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Rehabilitation after Distal Radius Fractures: Opportunities for Improvement

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Abstract

Background Exercises are frequently prescribed to regain function; yet there is no consensus on a standardized protocol, and adherence is low. Smart technology innovations, such as mobile applications, may be useful to provide home-based patient support in rehabilitation after distal radius fractures.

Purposes Our purpose was to establish the potential of digital innovations for support and monitoring of patients and treatment adherence in rehabilitation programs, and additionally, to compare the current practice among physiotherapists to the various wrist exercise regimens and their effectiveness as described in the literature.

Methods Standard practice, including the use of support tools for treatment adherence, was evaluated using a nationwide survey. Then, scientific databases were searched using “distal radius fracture” and “physiotherapy” or “exercise therapy,” and related search terms, up until 23 March 2023. Results of the survey and literature review were compared.

Results The survey was completed by 92 therapists. Nonstandardized support tools were used by 81.6% of respondents; 53.2% used some form of technology, including taking photos on the patients’ smartphone for home reference. In the literature review, 23 studies were included, of which five described an exercise protocol. Treatment adherence was not reported in any of the included studies. Two studies described the use of smart technology or support tools.

Keywords
- wrist fractures
- exercise therapy
- treatment adherence
- gamification
- self-efficacy

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Conclusions There is no consensus on a standardized exercise protocol for rehabilitation after distal radius fractures, neither from a systematic literature search nor from a nationwide survey. Smart technology may facilitate monitoring of patients and exercise adherence, hereby supporting self-efficacy and improving adherence and outcomes.

Distal radius fractures make up 25% of all fractures in the pediatric population and 18% of fractures in the elderly population.[1] Wrist fractures account for approximately 18% of all patients with fractures presented to the emergency department.[2,3] Incidences have increased over the past years and are predicted to increase further in the near future.[1,4–7] Due to the high loss of productivity, these injuries are expensive to both patients and society.[8–10] Therefore, optimal and fast recovery is important. Distal radius fractures can be treated either nonoperatively by immobilization or by operative fixation.[11–13] After both nonoperative and after operative management of the primary injury, rehabilitation is needed to regain strength and mobility in the wrist and hand.[14–17]

Surgical guidelines suggest that exercises are most likely beneficial to improve functional outcomes, yet do not recommend routine referral to a physiotherapist.[16,18,19] In accordance, the internationally recognized AO Surgery Reference states that "functional exercises can be performed under the supervision of a hand therapist"[14]. Both supervised and unsupervised or home-based exercises are advocated in research. An elaborate Cochrane review states that there is insufficient evidence to recommend one standard practice.[15]

Treatment adherence is an important factor in determining the effect of physiotherapy or exercise therapy. Overall adherence to exercise regimens has been estimated to be as low as 19 to 35%.[20,21] Previous studies showed adherence to be higher in supervised regimens compared with unsupervised programs.[20,21] Self-efficacy or the belief in ones capabilities to reach a certain goal is an important factor in determining physiotherapy outcomes[22,23] and a low self-efficacy can be an important barrier to treatment adherence.[24]

The use of novel e-health applications, including wearable motion sensors, applied games, and smartphone applications can provide easily accessible personal support tools in rehabilitation.[25–28] These smart technology strategies seem promising, as they could improve self-efficacy by providing reminders and continuous explanations, increasing treatment accessibility and treatment adherence.[27] In addition, the use of smart technology can possibly reduce the increasing demand for physiotherapy and hand therapy, by providing therapists with an accessible method of monitoring patients.

This study identifies opportunities for improving rehabilitation after distal radius fractures. This is achieved by comparing the currently evaluated standard of clinical practice, to what is known in the literature, especially focused on supporting self-efficacy and treatment adherence. By evaluating the use of support tools to enhance treatment adherence, we aim to identify methods to enhance patient guidance in times that see an increasing demand in easily accessible, home-based options for rehabilitation.

Methods

Survey

A random selection of 210 physiotherapy practices across the country was made using the national online database of physiotherapy practices. Fifty-nine physiotherapy practices specialized in hand and wrist rehabilitation were included in this selection. The survey was sent out via email. Therapists were given 30 days to reply. The first 50 responders had the chance to win an Apple iPad mini, decided by a raffle executed by an independent researcher.

The survey consisted of a questionnaire featuring two standardized cases of patients recovering from a distal radius fracture, describing one nonoperatively treated patient and one operatively treated patient (full description in supplementary material). The questionnaire was designed in cooperation with specialized hand and wrist physiotherapists and contained five general questions evaluating the level of experience of the physiotherapist and 20 questions about the proposed treatment for the case descriptions. Therapists were asked to describe any tools used for support and motivation of patients performing home exercises, such as web-based tools, documents, or leaflets providing extra instructions or reminders. Multiple choice and open questions were used. Results of the questionnaire were qualitatively analyzed using descriptive statistics in SPSS (Statistical Package for Social Sciences version 26, IBM, New York).

Systematic Review

The systematic review was executed according to the Quality of Reporting of Meta-analyses guidelines. The protocol for the review was registered in the International Prospective Register of Systematic Reviews database with registration number CRD42017070732.

Search Strategy and Criteria

A systematic literature search without publication date restrictions was conducted in the databases of MEDLINE via PubMed, Embase, the Cochrane Library, the Current Index to Nursing and Allied Health Literature, and the Physiotherapy Evidence Database, PEDro. The complete search terms are shown in the supplementary data. The search was last performed on the 23rd of March 2023.

