

## Patient-reported physical functioning and pain improve after scaphoid nonunion surgery: A Cohort Study

Abigael Cohen<sup>a,\*</sup>, Lisa Hoogendam<sup>b,c</sup>, Max Reijman<sup>a</sup>, Ruud W Selles<sup>b,c</sup>, Steven E R Hovius<sup>d</sup>, Joost W Colaris<sup>a</sup>

<sup>a</sup> Department of Orthopedic Surgery, Erasmus MC University Medical Center Rotterdam, PO Box 2040, 3000CA Rotterdam, the Netherlands

<sup>b</sup> Department of Plastic, Reconstructive and Hand Surgery, Erasmus University Medical Center Rotterdam, PO Box 2040, 3000CA Rotterdam, the Netherlands

<sup>c</sup> Department of Rehabilitation Medicine, Erasmus MC University Medical Center, Rotterdam, PO Box 2040, 3000CA Rotterdam, the Netherlands

<sup>d</sup> Hand and Wrist Center, Xpert Clinic, 1213 RH Hilversum, the Netherlands

### ARTICLE INFO

#### Article history:

Accepted 21 June 2021

### ABSTRACT

**Background:** Since all patients with a scaphoid nonunion are generally treated surgically to prevent progressive osteoarthritis, it is important to set postoperative expectations regarding physical functioning and pain. Previous study mainly focus on postoperative scaphoid union and physician-based outcomes. Therefore we aim to report the change from preoperative to postoperative patient-reported outcomes to inform patients with a scaphoid nonunion about their postoperative expectations.

**Material and Methods:** Data were prospectively collected as part of usual care at the Xpert Clinic in the Netherlands. Adult patients who underwent scaphoid nonunion surgery minimally 3 months after a scaphoid fracture, were eligible for inclusion. Only patients with complete preoperative and postoperative questionnaires regarding our primary outcome (Patient Rated Hand/Wrist Evaluation (PRWHE)) were included. As secondary outcomes, we assessed the Visual Analog Scale (VAS) pain and hand function, range of motion of the injured wrist measured by a hand therapist, and patient satisfaction with questionnaires.

**Results:** We included 118 patients with complete preoperative and postoperative (11 – 92 months) PRWHE questionnaires. The median PRWHE score improved significantly from 47 [IQR 27 – 62] preoperative to 11 [IQR 5 – 23] postoperative ( $p < 0.001$ ). Postoperative improvement in pain and physical functioning was also observed in the PWRHE subdomains pain and disability separately ( $p < 0.001$ ), VAS pain, and VAS function ( $p < 0.001$ ). There was no difference between preoperative and postoperative range of motion of the injured wrist. Satisfaction with the hand improved significantly from preoperative to postoperative ( $p < 0.001$ ). Good or excellent satisfaction with the treatment result was reported by 69% of the patients and 86% would undergo the treatment again.

**Conclusions:** Patients can expect an improvement in physical functioning and pain after scaphoid nonunion surgery. Most patients are satisfied with the treatment result.

© 2021 The Authors. Published by Elsevier Ltd.

This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>)

### Introduction

Because 75–100% of patients with symptomatic scaphoid nonunion develop scaphoid nonunion advanced collapse (SNAC) in 10 years, we generally treat these patients surgically [1–3]. The degenerative changes in patients with SNAC wrist progress gradually [4] and symptoms in these patients can vary from asymptomatic to

impaired physical functioning and pain [5]. Depending on the degree of wrist osteoarthritis and characteristics of the nonunion, the surgeon chooses which surgical technique they use [6]. The goal of non-salvage surgery is relieving symptoms and preventing progressive wrist osteoarthritis by restoring the shape of the scaphoid and achieving postoperative union [6,7]. However, postoperative union is not achieved in all patients [7–9].

Most studies evaluating scaphoid nonunion surgery report postoperative union or the postoperative Modified Mayo Wrist Score (MMWS), which is a physician-based scoring system [10]. The systematic review by Alluri et al. [11] reported a postoperative improvement on the MMWS in 216 patients with a scaphoid

\* Corresponding author.

E-mail addresses: [a.cohen.1@erasmusmc.nl](mailto:a.cohen.1@erasmusmc.nl) (A. Cohen),

[lhoogendam@erasmusmc.nl](mailto:lhoogendam@erasmusmc.nl) (L. Hoogendam), [m.reijman@erasmusmc.nl](mailto:m.reijman@erasmusmc.nl) (M. Reijman), [r.selles@erasmusmc.nl](mailto:r.selles@erasmusmc.nl) (R.W. Selles), [j.colaris@erasmusmc.nl](mailto:j.colaris@erasmusmc.nl) (J.W. Colaris).

nonunion after a vascularized bone graft across 8 studies. However, patient-reported outcome measures can help to inform patients about their postoperative functioning and pain. Nevertheless, there is no large cohort study comparing preoperative and postoperative patient-reported outcomes in patients after a scaphoid nonunion surgery. Therefore, we aim to report the difference between preoperative and postoperative physical functioning and pain with the Patient Rated Hand/Wrist Evaluation (PRWHE) as primary outcome and pain and hand function on the Visual Analog Scale (VAS), range of motion of the injured wrist and patient satisfaction, as secondary outcomes.

