hardware removal after USO in **Chapter 4**. We considered several patient-related and surgeon-related factors potentially associated with hardware removal in a relatively large cohort of 321 patients. Additionally, we reported on the complications after hardware removal. Of the patient-related factors, we found that lower age, female sex, and treatment side of the non-dominant side were independently associated with hardware removal. More interestingly, we found that anterior placement of the fixation plate was independently associated with a 38% decreased instantaneous risk of hardware removal compared to dorsal placement. Furthermore, we found that hardware removal was not without risk, as 20% of the patients experienced a complication, varying from the need for additional analgesics to the refracture of the ulna (2%). There was no difference in complication rates after hardware removal based on the initial plate location. We suggest that surgeons place the fixation plate at the anterior side of the ulna to decrease the risk of reoperation for hardware removal. Also, surgeons could use patient-related factors when informing patients about hardware removal.

The return to usual work (RTW) after USO was described in 111 patients with paid work prior to surgery in **Chapter 5**. Furthermore, we explored potential patient-related and surgeon-related risk factors associated with a delayed return to work. After 12 months, 92% of the patients had returned to their usual work after a median of 12 weeks. The type of work was independently associated with the duration until return to work, in which patients with heavier workloads returned to usual work later. We did not find a difference in RTW between patients who underwent a freehand USO or a jig-assisted USO. **Chapter 6** described the return to work after open triangular fibrocartilage complex (TFCC) reinsertion in 310 patients using the same methodology. In these patients, we found that 91% had returned to their usual work after one year, with a median duration of 12 weeks. As in our study on USO, the type of work was independently associated with the duration until return to work. Next to the physical workload, we found that younger age, female sex, and higher PRWHE score at baseline were independently associated with a delayed return to work. We conclude that most patients returned to their usual work after these major wrist surgeries, but a median time of 12 weeks of sick leave can be expected. Surgeons can use the identified risk factors for a delayed return to work to more accurately inform the patient about the rehabilitation phase and manage expectations.

Some patients at Xpert Clinics presented with combined UIS and scapholunate dissociation (SLD). Literature regarding the treatment for this combination of pathologies is scarce. We found one case report from 2020 reporting a successful single-stage USO and 3LT.[12] Combining these procedures might successfully address both pathologies, achieving a more satisfactory outcome and avoiding sequential procedures that might lead to extended rehabilitation and additional healthcare costs. On the other hand, safety risks should be considered; for example, a more extensive surgery might be associated with a higher incidence of complications or a more prolonged and painful recovery. Therefore, **Chapter 7** investigated the outcomes of single-stage USO and 3LT in 53 patients with combined UIS and SLD using similar methods as in **Chapter 2** and **Chapter 5**. We found an improvement in the patient-reported functional status after surgery. Grip strength improved to 90% of the contralateral side at 12 months, and the median return to work was 15 weeks. There were no cases of infection, nonunion, or complex regional pain syndrome. No reoperations were performed other than hardware removal. We conclude that single-stage USO and 3LT is safe and can provide satisfactory outcomes in patients with ulna impaction syndrome and scapholunate dissociation. We propose to combine these procedures to avoid two subsequent surgeries.

Although it is becoming more apparent that psychosocial factors are associated with symptom severity and surgical outcome for several musculoskeletal disorders, this has not been investigated in ulnar-sided wrist pathologies. Therefore, in **Chapter 8**, we examined the role of pain catastrophizing, anxiety and depression, and illness perception on patient-reported pain and dysfunction in 423 patients scheduled for ulnar-sided wrist surgery (either USO, TFCC repair, or pisiformectomy). Furthermore, we investigated to what extent the psychosocial profile was associated with the outcome of surgery after 12 months in 253 patients. We found that the psychosocial profile was strongly associated with the amount of patient-reported pain and function at baseline, explaining 35% of the variance. A more negative psychosocial profile was associated with higher pain levels and dysfunction at baseline. The association was also present in the 12-month outcome, although less apparent (18%). Interestingly, a more negative preoperative psychosocial profile did not diminish the improvement after surgical treatment, as a similar benefit was found compared to patients with a more positive profile. Patients with the highest expectations from the treatment results reported the best outcome after 12 months. We concluded that clinicians should be aware of the interplay between psychosocial factors and symptoms in patients with ulnar-sided wrist disorders. However, patients should not be withheld from surgical treatment based solely on their preoperative psychosocial profile.

In **Chapter 9**, we discussed this thesis's main findings and limitations. We provided a set of take-home messages for informing patients and considerations for clinicians. Lastly, we proposed suggestions for future research.

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CHAPTER 11

Nederlandse samenvatting

Ulnaire polsklachten worden van oudsher gezien als de 'black-box' van de hand- en polsaandoeningen vanwege de anatomische complexiteit en de uiteenlopende aard van chronische klachten.[1–5] De diagnose en behandeluitkomsten worden als zodanig beschouwd als een uitdagend onderdeel van de hand- en pols zorg. Het beoordelen van behandeluitkomsten kan bijdragen aan een betere voorlichting voor patiënten, een meer weloverwogen gezamenlijke besluitvorming en aan het verbeteren van de zorg.

In dit proefschrift hebben we de uitkomsten van ulnaire polschirurgie onderzocht op verschillende domeinen die door een internationaal consortium van experts (International Consortium for Health Outcomes Measurement; ICHOM) als essentieel worden beschouwd binnen de hand- en polschirurgie.[6] Verder is de veiligheid van het combineren van twee grote polsoperaties in één procedure onderzocht. Ook onderzochten we de relatie tussen ulnaire polssymptomen en psychosociale parameters. De focus lag op ulnaverkortings osteotomy (USO), een chirurgische ingreep die met name gebruikt wordt voor de behandeling van het ulna impactie syndroom. Gegevens voor deze onderzoeken werden routinematig verzameld bij Xpert Clinics, een multicenter-instelling voor hand- en polschirurgie in Nederland. In de volgende alinea's worden de belangrijkste bevindingen samengevat.