Relevant articles were selected by two independent reviewers (H.M. and J.vL.), with any disagreement resolved through discussion. Studies comparing either visual or written instructions for exercises or supervised active exercises to unsupervised or no exercises after any type of distal radius fracture in adults were included. Interventions starting exercises before definitive fracture treatment, as well as studies focusing on passive mobilization only, splinting, and complicated fracture healing were excluded. The risk of bias was assessed according to the Cochrane Handbook for Systematic Reviews, using Review Manager (RevMan 5.3, the Cochrane Collaboration Information Management System) for randomized studies and using the methodological index for nonrandomized studies tool for nonrandomized studies.[29]

Data Extraction and Synthesis

All included studies were screened for the use of support tools, ranging from written instructions to specifically developed tools such as mobile applications. When reported, exercise protocols, treatment adherence, and any support tools used to improve treatment adherence were analyzed.

Range of motion (ROM) and grip strength were registered as primary outcomes. Patient-rated outcomes, including pain on a visual analog scale or numerical rating scale, the Disabilities of Arm, Shoulder and Hand (DASH, or the shortened Quick-DASH version) questionnaire, and the patient-rated wrist evaluation were registered as secondary outcomes.

Studies were analyzed in two groups: supervised physiotherapy exercises (1) versus home-based exercises or (2) versus other interventions. Treatment was considered to be a home-exercise program when patients received any form of written or visual instructions or a single physiotherapy session for instructions.

Results

Nationwide Survey

A total of 92 respondents (response rate 44%) completed the survey. Review of the respondents' postal codes showed all provinces were represented equally in the questionnaire. Both small and larger practices were represented. The majority of respondents (65.2%) had more than 10 years of working experience but treated only up to 10 patients with distal radius fractures per year (►**Table 1**).

Treatment duration varied between 3 weeks to 1 year (►**Table 2**). Multiple exercise techniques were used during consultations, and patients were prescribed at least one type of homework exercise.

The majority of physiotherapists (82.5%) and a slightly smaller majority of specialized hand and wrist therapists (68%) did not use a standardized protocol but prescribed tailored exercises depending on the patient's injury severity and level of disability. To support treatment adherence, therapists mostly used informative leaflets (40.2%). Some therapists embraced novel technologies and used online webpages (10.8%) or the patient's own smartphone to take pictures or videos for home reference (17.4%). True mobile applications, either or not developed specifically for wrist rehabilitation, were used by 25% of therapists as support tools for patients.

Literature Review

The search yielded 2,156 unique articles, of which 23 were found eligible for inclusion (►**Fig. 1**). Overall, sample sizes were small (►**Tables 3** and **4**). The most common risk of bias was a lack of blinding (►**Fig. 2**). Rehabilitation settings varied from self-managed to daily supervised physiotherapy sessions.

Seventeen studies compared supervised to home-based exercises (►**Table 3**).[30–46] In almost all studies, patients started exercises within 1 week of operative fracture stabilization or cast removal (►**Tables 3** and **4**). In four studies, patients received 2 weeks of splint immobilization after volar plate fixation, before starting active exercises.[35,37–39] In one study, nonoperatively treated patients started exercises 6 weeks after cast removal, and in another trial, patients were only referred to a physiotherapist when they requested

Table 1 Survey respondents

Specialization	Number ($n = 92$)	Experience (years)			Number of patients with distal radius fractures treated per year		
		0–5 y	6–10 y	>11 y	<10 patients	11–20 patients	>20 patients
Physiotherapy	80	10	17	53	53	15	12
General physiotherapy only	25	6	9	10	18	4	3
Physio and manual therapy	15	1	2	12	15	0	0
Physio and hand therapy	17	2	1	14	4	5	8
Physio and exercise therapy	2	0	0	2	0	1	1
Physio and another specialization	21	1	5	15	16	5	0
Hand physiotherapy	6	0	2	4	2	2	2
Manual therapy	3	1	1	1	2	1	0
Other	3	0	3	0	3	0	0

Table 2 Standard therapy as described by therapists. A total of 92 respondents (response rate 44%) filled out the nationwide survey

	Percentage of therapists
Type of protocol used	
Own protocol	11.6%
Standardized protocol	17.4%
No protocol	70.9%
Frequency of visits	
Weekly	54.1%
Every other week	21.2%
Monthly	0%
Other	24.7%
Length of treatment program	Mean 13.5 wk (SD 7.4) Median 12 wk (range 3–52, IQR 8–15)
Types of exercises during treatment[a]	
Joint mobilization	90.2%
Stretching	68.5%
Strength exercises	73.9%
Coordination	65.2%
Other	23.9%
Type of home exercises[a]	
Active range of motion exercises	91.3%
(Grip) strength exercises	79.3%
Passive mobilization exercises/stretches	67.4%
Other exercises	27.2%
Support tools used[a]	
Leaflets	40.2%
Online webpage	10.8%
Mobile applications	25.0%
Pictures/visual support (videos)	17.4%
Other	30.4%
None	18.4%

Abbreviations: IQR, interquartile range; SD, standard deviation.
[a]More than one answer per therapist possible.

this.[30,40] Most studies provided patients with written exercise instructions.[31,36–44] Two trials provided video-based instructions.[30,35]

Four trials found statistically significant advantages of supervised therapy over home exercises in grip strength and ROM, of which one showed clinically relevant differences.[41–45] Three studies found opposite results, favoring home-exercise programs over supervised therapy, of which one showed clinically relevant differences in ROM and grip strength.[37,39,46] Other studies found no differences between supervised and home-based exercises.[31–36,40]

Six studies compared supervised physiotherapy to other interventions (►**Table 4**).[47–52] Of these studies, one described providing patients with written exercise instructions.[52] Two trials comparing home-based exercise or a single exercise session to a control group receiving no exercise instructions found statistically significant advantages of exercise over no exercises.[49,52] Patients receiving additional occupational therapy showed a statistically significant increase in grip strength compared with patients receiving physiotherapy alone.[48] Patients receiving additional mirror therapy, gamification, and robot-assisted arm training showed only a beneficial effect of gamification in pain scores, active ROM, and DASH scores, compared with patients receiving only regular supervised exercises.[47,50,51]

Exercise Protocols, Support Tools and Treatment Adherence

Eleven studies provided patients with written instructions for exercises for home reference,[31,36–44] two used video-based instructions,[30,35] and ten trials did not report using any form of support tools for patients.[32–34,45–51] Seven studies described the used exercise protocol in detail, and four articles included a complete graphical depicted home-exercise protocol[35–37,43]. While exercise understanding was checked at follow-up in almost all trials, none of the included studies specifically reported treatment adherence or described the use of monitoring tools.