## Methods

### Study design

We conduct this cohort study with prospectively collected data at the Xpert Clinic between September 2011 and April 2019. The study is written following the Strengthening The Reporting of Observational Studies in Epidemiology (STROBE) statement. Data collection occurred as part of usual care at the Xpert Clinic and Handtherapie Nederland, currently comprising 28 specialized treatment centers in the Netherlands for patients with hand and wrist problems. Our treatment centers employ currently 23 surgeons certified by the Federation of European Societies for Surgery of the Hand. The study was performed following the declaration of Helsinki and approved by the local medical ethical research committee (MEC-2018–1088). The Xpert Clinic invited patients to be part of a routine system for outcome measurement after their first consultation with a surgeon. After written informed consent was obtained, patients received Internet-based questionnaires preoperative and postoperative. The details about our cohort are published previously [12].

### Study population

For our present study, we included adult patients, who were minimally 18 years, undergoing scaphoid nonunion at the Xpert Clinic. We defined scaphoid nonunion as previously reported as failed union, minimally 3 months after the initial trauma based on radiographs, CT, or MRI [8,13]. Patients were excluded if (1) a salvage procedure (e.g. proximal row carpectomy, distal pole resection of the scaphoid, four-corner fusion) was the primary surgery at the Xpert clinic, or (2) patients had concomitant ipsilateral hand or wrist injury, or (3) preoperative PRWHE questionnaires regarding physical functioning and pain were incomplete. The eligible patients from whom the one-year postoperative questionnaires were not available ( $n = 67$ ) were contacted in April 2020 to fill in the questionnaires. All patients without complete one-year postoperative PRWHE questionnaires in May 2020, were excluded.

We included 118 patients in our study (Fig. 1). Of these patients, 78 patients had already completed their postoperative questionnaires between 11.3 to 12.5 months postoperative. Of the 67 patients with only complete preoperative questionnaires, 40 patients filled in the postoperative questionnaire (range 13.2 months to 7.6 years postoperative) after contact in April 2020. We compared the postoperative PRWHE score between patients with complete postoperative questionnaires without contact ( $n = 68$ ) and complete postoperative questionnaire after contact in April 2020 ( $n = 40$ ) to identify bias between these groups. Due the wide time range of complete postoperative questionnaires (11.3 months – 7.6 years), we compared the primary outcome between short-term follow-up (<18 months postoperative,  $n = 82$ ) and mid-term follow-up ( $\geq 18$  months postoperative,  $n = 36$ ).

### Surgical procedure and postoperative protocol

The Xpert clinic does not treat patients with an acute scaphoid fracture. Patients were referred to the Xpert clinic by their general practitioner or another physician. After diagnosing the patient at the Xpert clinic with a scaphoid nonunion, the treating surgeon determined the surgery type (e.g., approach, graft, and fixation type), the postoperative treatment, and the duration of the follow-up (Table 2).

The Xpert Clinic changed the duration of postoperative cast after scaphoid nonunion surgery in June 2015. Before June 2015, the postoperative below-elbow cast was replaced 10–14 days postoperative to a removable splint, whereas after June 2015, the cast was changed to a removable splint 3–5 days postoperative. Hand therapy started when patients received their removable splint. Until 6 weeks, the hand therapist performed scar management and optimized the range of motion of the fingers and thumb to prevent stiffness. After 6 weeks, the hand therapist encouraged active movement of the wrist without load with caution during hand therapy. After 9 to 13 weeks, patients could remove their splint with unloaded activities. Radiographs were made after 3 months during the outpatient department visit. Based on the radiographs (signs of union of the scaphoid), patients were allowed to remove the splint with loaded activities and able to practice on coordination, strength, and stability with hand therapy.

### Outcomes

We collected data from the electronic patient record regarding scaphoid nonunion characteristics and complications in April 2020. Regarding the postoperative complications, the researcher assessed all electronic patient records from surgery until April 2020. Patients gave preoperative information regarding baseline demographics as age, sex, Body Mass Index (BMI), smoking, affected dominant side, time of the trauma, previous treatment of the affected wrist, Type of work (not employed, light occupational intensity as computer work in an office, moderate occupational intensity as working in a shop or being a cleaner, or severe occupational intensity as performing construction work), and if patients were referred to the Xpert Clinic for a second opinion.

#### Primary outcome

The primary outcome was the patients' perception of disability and pain as measured by the PRWHE. The PRWHE comprises 15 questions regarding pain and functioning of the injured wrist in the past week. Each question can be scored from 0 – 10 (range 0 – 100; higher score indicates worse physical functioning and pain). Subscores can be calculated for both pain and function domain separately (range 0 – 50) and these scores were secondary outcomes. The PRWHE is a reliable, valid, and responsive tool for patients with traumatic wrist injury [14]. Previous studies reported a minimally clinical important difference (MCID) of 11.5 in patients with a distal radius fracture [15].

#### Secondary outcomes

A visual analog scale (VAS) was also used to measure pain (range 0–100; higher score indicates more pain) and hand function (range 0 – 100; higher score indicates better function). To assess wrist movement, a hand therapist measured the range of motion of the injured wrist with a goniometer preoperative and 12 months postoperative as part of usual care at the outpatient clinic (palmar flexion, dorsal flexion, supination, pronation, ulnar deviation, and radial deviation).