De effectiviteit van de ulnaverkorting om pijn te verlichten en hand functie te verbeteren is amper geanalyseerd met behulp van gevalideerde patiënt gerapporteerde uitkomstmaten (PROMs). Studies die de gezondheidsstatus met PROMs voor en na de ulnaverkorting vergelijken zijn nog schaarser. Ook was het niet bekend of de oorzaak van het ulna impactie syndroom een rol speelt op de uitkomst van de ingreep. Daarom hebben we in **Hoofdstuk 2** de effectiviteit van de ulnaverkorting bestudeerd in patiënten met idiopathische ulna impactie en ulna impactie secundair aan een distale radius fractuur met behulp van de Patient Rated Wrist Hand Evaluation (PRWHE)[7]. De PRWHE is de door ICHOM aanbevolen PROM voor het evalueren van polsbehandelingen.[6] De PROM-scores, knijpkracht, en actieve bewegelijkheid van de pols werden gemeten op baseline en vervolgens op 3 en 12 maanden na de behandeling. In onze steekproef van 106 patiënten met ulna impactie vonden we een significante verbetering in de PRWHE-score na 12 maanden, waarin het grootste deel van de verbetering al optrad gedurende de eerste 3 maanden na de operatie. De gemiddelde verbetering niet alleen statistisch significant maar ook klinisch relevant was. Vergelijkbare effect groottes werden gezien bij patiënten met idiopathische ulna impactie of ulna impactie secundair aan een distale radius malunion. Hoewel we geen klinisch

relevante verandering zagen in actieve bewegelijkheid van de pols nam de knijpkracht wel toe na de operatie. Bij het analyseren van de complicaties zagen we dat irritatie van het fixatiemateriaal heel gebruikelijk was: 47% van de patiënten ervoer pijn of functionele problemen van de plaat. Bovendien had 6% van de patiënten een non-union, die genas na verdere behandeling. We concludeerden dat de ulnaverkorting een effectieve behandeling is om pijnklachten te verminderen en handfunctie te verbeteren in patiënten met ulna impactie; echter, patiënten kunnen restklachten ervaren en irritatie van het fixatiemateriaal is gebruikelijk.

Verscheidene studies merken op dat er artrose in het polsgewricht kan ontstaan na een ulnaverkorting of dat deze toe kan nemen.[8–11] Daarom waren we geïnteresseerd in de vraag of de veelbelovende kortetermijns PROMs die we vonden in **Hoofdstuk 2** op de langere termijn aanhielden of waren verslechterd. Daartoe stuurden we verscheidene vragenlijsten, inclusief de PRWHE, naar patiënten die minimaal vier jaar geleden een ulnaverkorting ondergingen. Deze studie van 66 patiënten met ulna impactie wordt besproken in **Hoofdstuk 3**. We vonden dat de PRWHE-scores een aanhoudende verbetering lieten zien vanaf twaalf maanden postoperatief tot de (gemiddelde) follow-up van zes jaar. 88% van de patiënten gaf aan dat ze de behandeling nogmaals zouden kiezen onder vergelijkbare omstandigheden. De lange postoperatieve revalidatiefase was de belangrijkste reden waarom sommige patiënten niet opnieuw dezelfde behandeling zouden ondergaan. Verder onderging 78% van de patiënten een vervolgbehandeling vanwege complicaties of terugkerende klachten, voornamelijk voor hardware-irritatie (64%). We concludeerden dat ulnaverkorting de door de patiënt gerapporteerde pijn en functie verbetert die duurzaam lijkt bij late follow-up. Hoewel de tevredenheid over het algemeen hoog is, zijn vervolgoperaties zoals het verwijderen van hardware gebruikelijk.

Nadat we in **Hoofdstuk 2 en 3** kennis hadden genomen van de hoge cumulatieve incidentie van het verwijderen van het osteosynthesemateriaal na een ulnaverkorting, onderzochten we dit verder in **Hoofdstuk 4**. We onderzochten de associatie tussen verscheidene patiënt- en chirurg gerelateerde factoren met het verwijderen van osteosynthesemateriaal in een relatief groot cohort van 321 patiënten. Daarbij rapporteerden we ook de complicaties volgend op het verwijderen van het osteosynthesemateriaal. Van de patiënt gerelateerde factoren vonden we dat een lagere leeftijd, vrouwelijk geslacht, en behandeling van de niet-dominante zijde onafhankelijk geassocieerd waren met het verwijderen van het osteosynthesemateriaal. Interessanter was dat we vonden dat een anterieure plaatsing van de fixatieplaat onafhankelijk

geassocieerd was met een 38% verminderd risico op een vervolgoperatie om het osteosynthesemateriaal te verwijderen vergeleken met dorsaal geplaatste fixatieplaten. Verder vonden we dat het verwijderen van het osteosynthesemateriaal niet zonder risico was aangezien 20% van de patiënten een complicatie ervoer; variërend van de behoefte tot extra pijnstillers tot een herfractuur van de ulna (2%). Er was geen verschil in het optreden van complicaties na het verwijderen van het osteosynthesemateriaal op basis van de oorspronkelijke plaatlocatie. Wij raden chirurgen aan om de fixatieplaat op de volaire zijde van de ulna plaatsen om het risico op een vervolgoperatie vanwege irriterend osteosynthesemateriaal te verkleinen. Verder kunnen chirurgen de patiënt gerelateerde factoren gebruiken om patiënten te informeren over het verwijderen van osteosynthesemateriaal.