Discussion

This nationwide survey and the systematic review of the current literature show overlapping strategies and yet provide no consensus on the current standard of wrist rehabilitation after distal radius fractures. Recent literature accordingly shows no clinically relevant differences between outcomes of supervised rehabilitation and independent exercises[15,53–55].

Our nationwide survey shows the use of various different treatment protocols for distal radius fracture rehabilitation. Prescribed treatment duration, frequency, and exercises vary per therapist, and most therapists prefer an individualized approach for each patient. In the survey, physiotherapists describe the use of numerous different support tools for home-based exercise programs. These tools may lead to a better treatment adherence, as well as improve self-efficacy, hereby improving patient outcomes.[20,22,24]

It can be concluded from the literature review that performing any sort of exercises seems better than performing no exercises. The type of exercises and whether these need to be performed under supervision, as well as the duration of exercise programs, cannot be deduced from the included studies. Some studies in the literature review describe giving patients written or video instructions for home exercises,[30,31,35–39,43,52] yet treatment adherence to exercise regimens is not reported in any of the included studies. Since treatment adherence influences intervention

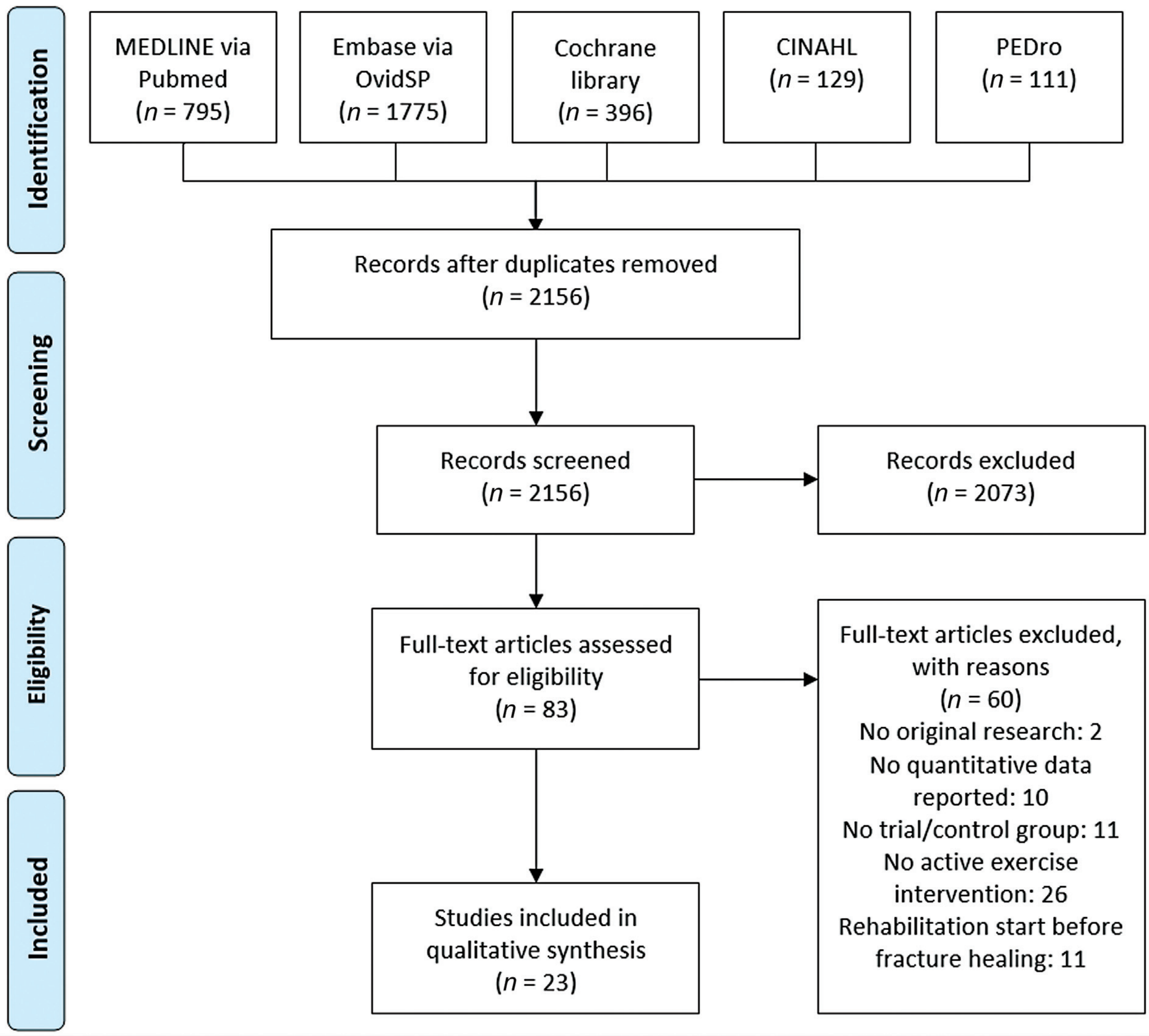

Fig. 1 PRISMA flow diagram.

effectiveness,[22,56] it is recommended that future studies monitor and report therapy adherence rates.