To report patient satisfaction, we used several questions; (1) VAS satisfaction with the hand (range 0–100; higher score indicates more satisfaction with the hand), (2) Satisfaction with treat-

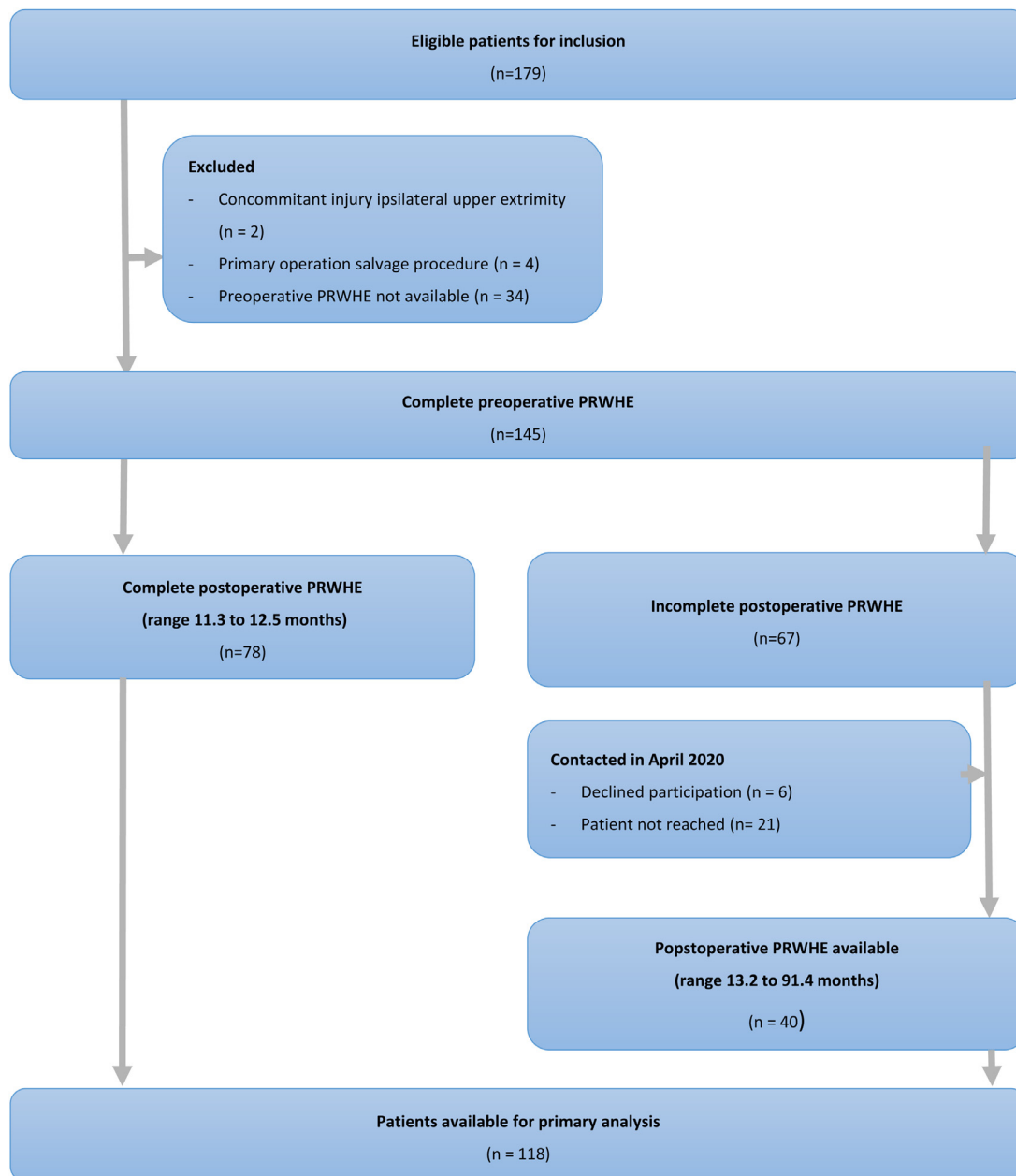


Fig. 1. Study flowchart.

ment result rated on a 5-point Likert scale (options: poor, moderate, fair, good, and excellent), and (3) patients were asked if they would undergo the treatment again under similar circumstances (yes or no).

Statistical methods

We tested the distribution of baseline variables by the Shapiro-Wilk test. The mean with ranges for normally distributed variables were reported and the median with interquartile ranges (IQR) for not normally distributed variables. A sensitivity analysis was performed to clarify if data are missing at random. When data were normally distributed, a *t*-test was performed. The Mann-Whitney U test or Wilcoxon one-sample test were used when data were not normally distributed. Categorical variables were analyzed with a Chi2 test.

We used R statistical computing, version 1.2.5001 for all analyses. A p-value smaller than 0.05 was considered statistically significant.

Results

In our study 118 patients, mainly male patients (92%) with a median age of 25 years [IQR 21 – 32], completed both the preoperative and postoperative PRWHE questionnaire. There were no significant differences in baseline characteristics between patients who completed both the preoperative and postoperative PRWHE questionnaire and patients that only completed the preoperative PRWHE questionnaire (Table 1). Of the included patients, the hand therapist measured in 48 patients the range of motion of the injured wrist preoperative and postoperative. The baseline characteristics of these patients were not different from those of whom