De terugkeer naar oorspronkelijke werkzaamheden (werkhervatting) na een ulnaverkorting werd beschreven in een groep van 111 patiënten met betaald werk voorafgaand aan de ingreep in **Hoofstuk 5**. Verder onderzochten we potentiële patiënt- en chirurg gerelateerde risicofactoren voor een vertraagde werkhervatting. Op 12 maanden na de ulnaverkorting was 92% van de patiënten weer teruggekeerd naar hun oorspronkelijke werkzaamheden na een gemiddeld ziekteverlof van 12 weken. Het soort werk was onafhankelijk geassocieerd met de duur tot aan de werkhervatting, waarbij patiënten met fysiek zwaarder werk later terug keerden naar hun oorspronkelijke werkzaamheden. We vonden geen verschil in werkhervatting tussen patiënten die een ulnaverkorting ondergingen middels een “freehand” techniek of met een zaagmal. In **Hoofdstuk 6**, beschrijven we de werkhervatting na open herstel van het TFCC in een groep van 310 patiënten gebruikmakend van dezelfde methodiek als in **Hoofdstuk 5**. 91% van de patiënten hervatten hun oorspronkelijke werkzaamheden gedurende het eerste jaar na de ingreep met een gemiddeld ziekteverlof van 12 weken. Net als in onze studie over de ulnaverkortingen was het soort werk onafhankelijk geassocieerd met de duur tot aan de werkhervatting. We vonden dat, naast het soort werk, jongere leeftijd, vrouwelijk geslacht en hogere PRWHE-score voorafgaand aan de ingreep onafhankelijk geassocieerd waren met een vertraagde duur tot aan werkhervatting. We concluderen dat de meeste patiënten in staat zijn hun oorspronkelijke werkzaamheden op te pakken na deze grote ulnaire polsoperaties, maar dat rekening gehouden moet worden met een gemiddeld ziekteverlof van 12 weken. Chirurgen kunnen de geïdentificeerde risicofactoren voor een vertraagde werkhervatting gebruiken om patiënten nauwkeuriger te informeren over de rehabilitatiefase en de verwachtingen te managen.

Sommige patiënten bij Xpert Clinics vertoonden gecombineerde ulna impactie en scapholunaire dissociatie (SLD). Literatuur over de behandeling van deze combinatie van pathologieën is schaars. We vonden één casus uit 2020 waarin melding werd gemaakt van een succesvolle eenfase-operatie van een ulnaverkorting en 3-ligament tenodese.[12] Door deze procedures te combineren, kunnen beide pathologieën potentieel met succes worden aangepakt, een bevredigender resultaat worden bereikt en opeenvolgende procedures worden vermeden die kunnen leiden tot langdurige revalidatie en extra zorgkosten. Aan de andere kant moeten veiligheidsrisico's worden overwogen; een uitgebreidere operatie kan bijvoorbeeld gepaard gaan met een hogere incidentie van complicaties of een langduriger en pijnlijker herstel. Daarom onderzocht **Hoofdstuk 7** de uitkomsten van eenfase ulnaverkorting en 3LT bij 53 patiënten met gecombineerde ulna impactie en SLD met behulp van vergelijkbare methoden als in **Hoofdstuk 2** en **Hoofdstuk 5**. We vonden een verbetering in de door de patiënt gerapporteerde functionele status na de operatie. De grijpkracht verbeterde tot 90% van de contralaterale zijde na 12 maanden, en de mediane terugkeer naar het werk was 15 weken. Er waren geen gevallen van infectie, non-union of complex regionaal pijnsyndroom. Er werden geen vervolgoperaties uitgevoerd anders dan het verwijderen van het osteosynthesemateriaal. We concluderen dat eenfase ulnaverkorting en 3LT veilig is en bevredigende resultaten op kunnen leveren bij patiënten met een gecombineerde ulna impactie en SLD. We stellen voor om deze procedures te combineren om twee opeenvolgende operaties te vermijden.

Hoewel het steeds duidelijker wordt dat psychosociale factoren geassocieerd zijn met de ernst van de symptomen en de chirurgische uitkomst van verschillende aandoeningen van het bewegingsapparaat, is dit niet onderzocht bij ulnaire polsaandoeningen. Daarom onderzochten we in **Hoofdstuk 8** de rol van pijn catastroferen, angst en depressie, en ziekteperceptie op door de patiënt gerapporteerde pijn en hand functie bij 423 patiënten die ingepland waren voor een ulnaire polsoperatie (ofwel ulnaverkorting, open herstel van het TFCC of pisiformectomie). Verder hebben we onderzocht in hoeverre het psychosociale profiel geassocieerd was met de uitkomst van een operatie na 12 maanden bij 253 patiënten. We vonden dat het psychosociale profiel sterk geassocieerd was met de mate van pijn en hand functie op baseline, wat 35% van de variatie verklaarde. Een negatiever psychosociaal profiel was geassocieerd met hogere pijnniveaus en disfunctie op baseline. De associatie was ook aanwezig bij de uitkomst na 12 maanden, hoewel minder uitgesproken dan op baseline (18%). Interessant is dat een negatiever

preoperatief psychosociaal profiel geen afbreuk deed aan de verbetering na chirurgische behandeling, aangezien een vergelijkbaar voordeel werd gevonden in vergelijking met patiënten met een positiever profiel. Patiënten met de hoogste verwachtingen van de behandeling rapporteerden het beste resultaat na 12 maanden. We concludeerden dat clinici zich bewust moeten zijn van de wisselwerking tussen psychosociale factoren en symptomen bij patiënten met ulnaire polsaandoeningen. Patiënten moeten echter niet worden onthouden van een chirurgische behandeling enkel op basis van hun preoperatieve psychosociale profiel.