As shown in one trial included in the review, gamification can be a method to support patient self-efficacy and facilitate support during rehabilitation exercises.[51] After successful validation, the use of novel technologies such as gamification and mobile applications may be promising in improving rehabilitation, when complying with the relevant laws and regulations.[57–59] These technologies can provide monitoring, increase self-efficacy[20,24,27], and may hereby improve outcomes in the near future. In addition, "gamification" principles have shown in previous studies to increase treatment adherence[27,60] and seem promising in improving functional outcomes in wrist rehabilitation.[51] Recent trials show a positive effect of active games compared with regular physiotherapy interventions.[61,62]

In the current era of self-tracking devices and consumer-based wearables, these can facilitate easy access to continuous treatment in case of self-isolation, as home-based therapy options were recently needed during the severe acute respiratory syndrome coronavirus 2 pandemic. Innovative technologies can also help meet the increasing demand for physiotherapy and rehabilitation programs. The additional options of providing personalized, home-based rehabilitation programs while also enabling remote monitoring of patient outcomes such as ROM, are promising and therefore imperative to investigate in future research.

Conclusion

Despite increasing numbers of patients, there is no consensus on exercise protocols after distal radius fractures, neither from a nationwide survey nor in the current scientific literature. Performing exercises, whether it be supervised or unsupervised, is necessary for recovery and therefore needs to be readily available to all patients. The current challenges consist of facilitating patient monitoring, increasing treatment adherence and providing patients with support tools to increase self-efficacy. Future research needs to establish consensus on exercise protocols and should

Table 3 Studies included in qualitative synthesis. A: Supervised physiotherapy exercises versus home-based exercises

Author, year	Study type	Patient population			Intervention	Control	Outcomes				
		Treatment	Sex	Age	(supervised physiotherapy)	(home-based exercise)	Measurements	Time points	Intervention	Control	*p*-Value (statistical test)
Bruder et al, 2016 [31]	Evaluator-blind RCT	Conservative (6–7 wk of plaster cast)	Intervention: F: 79% Control: F: 71%	Intervention: 51 (SD 17) Control: 58 (SD 18)	Physiotherapy (3 sessions) and a supervised exercise program (*n* = 19)	Physiotherapy (3 sessions) advice only (*n* = 14)	ROM (flexion, in degrees) PRWE (activity sub-scale) QuickDASH (scale 0–100) Grip strength (kgs)	7 wk 24 wk 7 wk 24 wk 7 wk 24 wk 7 wk 24 wk	15 (SD 7) 18 (SD 11) −20 (SD 9) −21 (SD 11) −31 (SD 14) −35 (SD 14) 7 (SD 4) 9 (SD 5)	17 (SD 10) 24 (SD 9) −18 (SD 15) −23 (SD 11) −28 (SD 24) − 38 (SD 19) 7 (SD 5) 10 (SD 5)	NS (ANCOVA)
Christensen et al, 2001 [32]	Unblinded RCT	Conservative (5 weeks of plaster cast)	M: 3 (10%) F: 27 (90%)	66 (range 46–82)	Occupational therapy and home-based exercises (*n* = 16)	Home-based exercise program (*n* = 14)	Modified Gartland and Werley functional score (median)	5 wk 3 mo 9 mo	13 8 3	12 6 2	> 0.05 > 0.05 > 0.05 (Mann–Whitney U)
Clementsen et al 2019 [38]	Unblinded RCT	Operative: volar plate fixation (with additional 2 weeks splint in control group)	M: 11F: 108	Intervention: 55 (SD 12.4) Control: 55 (SD 11.9)	Physiotherapy (6 sessions over 3 mo) and exercise instructions starting immediately post-surgery (*n* = 57)	Single physiotherapy session 2 wk after surgery, instructions for home exercises (*n* = 62)	QuickDASH	6 wk 3 mo 1 y 2 y	29.5 (SD 19.4) 17.1(SD 16.8) 10.1 (SD 17.9) 7.4 (SD 14.5)	37.3 (SD 19.1) 17.3 (SD 14.4) 1.07 (SD 14.5) 8.5 (S 14.2)	NS (linear mixed models)
							VAS pain score	6 wk 3 mo 1 y 2 y	1.8 (SD 1.8) 1.1 (SD 1.6) 0.7 (SD 1.8) 0.7 (SD 1.9)	2.2(SD 1.7) 1.0 (SD 1.2) 0.7 (SD 1.2) 0.7 (SD 1.5)	
							PRWE	6 wk 3 mo 1 y 2 y	29.6 (SD 21.3) 17.0 (SD 18.6) 10.2 (SD 19.1) 8.2 (SD 17.2)	35.7 (SD 21.2) 15.9 (SD 15.8) 10.7 (SD 15.4) 8.0 (SD 14.9)	
Coughlin et al 2021 [30]	Unblinded RCT	Conservative (6 weeks of plaster cast)	Face-to-face group: F: 28 (76%) Leaflet group: F: 26 (65%) Video group: F 26 (69%)	Intervention: 49 (SD 15.7) Control (leaflet): 44 (SD 14.8) Control (video): 54 (SD 12.8)	Face-to-face therapy (at least 4 physiotherapy sessions in 6 wk)	Home-based exercises 1: explained in a leaflet 2: explained in a step-wise video	DASH	6 wk	13 (SD 13)	Leaflet 15 (SD 16)[a] Video 12 (SD 14)	0.01 Other: NS (ANOVA)
								1 y	5 (SD 11)	Leaflet 8 (SD 11) Video 5 (SD 2)	
Gamo et al 2022 [45]	Evaluator-blind RCT	Operative: volar plate fixation (no cast)	F: 100%	Intervention: 68.9 (SD 8.5) Control: 66.8 (SD 10.7)	Hand therapy, 2 sessions per week for 12 wk (*n* = 29)	Independent exercise with a single instruction session (*n* = 28)	QuickDASH	6 wk 6 mo	12.5 (SD 8.6) 4.4 (SD 7.2)	19.4 (SD 12.4) 2.4 (SD 3.3)	0.027 NS (t-test)
							PRWE	6 wk 6 mo	18.0 (SD 11.5) 3.8 (SD 7.3)	22.9 (SD 18.4) 1.1 (SD 1.7)	NS NS (t-test)
							Pain (VAS)	6 wk 6 mo	10.2 (SD 10.5) 3.4 (SD 8.7)	17.6 (SD 14.8) 2.2 (SD 5.3)	0.046 NS (t-test)