**Table 1**  
Baseline characteristics of patients with and without available postoperative PRWHE.

Characteristics	Preoperative and postoperative PRWHE(n = 118)	Only Preoperative PRWHE(n = 27)	p-value
Age, median [IQR]	25 [21 - 32]	29 [26 - 40]	0.160
Male sex,% (n)	91% (107)	92% (25)	1.000
BMI, median [IQR]	24 [22 - 25] ^	25 [23 - 26]*	0.282
Smoking,% (n)	25% (24) §	35% (7) *	0.487
Second Opinion,% (n)	41% (48)	48% (13)	0.622
Dominant side treated,% (n)	42% (50)	56% (15)	0.304
<b>Type of Work,% (n)</b>			0.662
Unemployed	22% (26)	22% (6)	
Light physical labor	30% (35)	19% (5)	
Moderate physical labor	23% (27)	26% (7)	
Heavy physical labor	25% (30)	33% (9)	
Preoperative PRWHE score, median [IQR]	47 [27 - 63]	40 [30 - 52]	0.233

PRWHE: Patient Rated Wrist/Hand Evaluation. BMI: Body Mass Index. ^ n = 88.\* n = 16. § n = 98. \* n = 20.

**Table 2**  
Preoperative and postoperative clinical characteristics and complication rates of included patients.

Preoperative and postoperative details	Included patients(n = 118)
Duration of symptoms in months, median (IQR)	13 [6 - 29] ∞
<b>Location nonunion,% (n)</b>	
Distal	11% (13)
Waist	49% (58)
Proximal	39% (46)
Double fracture (Proximal and Waist)	1% (1)
<b>Treated before for scaphoid fracture,% (n)</b>	
Conservative	24% (28)
Operative	6% (7)
Not treated before	70% (83)
Operated before for scaphoid nonunion,% (n)	9% (11)
<b>Bonegraft,% (n)</b>	
Non-vascularized bone graft	76% (90)
Vascularized bone graft	16% (19)
No graft used	8% (9)
<b>Transplant origin,% (n)</b>	
Distal Radius	98% (108)
Iliac Crest	1% (1)
Distal Radius and Iliac Crest	1% (1)
<b>Fixation type,% (n)</b>	
Screw fixation	95% (112)
K-wire fixation	2.5% (3)
No fixation	2.5% (3)
<b>Postoperative Complications,% (n)</b>	
Avulsion scaphoid	2% (2)
Screw protrusion through the cartilage	5% (6)
Flexor carpi radialis tendinitis	1% (1)
Extensor carpi radialis longus tendinitis	1% (1)
Quervain's Disease	1% (1)
Scar problems	1% (1)
Carpal tunnel syndrome	1% (1)
<b>Reoperation,% (n)</b>	
Screw removal	5% (6)
Revision Surgery	3% (4)
Salvage Procedure	4% (5)

∞ n = 114.

range of motion was only preoperative measured (n = 62) (Supplementary Table 1).

*Details of the surgery and postoperative complications*

Patients were surgically treated after a median time of 13 [IQR 6 - 29] months after the trauma, but one patient even presented 30 years after the trauma (Table 2). Screw fixation was used in most patients (95%) with a bone graft (92%) from mainly the distal radius (98%). The screw was postoperatively removed in 6 patients due to protrusion through the cartilage.

Postoperatively, 4 patients needed revision surgery (vascularized bone graft after initial non-vascularized bone graft in 3 patients, and olecranon graft in 1 patient after vascularized bone

graft). The revision surgery was performed between 3 and 19 months after the primary surgery at the Xpert clinic. A salvage procedure was performed in five other included patients between 5 and 50 months after their nonunion surgery (proximal row carpectomy with radial styloidectomy, distal pole resection of the scaphoid with radial styloidectomy or four-corner fusion).

*Pain and physical functioning*

The median PRWHE score improved significantly from 47 [IQR 27 - 62] preoperative to 11 [IQR 5 - 23] postoperative (p<0.001) (Fig. 2). Ninety patients (76%) reached the MCID by improving at least 11.5 points on the PRWHE score from preoperative to postoperative. Worse postoperative PRWHE scores were seen in 14 patients, from whom 5 patients showed a worse score exceeding the MCID of 11.5 points.

The PRWHE score did not differ significantly (p = 0.259) between patients with complete postoperative questionnaires without contact (median 12 [6 - 26]) and patients with complete postoperative questionnaires after contact in April 2020 (median 11 [3 - 18]). We compared the median PRWHE scores of the 82 patients with short-term follow-up (11 [5 - 24]) to the 36 patients with mid-term follow-up (11 [7 - 19]) and found no significant difference regarding PRWHE scores either (p = 0.378).

When we evaluated the subscales pain and disability of the PRWHE separately, the median PRWHE pain score improved significantly (p<0.001) from preoperative 27 [IQR 18 - 33] to postoperative 8 [IQR 3.3 - 15.8]. Patients also report a significant decrease from preoperative to postoperative pain at rest and pain at activity on the VAS (Table 3).