In **Hoofdstuk 9** hebben we de belangrijkste bevindingen en beperkingen van dit proefschrift besproken. We hebben een reeks “take-home” conclusies verstrekt om patiënten te informeren en overwegingen voor clinici. Tot slot hebben we suggesties gedaan voor toekomstig onderzoek.

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APPENDICES

Research data management

Authors and affiliations

List of publications

Portfolio

Curriculum vitae

Dankwoord

Research data management

The data used in this PhD thesis were handled using the FAIR Data Principles[1]. All studies of this thesis were performed with data from the Hand and Wrist Cohort, which were routinely collected during daily care in the Xpert Clinics and Xpert Handtherapie, The Netherlands. The cohort and data collection process have been extensively described and published previously by senior authors of the research group.[2,3]

Xpert Clinics is a multicentre institution for hand and wrist surgery and therapy in the Netherlands. Since 2011, all patients visiting the Xpert Clinics are invited to participate in a routine outcome measurement system to monitor patients and evaluate their treatment outcomes. Upon agreement, patients receive questionnaires using GemsTracker (Generic Medical Survey Tracker, Erasmus MC & Equipe Zorgbedrijven) electronic data capture tool[4]. GemsTracker is a secure open-source web-based application for the automatic distribution of questionnaires and forms during clinical research and quality registrations. Patients also undergo measurement of grip strength and range of motion by certified Hand therapists at prespecified time points.[2]

All data acquired from the questionnaires and clinical measurements are stored in PULSE (https://pulse.equipezorgbedrijven.nl). To ensure data safety, measurements are administered using methods similar to those in electronic patient records, including annual audits and tests, two-way authentication login, and logging and monitoring of all activity.

The Pulse dataset is comprised of 8 measurement tracks (Wrist Regular & Wrist, Finger Regular & Extended, Thumb Regular & Extended, Nerve decompression, and Dupuytren), containing data on (1) Medical, demographic and psychological characteristics of patients; (2) Details on the type of treatment; (3) Patient Reported Outcomes Measurement (PROM), and Clinician Reported Outcome Measurement (CROM) data measured at baseline, 6 weeks, 3, 6 and 12 months after the start of treatment; and (4) Description of experiences during the healthcare process (PREM data)[2]. The amount of data collected for each treatment is available on the website (https://www.handwriststudygroup.org/data-content).

This thesis only incorporated data from the measurement track “Pols lang”, exported from PULSE as datasets with pseudonymized patient identifiers by the Xpert Clinics data manager. Data on workup (e.g., findings during anamneses, physical examination, and

imaging), surgical specifics, and complications were manually collected from the electronic patient dossiers (EPD) and saved in Microsoft Excel files. Patient identifiers were provided by the data manager on request only after the Hand and Wrist Management Team approved the research proposals. All data files were locally stored on a Bitlocker encrypted hard drive, on which data could be read with the correct encryption keys.

Excel/SAV/R- files were loaded into Rstudio, where patient selection and analysis were performed. The R scripts were shared on the software development platform GitHub "PulseR" workspace to ensure transparency and interpretability of the data. These scripts are accessible by researchers of the Hand Wrist Study Group (incorporating researchers from Xpert Clinics, Radboudumc, and Erasmus MC).

This thesis is based on the results of human studies, which were conducted following the principles of the Declaration of Helsinki. The Erasmus University Medical Center ethics committee approved study protocols for collecting and analysing Hand and Wrist Cohort data.

The pseudonymized datasets, R scripts for data analyses, final versions of the manuscript, and published PDFs are available at the Digital Research Environment (DRE) (https://mydre.org/). This is a cloud-based, globally available research environment where data can be safely stored. The files are indexed per research project on the virtual machine "dws334ULNACTNserver1" (joris.teunissen@mydre.org) that the Radboud University Medical Centre owns. The folder used in this thesis are: /data/Outcomes of ulna shortening osteotomy; /data/Long-term outcomes ulna shortening osteotomy; /data/RTW ulna shortening osteotomy; /data/Hardware removal after ulna shortening osteotomy; /data/Combined treatment of ulna shortening osteotomy and three-ligament tenodesis; and /data/Impact of psychosocial variables.

The research data of this thesis will be saved for 15 years after publication (until 2037). The datasets analysed for each study in this thesis are available upon reasonable request.

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List of publications

1. **Teunissen JS**, Wouters RM, Shaer S Al, Zöphel OT, Vermeulen GM, Hovius SER, et al. Outcomes of ulna shortening osteotomy: a cohort analysis of 106 patients. J Orthop Traumatol 2022;(23):1.