(*Continued*)

Table 3 (*Continued*)

Author, year	Study type	Patient population			Intervention	Control	Outcomes				
		Treatment	Sex	Age	(supervised physiotherapy)	(home-based exercise)	Measurements	Time points	Intervention	Control	*p*-Value (statistical test)
							Grip strength (% of uninjured side)	6 wk 6 mo	66.4 (SD 20.0) 88.5 (SD 18.3)	65.8 (SD 18.2) 86.9 (SD 13.8)	NS NS (t-test)
							Active ROM flexion-extension arc Active ROM pronation-supination arc	6 wk 6 mo	84.8 (SD 13.7) 89.9 (SD 10.1)	72.4 (SD 21.8) 89.3 (SD 12.8)	0.020 NS (t-test)
							Active ROM flexion-extension arc Active ROM pronation-supination arc	6 wk 6 mo	95.7 (SD 12.5) 99.8 (SD 12.3)	88.2 (SD 7.1) 98.0 (SD 4.4)	0.012 NS (*t*-test)
Gutiérrez -Espinoza et al, 2017[43]	Evaluator-blind RCT	Conservative (6–7 wk of plaster cast)	M: 3 F: 71	Intervention: 72.10 (SD 7.44) Control: 71.62 (SD 7.83)	Supervised physiotherapy for 6 wk ($n = 37$)	Home-based exercise program for 6 wk ($n = 37$)	PRWE	6 wk 6 mo	27.94 (SD 9.26) 15.75 (SD 6.16)	45.62 (SD 15.80) 32.81 (SD 1.21)	< 0.001 (*t*-test, Mann–Whitney U)
							Grip strength (kgs)	6 wk 6 mo	66.35 (SD 9.40) 78. 64 (SD 7.23)	45.13 (SD 18.98) 52.83 (SD 21.16)	
							Pain (VAS)	6 wk 6 mo	1.27 (SD 0.90) 0.94 (SD 0.88)	3.05 (SD 1.76) 1.91 (SD 1.01)	
							Active ROM flexion	6 wk 6 mo	61.35 (SD 8.94) 71.08 (SD 4.87)	49.05 (SD 15.08) 53.37 (SD 15.59)	
							Active ROM extension	6 wk 6 mo	71.08 (SD 6.25) 77.02 (SD 2.48)	50.81 (SD 18.20) 57.97 (SD 15.78)	
Kay et al, 2000 [44]	Evaluator-blind RCT	Conservative (6 wk of plaster cast) and operative (6 wk of pins and plaster cast)	Intervention: F: 79% Control: F: 60%	Intervention: 54.7 (SD 13.1) Control: 51.6 (SD 18.8)	Supervised physiotherapy with passive mobilization (9 sessions) for 6 wk ($n = 20$)	Physiotherapy (3 sessions) with a home-based exercise program for 6 wk ($n = 19$)	Active ROM flexion	6 wk	61.6 (SD 13.2)	58.3 (SD 12.6)	0.56
							Active ROM extension	6 wk	51.8 (SD 10.7)	50.5 (SD 13.4)	0.02
							Grip strength (kgs)	6 wk	17.3 (SD 7.4)	20.8 (SD 13.3)	0.61 (repeated measures ANOVA)
Krischak et al, 2009 [37]	Unblinded RCT	Operative: internal fixation with locking plates (2 wk splint postoperatively)	Intervention: F: 65% Control: F: 65%	Intervention: 53.7 (SD 17.9) Control: 56.0 (SD 11.1)	Supervised physiotherapy (12 sessions) over 6 wk ($n = 23$)	Unsupervised home-exercise program with raining-diary ($n = 23$)	PRWE	6 wk	36.1 (SD 13.9)	18.5 (SD 15.9)	< 0.001
							Grip strength (% of uninjured side)	6 wk	32%	54%	0.003
							ROM; extension and flexion (% of uninjured side)	6 wk	52%	79%	< 0.001 (Mann–Whitney U)

Table 3 (*Continued*)