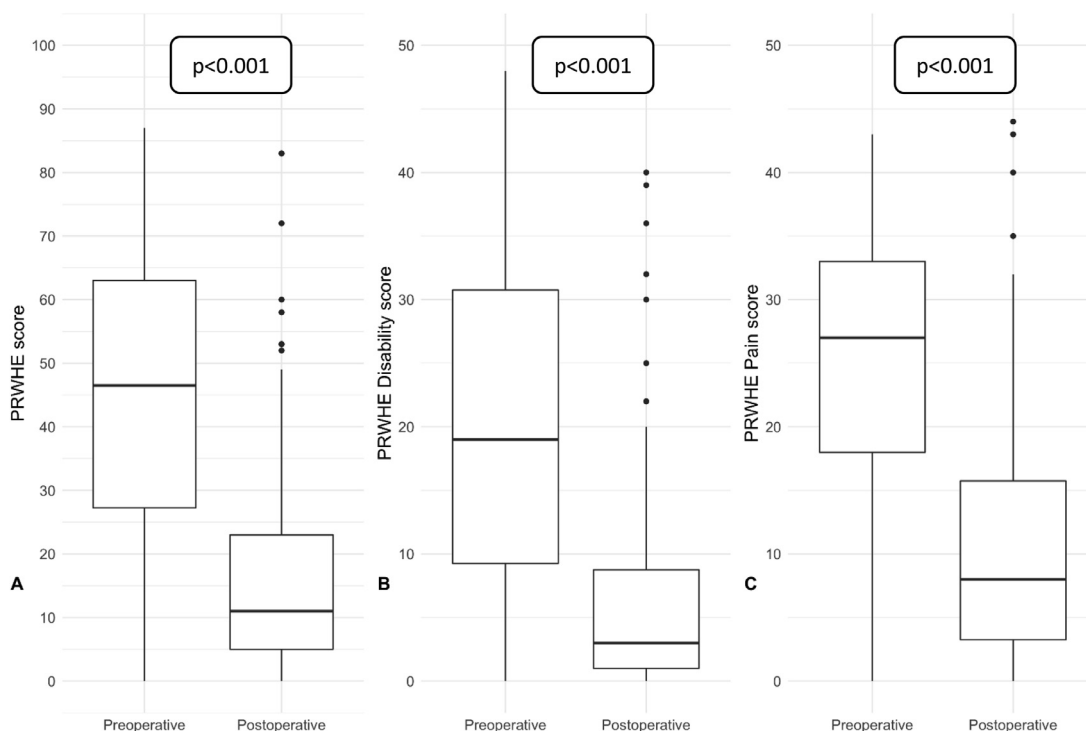
The median PRWHE disability score improved from 19 [IQR 9 - 31] preoperative to 3 [1 - 9] postoperative. Patients also rated a significant improvement in postoperative hand function on the VAS. There was no difference between the preoperative and postoperative range of motion of the affected wrist in the included patients (Table 3).

*Satisfaction*

We found a significant improvement in satisfaction with the hand on the VAS from 23 [10 - 44] preoperative to 83 [69 - 93] postoperative (Fig. 3A). Of the 116 patients that responded to the satisfaction with treatment results questions, 69% reported either good or excellent satisfaction (Fig. 3B) and 86% would undergo the treatment again.

**Discussion**

Since all patients with a scaphoid nonunion are generally treated surgically to prevent progressive osteoarthritis [16], it is



**Fig. 2.** A-C. Boxplots demonstrating the preoperative (left) and postoperative (right) (A) PRWHE total score, (B) PRWHE subdomain Disability score, (C) PRWHE subdomain Pain score. A significant improvement from preoperatively to postoperatively ( $p < 0.001$ ) is seen in figures A-C. The horizontal line represents the median, the boxes the first and the third quartile and the dots represent outliers; PRWHE: Patient Rated Wrist/Hand Evaluation.

**Table 3**  
Secondary outcomes regarding physical functioning, pain, and wrist movement.

Outcomes	Preoperative	12 months	p-value
VAS Pain at rest, median [IQR]	16 [2 – 38]	1 [0 – 10]	<0.001
VAS pain at activity, median [IQR]	65 [42 – 77]	15 [2 – 34]	<0.001
VAS Function, median [IQR]	48 [28 – 74]	86 [73 – 94]	<0.001
<b>Injured wrist range of motion, median [IQR]</b>			
Palmar flexion	66° [50 – 74]	62° [52 – 71]	0.943
Dorsal flexion	58° [50 – 66]	60° [51 – 70]	0.069
Radial deviation	16° [11 – 19]	16° [10 – 20]	0.852
Ulnar deviation	30° [22 – 32]	28° [22 – 35]	0.587
Supination	85° [75 – 90]	83° [80 – 90]	0.961
Pronation	80° [75 – 82]	80° [76 – 83]	0.600

VAS: Visual analog scale questions were reported by 114 patients. Physical examination was performed in 48 patients.

important to set their postoperative expectations with information on postoperative physical functioning and pain. Therefore, we present a large cohort study of 118 patients with prospectively collected data of patient-reported physical functioning and pain after a scaphoid nonunion surgery.