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PhD portfolio of J.S. Teunissen

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PhD Co-supervisor: **Dr. E.P.A. van der Heijden**

Training activities	Hours
Courses	
- NIHES - Biostatistical Methods I: Basic Principles (CE01) (2018)	159.60
- NIHES - Biostatistical Methods II: Classical Regression Models (EP03) (2018)	120.40
- NIHES - Principles in Causal Inference (EP01) (2018)	39.20
- NIHES - Clinical Epidemiology (CE02) (2018)	103.60
- NIHES - Clinical Translation of Epidemiology (CE01) (2018)	56.00
- NIHES -Study design (CC01) (2018)	120.40
- NIHES - Value-Based Healthcare, from theory to implementation (ESP76) (2018)	19.60
- NIHES - The Practice of Epidemiologic Analysis (ESP65) (2018)	19.60
- NIHES - Fundamentals of Medical Decision Making (ESP70) (2018)	19.60
- NIHES - Methods of Public Health Research (ESP11) (2018)	19.60
- NIHES - Principles of Research in Medicine and Epidemiology (ESP01) (2018)	19.60
- NIHES - Clinical Trials (ESP14) (2018)	19.60
- NIHES - Advanced topics in Decision-making in Medicine (EWP02) (2018)	67.20
- NIHES - Joint Models for Longitudinal and Survival Data (ESP72) (2019)	19.60
- NIHES - Health Economics (ESP25) (2019)	19.60
- NIHES - Introduction to Bayesian Methods in Clinical Research (ESP68) (2019)	39.20
- NIHES - Markers and Prediction Research (ESP62) (2019)	19.60
- NIHES - Topics in Meta-analysis (ESP15) (2019)	19.60
- NIHES - Missing Values in Clinical Research (EP16) (2019)	47.60
- NIHES - Repeated Measurements in Clinical Studies (CE08) (2019)	47.60
- NIHES - Quality of Life Measurement (HS11) (2019)	25.20
- NIHES - Intermediate course in R (BST02) (2019)	39.20
- RIHS – Introduction course for PhD candidates (2019)	15.00
- Radboudumc – Scientific integrity course (2019)	20.00
- EARP – Erasmus MC Anatomy Research Project: upper extremity (2019)	40.00
- NIHES - Advanced Analysis of Prognosis studies (EWP13) (2020)	25.20
- NIHES - Advanced Clinical Trials (EWP10) (2020)	53.30
- NIHES - Scientific Writing in English for Publication (SC07) (2020)	56.00
- NIHES - Pharmaco-epidemiology and Drug Safety (EWP03) (2020)	53.20
- Radboudumc – eBROK (for Radboudumc researchers working with human subjects) (2022)	42.00
- Dept of Plastic Surgery, Radboudumc – Education (2019-2022)	100.00
Seminars	
- VCA – Nijmegen, The Netherlands (2021)	3.00
- Invited lecture (oral presentation) – A long story short: Outcomes of ulna shortening osteotomy (Clinical trials unit, University of Warwick, Warwick, UK) (2022)	15.00
- Invited lecture (oral presentation) – A long story short: Outcomes of ulna shortening osteotomy (Dept of Plastic Surgery, Stoke Mandeville Hospital, Aylesbury, UK) (2022)	15.00
- Invited lecture (oral presentation) – A long story short: Outcomes of ulna shortening osteotomy & Studyathon Oxford (Dept of Plastic Surgery, Erasmus University Rotterdam, Rotterdam, The Netherlands) (2022)	15.00

Conferences	
- NOV - 's Hertogenbosch, The Netherlands (2017)	8.00
- IFSSH - Berlin, The Netherlands (2019)	30.00
Return to work following trapeziectomy with LRTI for basal thumb osteoarthritis (oral presentation)	15.00
- PhD Retreat – `s Hertogenbosch, The Netherlands (2019)	16.00
- FESSH - Basel, Switzerland (2020)	4.00
Patient-reported outcomes of ulnar shortening osteotomy for malunited distal radius fractures (oral presentation)	15.00
Plate location and the prevalence of hardware removal after ulnar shortening osteotomy: a systematic review and meta-analysis (oral presentation)	15.00
- FESSH - Rotterdam, The Netherlands (2021)	16.00
The prevalence, incidence, and progression of basal thumb osteoarthritis in the general population (oral presentation)	15.00
Return to work following ulnar shortening osteotomy (oral presentation)	15.00
The association between pain catastrophizing, psychological distress, and illness perception and patient-reported outcomes in patients undergoing surgery for ulnar-sided wrist pain (oral presentation)	15.00
- NVPC - Amsterdam, The Netherlands (2021)	10.00
- BSSH - Oxford, UK (2021)	24.00
- IWIW - Virtual meeting (2021)	1.00
Volar plate placement is associated with lower rates of hardware removal following ulna shortening osteotomy: a cohort study of 326 procedures (oral presentation)	15.00
- IFSSH - London, UK (2022)	30.00
Outcomes of Proximal Row Carpectomy: a Prospective Cohort Study on 304 Patients part of the BSSH Studyathon 2021 (oral presentation)	15.00
Long-term patient-reported outcomes after ulna shortening osteotomy for ulnar impaction syndrome: a mean follow-up of 6.3 years (oral presentation)	15.00
Volar plate placement is associated with lower rates of hardware removal following ulna shortening osteotomy: a cohort study of 326 procedures (oral presentation)	20.00
- VSOU - Baden Baden, Germany (2022)	15.00
Routinemäßig gemessene Ergebnisse einer Ulna-Verkürzungsosteotomie: eine Kohortenanalyse (oral presentation)	15.00
- Thames Valley & Wessex Hand Surgery Conference - Oxford, UK (2022)	8.00
Cubital Tunnel Release: outcomes from the UK Hand Registry (oral presentation)	15.00
- BSSH (Winchester, UK, 2022)	
Hand Registry data demonstrate discordance between hand function and health state utility from cubital tunnel release, complicating health economic evaluations (oral presentation)	15.00
Computerized adaptive testing reduces the burden of the PEM PROM in cubital tunnel syndrome by 80% while achieving good validity (oral presentation)	15.00
Making plastic surgery PROMs more valid: plausible value imputation challenges "conventional" improvement scores in cubital tunnel release (oral presentation)	15.00
- DGH – Garmisch, Germany (2022)	15.00
Return to work following hand and wrist surgery in a cohort of 15727 patients (oral presentation)	15.00
- NVPC – Amsterdam, The Netherlands (2022)	8.00
VOSM na ulnaverkortingsosteotomie: maakt de plaatlocatie uit?	15.00