Author, year	Study type	Patient population			Intervention	Control	Outcomes				
		Treatment	Sex	Age	(supervised physiotherapy)	(home-based exercise)	Measurements	Time points	Intervention	Control	*p*-Value (statistical test)
Lara et al 2022[35]	Unblinded RCT	Operative: volar plate fixation (2 wk splint postoperative-ly)	Intervention: F: 15 (57%) Control: F: 5 (71%)	Intervention: 58 (range 46–67) Control: 54 (range 46–63)	Supervised physiotherapy (median of 5 sessions over 12 wk) (*n* = 29)	Self-directed physiotherapy by digital media (*n* = 22)	QuickDASH	2 wk 6 wk 12 wk	36.6 (SD 5.0) 43.9 (SD 4.0) 29.4 (SD 4.3)	41.1 (SD 5.4) 32.6 (SD 4.8) 19.2 (SD 5.2)	NS NS NS (repeated measures ANOVA)
Maciel et al, 2005 [33]	Evaluator-blind RCT	Conservative (6–7 wk of plaster cast)	Intervention: F: 83% Control: F: 67%	Intervention: 55.7 (SD 17.7) Control: 55.8 (SD 19.4)	Activity focused physiotherapy for 6 wk (*n* = 23)	Advice and explanation of an unsuper-vised exercise program (*n* = 18)	PRWE	6 wk 24 wk	26.9 (SD 24.0) 21.4 (SD 24.5)	28.2 (SD 20.6) 24.8 (SD 22.2)	NS (repeated measures ANOVA)
							Grip strength (kgs)	6 wk 24 wk	15.5 (SD 11.6) 19.0 (SD 14.0)	14.8 (SD 8.1) 20.8 (SD 11.1)	
							ROM flexion	6 wk 24 wk	48.9 (SD 15.9) 56.7 (SD 16.5)	51.6 (SD 16.5) 54.3 (SD 14.4)	
							ROM extension	6 wk 24 wk	42.7 (SD 13.7) 50.7 (SD 15.6)	46.9 (SD 9.3) 51.3 (SD 11.6)	
Oskarsson et al, 1997 [40]	Matched pairs cohort study	Conservative (4–6 wk of plaster cast)	F: 83%	58 (SD NR)	Supervised physiotherapy exercises (*n* = 40)	Unsupervised home-based exercises (*n* = 40)	Gain in wrist movement score	35 wk (% of uninjured side)	30.9 (25.4–36.0) 30.06%	27.2 (23.4–32.0) 33.78%	NS (*t*-test)
							Gain in grip strength	35 wk (% of uninjured side)	14.8 (11.9–19.5) 13.58%	10.5 (8.6–12.5) 14.12%	NS (*t*-test)
Pasila et al, 1974 [34]	Unblinded RCT	Conservative (5 wk plaster cast)	F: 93%	NR	Supervised physiotherapy and instruc-tions for home-based exercises (*n* = 48)	Instructions for unsupervised home-based exercises only (*n* = 48)	Grip strength (kg/cm2)	12 wk	0.29 (SD 0.13)	0.31 (SD 0.16)	NS
							p>ROM flexion	12 wk	42.4 (SD 12.1)	43.5 (SD 11.5)	NS
							ROM extension	12 wk	49.7 (SD 14.1)	48 (SD 11.5)	NS (unknown)
Saito et al 2022[39]	Retrospec-tive study (matched controls)	Operative: volar plate fixation (maximum of 2 wk splint post-operatively)	Intervention: F: 90.6% Control: F: 89.6%	Intervention: 76.82 (SD 7.10) Control: 76.44 (SD 6.93)	Supervised physiotherapy (*n* = 308)	Independent home exercise (*n* = 308, matched controls)	Pain (NRS)	1 mo 3 mo 6 mo	2.59 (SD 1.94) 1.33 (SD 1.36) 0.71 (SD 1.13)	2.03 (SD 1.32) 1.00 (SD 1.22) 0.46 (SD 0.87)	<0.05 <0.05 <0.05
							ROM extension	3 mo 6 mo 12 mo	55.86 (15.68) 65.49 (SD 12.08) 66.81 (SD 12.38)	52.91 (SD 16.21) 63.71 (SD 13.54) 66.45 (SD 12.51)	0.037 NS NS
							ROM flexion	3 mo 6 mo 12 mo	61.68 (SD 14.41) 59.60 (SD 15.53) 64.31 (SD 16.82)	56.12 (SD 15.68) 59.21 (SD 15.39) 61.61 (SD 14.56)	<0.05 NS NS

(*Continued*)

Table 3 (*Continued*)

Author, year	Study type	Patient population			Intervention	Control	Outcomes				
		Treatment	Sex	Age	(supervised physiotherapy)	(home-based exercise)	Measurements	Time points	Intervention	Control	*p*-Value (statistical test)
							Grip strength (kgs)	3 mo 6 mo 12 mo	13.93 (SD 5.38) 15.05 (SD 5.98) 15.58 (SD 5.57)	11.94 (SD 5.29) 15.62 (SD 6.79) 15.88 (SD 5.74)	NS NS NS (*t*-test, Mann–Whitney U)
Souer et al, 2011 [46]	Unblinded RCT	Operative: volar plate fixation (no cast)	NR	NR	Supervised occupational therapy ($n = 46$)	Instructions for independent exercises ($n = 48$)	ROM flexion/ extension arc Grip strength (kgs) DASH score	3 mo 6 mo 3 mo 6 mo 3 mo 6 mo	104 (SD 22.9) 118 (SD 17.7) 26 (SD 7.8) 23 (SD 8.1) 13.3 (SD 9.5) 6.7 (SD 6.7)	111 (SD 22.4) 129 (SD 22.6) 24.8 (SD 10.2) 25.7 (SD 8.3) 13.1 (SD 12.1) 7.8 (SD 7.8)	0.10 < 0.05 < 0.05 0.06 0.91 0.42 (*t*-test, Mann–Whitney U)
Valdes et al, 2015 [36]	Unblinded RCT	Operative: volar plate fixation (no cast)	Intervention: F 93% Control: F: 68%	Intervention: range 28–81 Control: range 23–91	Supervised exercise therapy (16 sessions average) ($n = 26$)	Home-based therapy ($n = 24$)	PRWE (change) ROM flexion/ extension arc (change, deg)	6 mo 12 wk	−65 (SD NR) 67 (SD NR)	−56 (SD NR) 77 (SD NR)	NS (repeated measures ANOVA)
Wakefield and McQueen 2000 [42]	Evaluator blind RCT	Conservative: cast (4–6 wk of plaster cast)	Intervention: F: 90% Control: F: 91%	Intervention: 72 (SD 9.8) Control: 74 (SD 9.1)	Supervised physiotherapy and home-exercises sheet ($n = 49$)	Explanation of home-exercises only ($n = 47$)	Grip strength (lbs) ROM flexion/ extension arc	3 mo 6 mo 3 mo 6 mo	41.6 (SD 4.3) 68.5 (SD 6.1) 82.9 (SD 1.8) 96.6 (SD 2.4)	40.7 (SD 4.6) 67.3 (SD 6.3) 80.0 (SD 1.9) 84.4 (SD 2.5)	0.899 0.885 0.269 0.001 (ANCOVA)
Watt et al, 2000 [41]	Evaluator blind RCT	Conservative: cast (6 wk of plaster cast)	Intervention: F: 100% Control: F: 88%	Intervention: 74.4 (SD 10.2) Control: 77.3 (SD 5.1)	Supervised physiotherapy exercises ($n = 9$)	No physiotherapy exercises ($n = 9$)	Grip strength (kgs)	6 wk	10.1 (range 7.0–13.5)	5.3 (range 4.3–6.1)	0.026
							ROM extension	6 wk	55.7 (SD 14.2)	38.3 (SD 14.2)	0.010 (Mann–Whitney U)