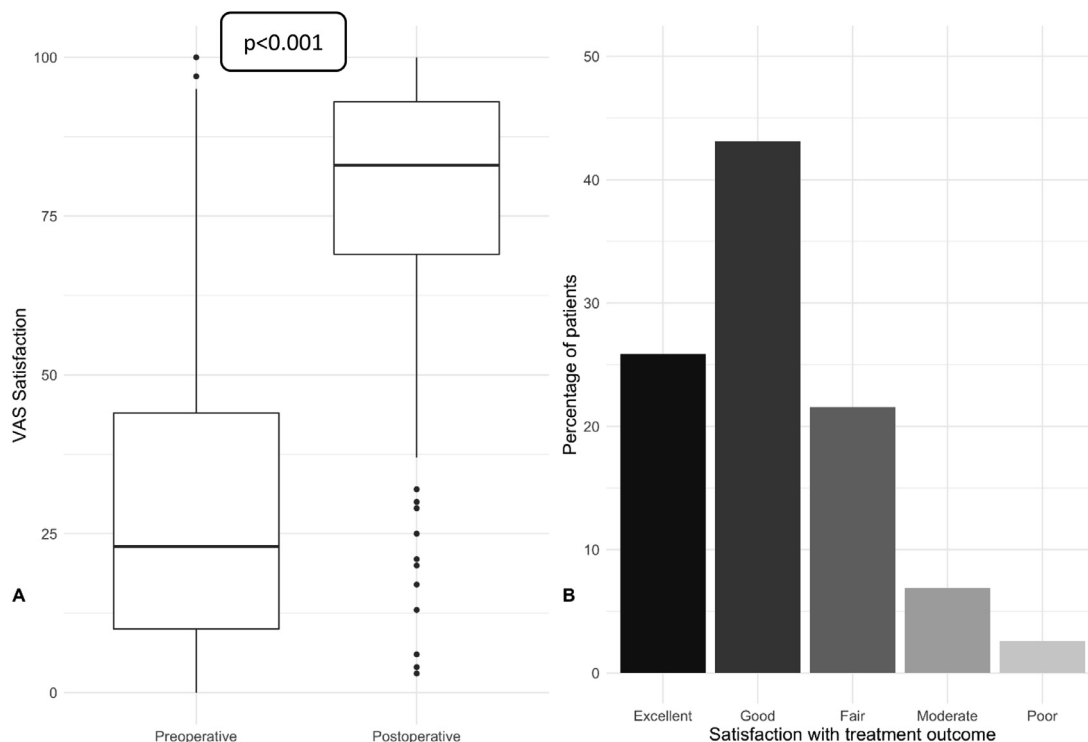
Our study showed that physical functioning and pain improved significantly in patients who underwent scaphoid nonunion surgery. Of all operated patients, 76% reached a clinically relevant improvement on the Patient Rated Hand/Wrist Evaluation (PRWHE) score. This finding is consistent with the results on the VAS pain and VAS hand function in our study, since a significant improvement was seen on these scales as well. Our findings are also in line with previous studies reporting on patient-reported outcomes after scaphoid nonunion surgery. The review by Alluri et al. [11] reported that across 4 studies with a total of 69 patients, the Disabilities of the Arm, Shoulder and Hand (DASH) score improved significantly after surgery with the use of a vascularized bone graft. Good postoperative results on the Quick-DASH after a non-vascularized bone graft were reported by Goyal et al. [17] in 100 patients after 3 years of follow-up. They also reported that 76% of the patients af-

ter a non-vascularized bone graft from the distal radius, had good to excellent postoperative functional results on the Modified Mayo Wrist Score (MMWS) [18].

Most of our patients (69%) reported excellent or good satisfaction with the treatment result and even 86% would undergo the treatment again under the same circumstances. On the VAS satisfaction with the hand, a significant postoperative improvement was seen as well. It implies that most patients are satisfied after scaphoid nonunion surgery. This is in line with the results on patient-reported satisfaction after a vascularized bone graft from Alluri et al. [11]. They reported that, across 5 studies with a total of 166 patients, 92% of the patients were satisfied with the results of the procedure.

We included patients with different types of scaphoid non-unions and different types of scaphoid nonunion surgery were performed. Therefore, we have heterogeneity of patients with a scaphoid nonunion, which allows our results to be generalizable to daily practice. Since there is no standardized protocol to determine how each patient with a scaphoid nonunion should be treated, our hand surgeons determined which surgery was performed on





**Fig. 3.** A-B. Patient satisfaction outcomes. (A) A significant difference was seen from preoperative (0) to 12 months postoperative on the VAS Satisfaction with the hand. The horizontal line represents the median. The dots represent outliers. (B) Distribution of the percentage of patients on level of satisfaction with the treatment results. VAS: Visual Analog Scale.

each patient. This might influence the clinical outcome, but it corresponds to daily practice as well. This allows us to evaluate the current surgical strategies used in this group of hand surgeons.

In our cohort, a non-vascularized bone graft from the distal radius with Herbert screw fixation was used in most patients. This is in line with the literature regarding scaphoid nonunion surgery. Bone grafting and screw fixation show good results for the treatment of scaphoid nonunion [19]. A bone graft from the distal radius has less donor site morbidity than a bone graft that was harvested from the iliac crest [17].

Our study has some strengths and limitations. Concerning limitations, we used prospectively collected data in our study, which are routine outcome measurements as part of usual care. The downside of this data might be that patients are less willing to answer questionnaires and return for follow-up measurements. To reduce the loss of follow-up of patients in our study, we contacted all patients with complete preoperative PRWHE questionnaires, but incomplete postoperative questionnaires ( $n = 67$ ), to fill in the postoperative questionnaires in April 2020. Eventually, 118 patients were included in our study. We performed a sensitivity analysis and found no difference in baseline characteristics between the patients with and without a complete postoperative PRWHE questionnaire. Therefore, we believe our data regarding our primary outcome is missing at random. Additionally, the PRWHE score did not differ between patients that completed the questionnaires without contact ( $n = 78$ ) and patients that completed the questionnaires after contact in April 2020 ( $n = 40$ ). This might imply there is no selection bias between patients that completed questionnaires with and without contact.