Other	
- Faculty of the seminar “Hand and Wrist data science in a day” (Rotterdam, The Netherlands) (2020)	15.00
- Faculty of the BSSH Studyathon: Outcomes of proximal row carpectomy (Oxford, UK) (2021)	30.00
- Organization of Promovendiclub NVPC: How to promote your research (Webinar) (2021)	15.00
- Organization of Promovendiclub NVPC: How to tell a story with your data (Webinar) (2022)	15.00
- Organization of Traumaplatform Symposium (Stockholm, Sweden) (2023)	50.00
- Research Fellow (Nuffield Department for Surgical Sciences, University of Oxford, Oxford, UK) (2022)	450.00
Teaching activities	
Lecturing	
- Hand and Wrist Anatomy – Bachelor students, Erasmus MC (2019-2022)	40.00
- Hand and Wrist Anatomy – Master student, Erasmus MC (2020-2022)	30.00
- Introduction to R statistical programming – Researchers at Departments of Plastic Surgery, Radboudumc (2021-2022)	10.00
- Linear regression modeling – Researchers at Departments of Plastic Surgery, Radboudumc (2021-2022)	6.00
- Mixed regression modeling - Researchers at Departments of Plastic Surgery, Radboudumc (2021-2022)	6.00
- Survival analyses - Researchers at the Department of Plastic Surgery, Radboudumc (2021-2022)	6.00
Supervision of internships	
- Systematic Review – Master student, Radboudumc (2021)	30.00
- Original Research – Master student, Radboudumc (2020)	30.00
- Systematic Review – Minor Students, Erasmus MC (2019)	40.00
- Original Research – Master student, Erasmus MC (2022)	30.00
Total	**2761,9**

Curriculum vitae

Joris Sebastiaan Teunissen was born on the 9th of August 1997 in Eindhoven, the Netherlands. He graduated cum laude from the Van Maerlant Lyceum (Gymnasium) in Eindhoven in 2015. During high school, he participated in the Erasmus MC Junior Med School.

In 2015, he started his bachelor's in Medicine at the Erasmus University Rotterdam where he took part in the Erasmus MC honours class. Joris further developed his interest in surgery during his minor "Reconstruction Head to Hands" at the Erasmus University Rotterdam. He also was a member of student rowing club "Skadi", where he rowed in the freshman's Varsity heavyweight eight and participated in several committees.

After his bachelor, he participated in the Clinical Research Master at the Netherlands Institute for Health Sciences (NIHES) before starting his master's in Medicine. He wrote his NIHES thesis in the Hand and Wrist Study Group under the supervision of prof. R.W. Selles (PhD) and R.M. Wouters (PT, PhD), which was published in Osteoarthritis and Cartilage. Simultaneously, he completed the Erasmus Anatomy Research Project (EARP) on the upper extremity anatomy.

In 2019, he started as a full-time PhD student at the Department of Plastic, Reconstructive and Hand Surgery of the Radboud University Medical Centre under supervision of prof. D.J.O. Ulrich (MD, PhD), prof. S.E.R. Hovius (MD, PhD), prof. R.W. Selles (PhD), and E.P.A. van der Heijden (MD, PhD). During this period, Joris became a board member of the Dutch Association for PhD Students in Plastic Surgery. He also chairs the scientific committee of the Traumaplatform to organize the upcoming Winter 2023 Symposium & Challenge "Skate for Trauma" in Sweden to promote a multidisciplinary approach for trauma patients.

Joris stayed for three months at the University of Oxford to improve the structural validity of Patient Reported Outcome Measures using item-response theory and artificial intelligence under the supervision of J.N. Rodrigues (MD, PhD) and C.J. Harrison (MD). Since July 2022, he has been an honorary research fellow at the Nuffield Department of Orthopaedics, Rheumatology, and Musculoskeletal Sciences (University of Oxford).

In September 2022, Joris started his master's in Medicine at the Erasmus University Rotterdam in pursuit of his dream of becoming a surgeon.

DANKWOORD

"If I have seen further, it is by standing on the shoulders of giants" – Sir Isaac Newton

Afgelopen jaren ben ik erachter gekomen dat het bewandelen van een PhD traject echt een teamsport is, waarbij ik van een groot aantal mensen heb mogen leren en door nog meer mensen ben gesteund. Zonder deze mensen was dit proefschrift niet mogelijk geweest. Een aantal wil ik er in het bijzonder noemen om te bedanken.

Prof. dr. D.J.O. Ulrich, dank voor het bieden van de mogelijkheid om een promotietraject te doen vanuit de afdeling Plastische, Reconstructieve en Hand Chirurgie van het Radboudumc. Ik heb een geweldige tijd gehad en dat komt mede door het vertrouwen en de vrijheid die u mij heeft gegeven en de extra mogelijkheden die u heeft geboden. Ik zie het als een grote eer om bij uw afdeling te mogen promoveren.