Abbreviations: ANCOVA, analysis of covariance; ANOVA, analysis of variance; DASH, Disabilities of Arm, Shoulder and Hand; NR, not reported; NRS, numerical rating scale; NS, not significant; PRWE, patient-rated wrist evaluation; RCT, randomized controlled trials; ROM, range of motion; SD, standard deviation; VAS, visual analog scale.

Table 4 Studies included in qualitative synthesis. A: Physiotherapy (supervised) exercises versus other interventions

Author, year	Study type	Patient population			Intervention	Control	Outcomes				
		Treatment	Sex	Age			Measurements	Time points	Intervention	Control	*p*-Value (statistical test)
Bayon-Calatayud et al, 2017 [47]	Evaluator blinded RCT	Operative and conservative (type of treatment not specified)	Intervention F: 73% Control F: 64%	Intervention: 61.09 (SD 13.05) Control: 55.36 (SD 18.28)	Conventional physiotherapy with 15 sessions of 30 minutes mirror therapy ($n=11$)	Conventional therapy with 15 sessions of 30 minutes occupational therapy ($n=11$)	ROM extension (mean change)	3 wk	17 (SD 7)	13 (SD 11)	0.409 (NS)
							Quick-DASH (mean change)	3 wk	−26.6 (SD 16.7)	−30.57 (SD 7.76)	0.191 (NS) 0.807
							Pain (VAS, median change)	3 wk	−2.0 (IQR −5.0 to −1.0)	−2.0 (IQR −4.0–0)	(Mann–Whitney U)
Filipova et al 2015 [48]	Evaluator blinded RCT	Conservative (4–6 wk of plaster cast)	Intervention F: 83.3% Control F: 74.2%	Intervention: 62 (SD 14) Control: 58 (SD 14.5)	Conventional physiotherapy (9 sessions in 3 wk) with 30mins additional occupational therapy per session ($n=30$)	Conventional physiotherapy (9 sessions in 3 wk) ($n=31$)	ROM flexion/ extension arc (mean)	4 wk 8 wk	112 (95% CI 103–121) 123 (95% CI 115–131)	116 (95% CI 108–142) 124 (95% CI 116–132)	0.228
							Grip strength (% of uninjured side)	4 wk 8 wk	56 (95% CI 49–63) 67 (95% CI 60–74)	44 (95% CI 36–52) 53 (95% CI 45–61)	0.021
							DASH (mean, 95% CI)	4 wk 8 wk	35 (95% CI 29–41) 21 (95% CI 15–36)	39 (95% CI 33–46) 26 (95% CI 21–32)	0.264 (ANOVA)
Kay et al, 2008 [52]	Evaluator blind RCT	Operative and conservative (6 wk of immobilization using plaster cast or pins with plaster cast) ($n=56$)	Intervention F: 71% Control F: 68%	Intervention: 55.0 (SD 20.3) Control: 55.8 (SD 19.9)	Advice and physiotherapy exercises (2–3 sessions per week) ($n=28$)	No advice or exercises ($n=28$)	ROM flexion	3 wk 6 wk	21 (SD 12) 26 (SD 18)	16 (SD 9) 21 (SD 9)	NS NS
							p>ROM extension	3 wk 6 wk	13 (SD 13) 17 (SD 12)	13 (SD 9) 19 (SD 10)	NS NS
							Grip strength (kgs)	3 wk 6 wk	7.0 (SD 7.1) 10.2 (SD 8.0)	5.9 (SD 4.7) 8.5 (SD 4.9)	NS NS
							PRWE pain subscale	3 wk 6 wk	−19 (SD 20) −26 (SD 20)	−5 (SD 18) −13 (SD 18)	0.06 0.03
							PRWE function subscale	3 wk 6 wk	−33 (SD 25) −47 (SD 24)	−23 (SD 28) −46 (SD 19)	NS NS (*t*-test)
Mitsukane et al, 2015 [49]	Unblinded RCT	Operative ($n=17$) and conservative ($n=11$; plaster cast immobilization 5–7 wk)	Intervenion F: 64.3% Control F: 71.4%	Intervention: 62 (SD 13) Control: 64 (SD 14)	Passive ROM exercises with a single session of repetitive wrist extension exercises ($n=14$)	Passive ROM exercises ($n=14$)	Grip strength (kgs)	Single session	16.4 (SD 9.9)	15.3 (SD 8.2)	0.26 (Mann–Whitney U)
Naqvi et al 2022 [51]	Unblinded RCT	Operative (k-wire fixation)	Intervention F: 20%	Mean/SD not reported	Guided rehabilitation (4 wk, 20 sessions) with	Guided rehabilitation (4 wk, 20 sessions) with	DASH	2 wk 4 wk	34.5 (SD 3.74) 48.8 (SD 4.34)	18.8 (SD 1.68) 34.6 (SD 3.53)	<0.001 <0.001