The postoperative questionnaires were completed between 11.3 months and 7.6 years postoperative. Of the 118 included patients, 69% responded to the questionnaire within 18 months (short-term follow-up) and 31% responded after 18 months (mid-term follow-up). We found no difference in median PRWHE score between

patients with short-term follow-up and patients with mid-term follow-up. This implies that patients remain satisfied even after longer follow-up. This is in line with Malizos et al. [18] who reported good postoperative scores on the MMWS after at least 5 years follow up and Deacke et al. [20] who reported a good function on the DASH score after more than 10 years follow up in 50 patients.

Most studies regarding scaphoid nonunion focused on postoperative union since a scaphoid nonunion surgery is performed to achieve union and prevent progressive osteoarthritis. Defining union following nonunion surgery is difficult and the review by Ferguson et al. [8] reported eight different definitions used by 50 studies to determine postoperative union based on either radiographs, CT, MRI or clinical signs. Based on their findings, they suggest MRI, CT or scaphoid view radiographs minimally 6 months postoperative to determine postoperative union. Since the protocol of the Xpert clinic suggested postoperative radiographs after 3 months, we do not have imaging after 6 months and cannot report postoperative union.

It is known that postoperative union is not achieved in all patients, and osteoarthritis is not prevented in all patients [8,18,20–22]. The health care is shifting towards patient-centered care and postoperative union provides information about postoperative outcomes, but does not consider the daily experience of a patient. Patient reported outcome measures are valuable tools to gather information about patient’s physical functioning, ability to resume normal activities or amount of pain [14]. These information on patient perspective and experience are important to enhance shared decision making [23,24]. Therefore, we focused in the present study on patient-reported physical functioning and pain.

Another strength of our study is the use of PRWHE as our primary outcome in this large cohort, to report physical functioning and pain. The PWRHE is a reliable and valid tool for patient-reported disability in patients with hand-wrist trauma [14]. Pre-

vious studies reporting on the postoperative treatment results, mainly use the MMWS. The MMWS is a physician-based scoring system with only 4 domains regarding pain, grip strength, range of motion, and return to employment. There is not much known about the reliability, validity, and responsiveness of this questionnaire [14].

## Conclusion

In conclusion, patients improve in physical functioning and pain, and most patients are satisfied after scaphoid nonunion surgery. These results are useful to set clear expectations for both surgeons and patients.

## The hand-wrist study group collaborators

Berbel Sluiter, MD, PhD. B.sluiter@xpertclinic.nl, Dirk-Jan van der Avoort, MD. D.vanderavoort@equipezorgbedrijven.nl, Erik Walbeehm, MD, PhD. E.walbeehm@equipezorgbedrijven.nl, Guus Vermeulen, MD, PhD. G.vermeulen@xpertclinic.nl, Hans Temming, MD. H.temming@xpertclinic.nl, Jeroen Smit, MD, PhD. J.smit@xpertclinic.nl, Jeroen van Uchelen, MD, PhD. J.vanuchelen@equipezorgbedrijven.nl

Luitzen de Boer, MD. L.deboer@xpertclinic.nl, Nicole de Haas MD. N.dehaas@xpertclinic.nl, Oliver Zöphel, MD, PhD. O.zophel@xpertclinic.nl, Reinier Feitz, MD, PhD. R.feitz@xpertclinic.nl, Sebastiaan Souer, MD, PhD. S.souer@xpertclinic.nl, Thybout Moojen, MD, PhD. T.moojen@xpertclinic.nl, Xander Smit, MD, PhD. X.smit@xpertclinic.nl, Rob van Huis, PT, CHT-NL. r.vanhuis@handtherapie.nl, Handtherapie Nederland, HNL

Pierre-Yves Pennehouat, PT, CHT-NL, Handtherapie Nederland. P.pennehouat@xpertclinic.nl

Karin Schoneveld, PT, CHT-NL, MSc, Hnl k.schoneveld@handtherapie.nl, Joris Veltkamp, PT, CHT-NL, j.veltkamp@xpertclinic.nl Hnl, Alexandra Fink, PT, MSc a.fink@xpertclinic.nl Hnl, Willemijn de Ridder, Msc, PT, w.deridder@xpertclinic.nl, Harm Slijper, PhD, Xpert harm.slijper@gmail.com Xpert, Ralph Poelstra, MD, PhD, ralph.poelstra@gmail.com, Mark van der Oest, BSc, m.vanderoest@erasmusmc.nl, Marloes ter Stege, MSc, m.terstege@equipezorgbedrijven.nl, Robbert Wouters, PhD, PT, CHT-NL, HNL/Erasmus MC robbertwouters@gmail.com, Joris Teunissen, BSc, Radboudumc Joris.Teunissen@radboudumc.nl, Yara van Kooij, PT, CHT-NL, Msc, yaravk@hotmail.com

## Funding

AC received a grant from ZonMw (843002802), a Dutch organization for health research and care innovation, and co-funding from CZ (201700008), a Dutch health insurance company. Both organizations were not involved in the study design.

## Declaration of Competing Interest

The institution of one or more of the authors (AC) has received funding from ZonMw, a Dutch organization for health research and care innovation, and co-funding from CZ, a Dutch health insurance company.

## Acknowledgements

The authors thank all patients who participated and allowed their data to be anonymously used for the present study. The collaborators of the Hand-Wrist Study Group are: BJR Sluiter, DJJC van

der Avoort, J Smit, ET Walbeehm, GM Vermeulen, JFM Temming, JH van Uchelen, HL de Boer, KP de Haas, OT Zöphel, R Feitz, JS Souer, TM Moojen, X Smit, R van Huis, PY Pennehouat, K Schoneveld, YE van Kooij, RM Wouters, J Veltkamp, A Fink, WA de Ridder, HP Slijper, R Poelstra, MJW van der Oest, JS Teunissen, MHP ter Stege.

## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:[10.1016/j.injury.2021.06.016](https://doi.org/10.1016/j.injury.2021.06.016).

## References

- [1] Mack GR, Bosse MJ, Gelberman RH, Yu E. The natural history of scaphoid non-union. *J Bone Joint Surg Am* 1984;66:504–9.
- [2] Vender MI, Watson HK, Wiener BD, Black DM. Degenerative change in symptomatic scaphoid nonunion. *J Hand Surg Am* 1987;12:514–19.
- [3] Inoue G, Sakuma M. The natural history of scaphoid non-union. Radiographical and clinical analysis in 102 cases. *Arch Orthop Trauma Surg* 1996;115:1–4.
- [4] Weiss KE, Rodner CM. Osteoarthritis of the Wrist. *J Hand Surg Am* 2007;32:725–46.
- [5] Shah CM, Stern PJ. Scapholunate advanced collapse (SLAC) and scaphoid nonunion advanced collapse (SNAC) wrist arthritis. *Curr Rev Musculoskelet Med* 2013;6:9–17.
- [6] Pao VS, Chang J. Scaphoid nonunion: diagnosis and treatment. *Plast Reconstr Surg* 2003;112:1666–76 quiz 77; discussion 78–9.
- [7] Buijze GA, Ochtman L, Ring D. Management of scaphoid nonunion. *J Hand Surg Am* 2012;37:1095–100 quiz 101.
- [8] Ferguson DO, Shanbhag V, Hedley H, Reichert I, Lipscombe S, Davis TR. Scaphoid fracture non-union: a systematic review of surgical treatment using bone graft. *J Hand Surg Eur Vol.* 2016;41:492–500.
- [9] Merrell GA, Wolfe SW, Slade JF. Treatment of scaphoid nonunions: quantitative meta-analysis of the literature. *J Hand Surg Am* 2002;27:685–91.
- [10] Slutsky DJ. Outcomes assessment in wrist surgery. *J Wrist Surg* 2013;2:1–4.
- [11] Alluri RK, Yin C, Iorio ML, Leland H, Wong J, Patel K. Vascularized bone grafting in scaphoid nonunion: a review of patient-centered outcomes. *HAND* 2016;12:127–34.
- [12] Selles RW, Wouters RM, Poelstra R, van der Oest MJW, Porsius JT, Hovius SER, et al. Routine health outcome measurement: development, design, and implementation of the Hand and Wrist Cohort. *Plast Reconstr Surg* 2020.
- [13] Ammori MB, Elvey M, Mahmoud SS, Nicholls AJ, Robinson S, Rowan C, et al. The outcome of bone graft surgery for nonunion of fractures of the scaphoid. *J Hand Surg Eur Vol.* 2019;44:676–84.
- [14] Dacombe PJ, Amirfeyz R, Davis T. Patient-reported outcome measures for hand and wrist trauma: is there sufficient evidence of reliability, validity, and responsiveness? *Hand (N Y)*. 2016;11:11–21.
- [15] Walenkamp MM, de Muinck Keizer RJ, Goslings JC, Vos LM, Rosenwasser MP, Schep NW. The minimum clinically important difference of the patient-rated wrist evaluation score for patients with distal radius fractures. *Clin Orthop Relat Res* 2015;473:3235–41.
- [16] Waitayawinyu T, Pfaeffle HJ, McCallister WV, Nemecek NM, Trumble TE. Management of scaphoid nonunions. *Orthop Clin North Am* 2007;38:237–49 vii.
- [17] Goyal T, Sankineani SR, Tripathy SK. Local distal radius bone graft versus iliac crest bone graft for scaphoid nonunion: a comparative study. *Musculoskelet Surg* 2013;97:109–14.
- [18] Malizos KN, Dailiana Z, Varitimidis S, Koutalos A. Management of scaphoid nonunions with vascularized bone grafts from the distal radius: mid- to long-term follow-up. *Eur J Orthop Surg Traumatol* 2017;27:33–9.
- [19] Mani KCK, Acharya P. Scaphoid nonunion: does open reduction, bone grafting and Herbert screw fixation justify the treatment? *Int Orthop* 2018;42:1099–106.
- [20] Daecke W, Wieloch P, Vergetis P, Jung M, Martini AK. Occurrence of carpal osteoarthritis after treatment of scaphoid nonunion with bone graft and herbert screw: a long-term follow-up study. *J Hand Surg Am* 2005;30:923–31.
- [21] Reigstad O, Thorkildsen R, Grimsgaard C, Reigstad A, Røkkum M. Is revision bone grafting worthwhile after failed surgery for scaphoid nonunion? Minimum 8 year follow-up of 18 patients. *J Hand Surg Eur Vol.* 2009;34:772–7.
- [22] Kawamura K, Chung KC. Treatment of scaphoid fractures and nonunions. *J Hand Surg Am* 2008;33:988–97.
- [23] Barry M.J., Edgman-Levitan S. Shared decision making—The pinnacle patient-centered care. 2012.
- [24] Slover J, Shue J, Koenig K. Shared decision-making in orthopaedic surgery. *Clin Orthop Rel Res* 2012;470:1046–53.