Prof. dr. S.E.R. Hovius, beste prof. Het is een voorrecht om onderzoek te mogen doen onder een professor die meer dan 90 succesvolle promovendi heeft begeleid. Uw actieve deelname aan het promotietraject is een essentieel ingrediënt dan wel katalysator geweest om het te laten werken. Ik ben u erg dankbaar voor alle inzichten die u heeft verschaft en uitvoerige gesprekken die we hebben gehad; zowel inhoudelijk over de onderzoeksprojecten, maar vooral ook daarbuiten. Ik zal onder andere het "spinazie eten" en "4-dimensionele" denken meenemen in mijn coschappen en latere carrière. Uw kritische klinische blik, enthousiasme en daadkracht zijn inspirerend en ik hoop dat u ook in de komende jaren nog als mijn mentor zult fungeren. Omnium artium medicina nobilissima est.

Prof. dr. R.W. Selles, beste Ruud. Dank voor de steun en begeleiding afgelopen jaren. Ik ben erg blij dat je mij op het hart hebt gedrukt om het 3^{e} jaar van mij promotie volledig te benutten om te oogsten wat we eerder gezaaid hebben; ik denk dat dat goed heeft uitgepakt. Waar ik in het begin van het promotietraject moeizaam een regel R code kon schrijven, vroeg je me twee jaar later om je te vergezellen voor een Studyathon in Oxford; een onvergetelijke ervaring waar ik later nogmaals de vruchten van heb mogen plukken. Erg leuk dat we een deel van onze besprekingen al rennend over de Erasmusbrug hebben gehad om het "aangename met het nuttige te verenigen".

Dr. E.P.A. van der Heijden, beste Brigitte, al vanaf het eerste moment (de lunch in de kantine van het Erasmus MC) hadden we een goede klik en konden we samen lachen.

Jouw enthousiasme voor het onderwerp motiveerde mij om de uitkomsten van onze analyses zo goed en snel mogelijk aan je terug te koppelen. Ik vind het heel bijzonder hoe jij ondanks je drukke schema altijd tijd wist te maken voor overleg of het reviseren van mijn stukken. Jouw pragmatische aanpak en bevlogenheid zijn inspirerend.

Dank aan de leden van de manuscriptcommissie**, Prof. dr. P.P.T Jeurissen, Prof. dr. A.C.H. Geurts, Prof. dr. D. Eygendaal** voor uw tijd en de mogelijkheid om mijn proefschrift aan uw expertise te mogen toetsten. Het is een eer om u als commissie te hebben.

Prof. dr. M.J.R. Edwards, dank voor de tijd die u heeft genomen voor de mentorgesprekken gedurende dit promotietraject.

Dr. R. Feitz, beste Reinier, het tweede proefschrift over de ulnaire pols binnen onze studiegroep is inmiddels een feit! Dank voor alle leerzame momenten (onder andere) op de OK waarbij we het naast de operaties ook veel tijd hebben besteed aan de communicatie naar de patiënt door middel van gesprekstechnieken en lichaamstaal. In Londen hebben we veel gesproken over lange termijn visies en de 10x club in het leven geroepen. Ik kijk uit naar de toekomstige projecten. Never split the difference.

Dr. M.J.W. van der Oest, beste Mark, dit hele avontuur is eigenlijk al onder jouw vleugels als student-begeleider na de minor begonnen. Vanaf het begin was je heel behulpzaam, enthousiast èn geduldig. In loop van de afgelopen jaren heb ik echt veel van je mogen leren op het gebied van statistische analyses in R, pragmatisch denken, het voorbereiden van OK's en whisky. Heel leuk dat je mij als paranimf terzijde zal staan gedurende de verdediging. Ik kijk uit naar onze voortdurende samenwerking en culinaire ervaringen.

Dr. O.T. Zöphel, beste Oliver, dank voor uw kritische blik gedurende onze gezamenlijke onderzoeksprojecten. Uw enthousiasme op de poli en op de OK is aanstekelijk.

Dr. S. Hummelink, beste Stefan, dank voor de begeleiding in de opstartfase en gezelligheid op de afdeling. We vonden elkaar in het kroketten eten tijdens de lunch en het biertje op de vrijdagmiddag maar ook zeker in een kritische blik tijdens de immer groeiende Plastische Research Meetings. Ik ben benieuwd wat de toekomst brengt!

Dr. R.M. Wouters, beste Robbert, wat hebben we in het begin (waardevolle) discussies gehad over de indicatie van een ulnaverkorting. Er zijn maar weinig collega's van wie ik

weet waar ik ze 's nachts voor wakker mag bellen. Dank voor alle tips gedurende dit avontuur, ik heb er veel baat bij gehad. Die gefrituurde Mars houd je tegoed.

Drs. S. al Shaer, beste San, het was in het begin best even schrikken toen bleek dat we met dezelfde dataset onderzoek aan het doen waren. Ik ben blij met de manier hoe we de handen ineen hebben geslagen en welke publicaties daaruit zijn gekomen (en volgen). Super mooi dat je als AIOS heelkunde in het UMC Utrecht bent begonnen! Hopelijk komen we elkaar in de toekomst een keer op de OK tegen.

Dr. J.N. Rodrigues and **Dr. C.J. Harrison**, dear Jeremy and Conrad. Thank you for an amazing time at Oxford. Not only have you taught me a lot about psychometrics in PROMs research and provided me with tons of valuable insights to improve scientific presentations, but you also made me feel at home in the UK. Moreover, I would like to thank you again for speaking on the webinar organized by the Dutch Association for PhD Candidates in the field of Plastic Surgery. I am looking forward to continuing our collaboration.

Dr. J.M. Zuidam, beste Michiel, dank voor jouw kritische klinische blik en waardevolle toevoegingen tijdens de HWSG labmeetings en het meermaals mee mogen kijken op de OK. Ik hoop dat er nog veel mooie artikelen over het vervolgonderzoek met de polsscopie data mogen volgen. Op naar de volgende koude duik!