(*Continued*)

Table 4 (*Continued*)

Author, year	Study type	Patient population			Intervention	Control	Outcomes				
		Treatment	Sex	Age			Measurements	Time points	Intervention	Control	*p*-Value (statistical test)
			Control F: 50%		additional VR games	conventional rehabilitation	Pain (VAS)	2 wk 4 wk	3.74 (SD 0.72) 1.77 (SD 0.38)	5.98 (SD 0.39) 4.18 (SD 0.27)	<0.001 <0.001
							Active ROM flexion	2 wk 4 wk	51.7 (SD 7.34) 63.7 (SD 3.88)	34.20 (SD 5.37) 52.70 (SD 3.91)	<0.001 <0.001
							Active ROM extension	2 wk 4 wk	43.6 (SD 5.75) 63.7 (SD 3.88)	34.8 (SD 3.11) 52.7 (SD 3.91)	<0.001 <0.001 (*t*-test)
Picelli et al, 2020 [50]	Evaluator blind RCT	Operative ($n = 13$) and conservative ($n = 7$; at most 8 wk after fracture)	Intervention F: 60% Control F: 70%	Intervention: 57.9 (SD 11.4) Control: 66.1 (SD 10.3)	Conventional physiotherapy (10 sessions of 60mins in 2 wk) with 30mins additional robot-assisted arm training per session ($n = 10$)	Conventional physiotherapy (10 sessions of 60mins in 2 wk) with 30mins additional occupational therapy per session ($n = 10$)	Active ROM flexion	2 wk 6 wk	63.9 (SD 10.8) 66.3 (SD 11.0)	65.3 (SD 8.8) 65.5 (SD 10.4)	0.288 0.268
							Active ROM extension	2 wk 6 wk	56.3 (SD 18.7) 53.4 (SD 19.3)	60.8 (SD 16.2) 55.3 (SD 14.6)	0.460 0.161
							Active ROM pronation	2 wk 6 wk	85.0 (SD 0.0) 85.0 (SD 0.0)	85.0 (SD 0.0) 85.0 (SD 0.0)	0.701 0.701
							Active ROM supination	2 wk 6 wk	65.6 (SD 28.9) 74.6 (SD 27.8)	66.6 (SD 32.0) 76.3 (SD 14.3)	0.426 0.337
							Grip strength	2 wk 6 wk	12.3 (SD 7.0) 15.6 (SD 7.3)	12.4 (SD 7.6) 14.3 (SD 6.9)	0.713 0.862
							PRWE	2 wk 6 wk	21.5 (IQR 10.8–53.3) 13.0 (IQR 4.2–35.2)	22.0 (IQR 8.0–43.5) 20.0 (IQR 0.0–24.5)	0.207 0.094 (Mann–Whitney U)

Abbreviations: ANOVA, analysis of variance; CI, confidence interval; DASH, Disabilities of Arm, Shoulder and Hand; IQR, interquartile range; NR, not reported; NRS, numerical rating scale; NS, not significant; PRWE, patient-rated wrist evaluation; RCT, randomized controlled trials; ROM, range of motion; SD, standard deviation; VAS, visual analog scale.

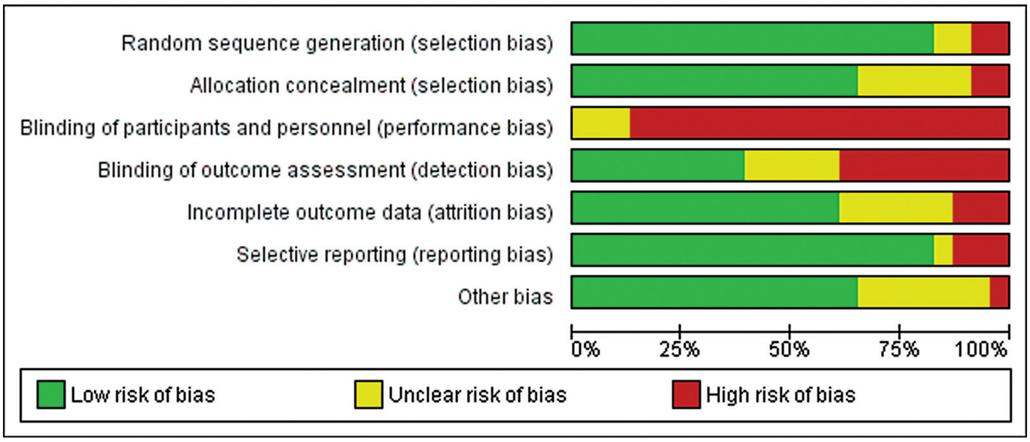

Fig. 2 Risk of bias graph.

routinely evaluate treatment adherence to determine the actual effect of exercises. The potential effect on treatment adherence and patient outcomes of support tools including gamification and mobile applications seems promising and needs to be explored in future studies.

Ethical Review

Ethical review is not applicable for this study, as this is a systematic literature research study, and a voluntary survey study among health care professionals.

No human/patient subjects were involved in any way and presented cases were fictional.

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