Dr. H.P. Slijper, beste Harm, wat een fantastisch data-collectie systeem heb jij samen met je team gebouwd. Het is echt een feest om met de data van het Hand and Wrist Cohort te kunnen werken. Het succes en productiviteit van de HWSG is mijns inziens voor een groot deel aan jouw technische innovaties te danken. Ik ben benieuwd naar jouw toekomstige innovaties.

Drs. L. Hoogendam, beste Lisa, dank voor het meedenken met alle statistische vraagstukken en handige R functies gedurende de beginfase van het promotietraject. Mooi om te zien hoe bevlogen je bent in het onderzoek. Ik weet zeker dat de postdoc je ook goed af zal gaan.

De **stafleden en arts-assistenten** van de afdeling Plastische Chirurgie van het Radboudumc. Dank voor jullie leerzame onderwijsmomenten, gezellige borrels en een fantastische skireis.

De onderzoekers van de afdeling Plastische Chirurgie van het Radboudumc, **Elleke**, **Kim Phi**, **Phillipe**, **Bart**, **Marieke**, **Lyse** en de rest. Veel dank voor jullie input tijdens de wekelijkse labmeetings en voor jullie gezelligheid tijdens alle onderwijsmomenten, koffiepauzes en vrijdagmiddagborrels.

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De handchirurgen en hand therapeuten van de Xpert Clinics. Dank voor alle leerzame meeloopdagen op de poli en OK. Het was heel interessant om meer te leren over hand-pols aandoeningen met bijbehorende (chirurgische) behandelingen en daarnaast de context van de dataverzameling voor dit proefschrift beter te begrijpen.

Mede Research Master studenten en vrienden **Tim**, **Saskia**, **Fréderike**, en **Rosalieke**. Als je na een Bachelor Geneeskunde wordt ondergedompeld in "Advanced Statistical Programming in R", dan toch maar beter met medestudenten waarmee je ontzettend kunt lachen. Dank voor jullie gezelligheid, mooie avonden en sparsessies. Succes met het afronden van jullie proefschriften, dat gaat helemaal goedkomen!

De mannen van 't Vat (of is het inmiddels Fof?), **Alain**, **Tim**, **Gijs**, **Sven, Tobias, Yuri** en **Stijn**. Alhoewel we allemaal ons eigen pad hebben bewandeld gedurende de studie, wisten we elkaar altijd weer te vinden. Waarschijnlijk zit ik in het buitenland als we de volgende borrel plannen, maar drink er dan maar een extra en have fun.

De **Jonghe Acht '17**. Van lang naar kort: **Ben**, **Oliver**, **Sven**, **Ruben**, **Wouter**, **Daan**, **Yordi**, **Mark**, **Bram**, **Sebas**, **Gijs**, **Eline** en **Auke**. Inmiddels voelen jullie als een stukje verlengde familie. Ik kan met ieder van jullie ontzettend hard lachen, diepgaande discussies voeren en weet ook dat ik op jullie kan bouwen. Dank voor jullie gezelligheid, belangstelling en medeleven. Ik kijk nu al uit naar de volgende mijlpalen binnen onze groep! Vergeet de riem niet mee te nemen naar de verdediging a.u.b. ;)

Dirk-Jan, **DJ**. Wij zijn al 22 jaar een team! Er is niemand waarmee ik liever in de keuken sta om met volle focus iets lekkers te bereiden. Heel cool om te zien hoe wij altijd zo gewaagd aan elkaar zijn, of het nou ging over LEGO bouwen, Pokémons levellen, tennissen, roeien of studeren. Ik ben super trots op jou! Dank voor alle ontspanning en relativering die jij afgelopen jaren hebt meegebracht.

Lieve **mama**, **papa**, **oma** en **opa**, **oma**. Waar zal ik beginnen met het bedanken? Is dat bij het samen boekjes lezen, knutselen, spelletjes spelen en later sporten, huiswerk maken en winkelen na school? Bij alle aandacht die ik heb gekregen en goede gesprekken die wij hebben aan de woonkamertafel? Bij jullie stimulatie, steun en goede voorbeeld om dromen waar te maken? Alle ontspannen vakanties en weekendjes weg om even op te laden voor het volgende? Of gewoon bij de onvoorwaardelijke liefde ik die altijd gevoeld heb en nog steeds voel die als een sterke basis dient voor alle andere zaken in het leven? Hoe dan ook heb ik het voltooien van dit proefschrift voor een groot deel aan jullie opvoeding te danken. Wat is het een ontzettend voorrecht om een deel uit te maken van onze familie. Ik hoop dat we nog lang van elkaar mogen genieten.

Lieve **Isa**, wat ben ik blij dat ik jou in de zomer van 2017 tijdens het bladen verven op Skadi heb leren kennen. Als je op een eerste date uren over sport en de ontwikkeling van het embryo kan praten met een cocktail in de ene hand en een bitterbal in de andere, dan weet je dat je goed zit ;) We zitten vaak op een lijn maar vullen elkaar aan waar nodig. We houden ervan om veel samen te doen maar geven elkaar ook de ruimte om onszelf te ontwikkelen: een PhD in Nijmegen, een fellowship in Oxford, als Rijkstrainee naar Genève, als beleidsmedewerker aan de slag bij VWS, wij zouden het allemaal wel eens even gaan regelen. Dank voor jouw onvoorwaardelijke steun, relativeringsvermogen, geduld en externe geheugencapaciteit gedurende dit PhD-traject. Als kers op de taart bedacht je de creatieve titel van dit proefschrift. Ik geniet van iedere dag samen met jou en hoop dat het er nog veel mogen zijn. Op naar de volgende mijlpaal.