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HANDSURGERY

Rehabilitation after distal radius fractures: is there a need for immobilization and physiotherapy?

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Abstract

Although the literature generally agrees that displaced distal radius fractures require surgery, no single consensus exists concerning the length of immobilization and type of post-operative physiotherapeutic rehabilitation program. Palmar locking plate fixation represents a very stable fixation of the distal radius, and was assessed biomechanically in various studies. Surprisingly, most authors report additional immobilization after plate fixation. One reason might be due to the pain caused during active wrist mobilization in the early post-operative stages or secondly to protect the osteosynthesis in the early healing stages preventing secondary loss of reduction. This article addresses the biomechanical principles, current available evidence for early mobilization/immobilization and impact of physiotherapy after operatively treated distal radius fractures.

Keywords Distal radius fracture · Volar locking plate · Complications · Outcome · Rehabilitation · Physiotherapy · Hand therapy

Introduction

Distal radius fractures (DRF) are one of the most common fractures of the upper extremities and incidence is rising, due to a growing elderly population [1–12]. In young adults, these injuries typically occur from high-energy traumas, whereas elderly adults suffer low-energy accidents, such as falls. Especially, women over 60 have a 15% higher lifetime risk, than men of similar age. Additionally, DRF in the elderly are often associated with poor bone quality and osteoporosis [13–20].

The conservative management for nondisplaced DRF involves wrist immobilization in a plaster cast for 5 weeks. In 1989, Lafontaine et al. [21] identified five predictors (age > 60 years, > 20° dorsal angulation, dorsal comminution, fracture extension into the radiocarpal joint and associated ulnar fracture) for instability. Since then, several studies have confirmed these predictors that define an unstable DRF, necessitating surgical intervention [22]. In a systematic review and meta-analysis, Walenkamp et al. [23] pooled the available data in the literature and found only dorsal comminution and women over 60 years as significant predictors for secondary displacement. A recent meta-analysis showed that although surgical treatment does provide a better radiological outcome, no significant differences in functional outcome or complication could be found between operative and conservative treatments [24].

In the past, DRF were treated conservatively by closed reduction plus casting or K-wires. Following the introduction of palmar angular stable locking plates in the 2000s with the subsequent success of internal fixation, a shift occurred in managing DRFs. K-wires or external fixator stabilization shifted towards palmar plate fixation. Even today, optimal treatment options for DRF still remain debatable. However, a

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recent Network Meta-analysis concluded, that plate fixation offers the best results in terms of early functional outcome and reduction of fracture healing complications [25–29].

The main principles for treating articular DRF match those for other articular fractures: anatomical reconstruction, stable fixation and early motion [30–33]. Surprisingly, early mobilization is not routinely performed in DRFs [34]. Although there is a general consensus in the literature that internal fixation requires shorter immobilization periods, the earlier return to daily life activities is possible. Only few studies exist that investigate the benefits of shorter immobilization [35, 36]. Specifically, prospective randomized trials are missing to make definitive statements for the best type of rehabilitation.

Post-operative rehabilitation is a mandatory part of the total management concept after DRFs with the increased risk of impairment due to the wrist joint involvement. Restoration of wrist function and reduction of impairment directly influence the quality of life and duration of sick leave [37]. As more than 50% of the affected patients are still employed [38], a mean sick leave duration of approximately 12 weeks plays an important socio-economical role [39].

Main aim of this article is to review and summarize the current literature for evidence influencing the duration of immobilization and therapeutic interventions after surgically treated DRF.

Biomechanics of palmar stabilized distal radius fractures

Biomechanical studies have shown, that active wrist joint motion during daily activities cause axial loads across the wrist by 100 N. In contrast, Putnam et al. [40] found that 26 N of force is distributed across the wrist for every 10 N of grip strength. Their model assumed a 50/50 force distribution across the radius and ulnar, but other studies have shown that the force ratio between radius and ulnar is 80/20. Therefore, the force across the distal radius would be 42 N per 10 N grip strength [41]. Thus, active finger flexion would produce axial loads by 250 N and, as grip strength in men is a maximum of 463 N, the axial load by maximal finger flexion is 1.926 N. Therefore, it is unlikely that immobilization of the wrist will prevent loss of reduction providing active movement of the fingers remain possible [42]. Further active movement of the scaphoid and lunate ensures that the multiple fragments are modeled into the articular surface [43]. Biomechanical studies have proved that palmar locking plates show a superior stability to K-wire fixation [44, 45]. They also guarantee a five-times higher stability than forces involved in active finger movement [41, 46, 47].

Patient-reported outcome measures after distal radius fractures

Previously, grip strength, range of motion, and radiographic measurements were used to objectify clinical assessment and report about clinical outcome. These parameters give useful information about the individual patient's outcome, but do not actually take into consideration the patient's functional abilities, pain levels, or ability to resume normal daily life activities [48]. Therefore, patient-reported outcome measures (PROM) are increasingly used to measure and report upper limb activity limitations after trauma and orthopedic surgery [49]. The most commonly used scores after DRF are the Disabilities of the Arm, Shoulder, and Hand (DASH), Shortened Disabilities of the Arm, Shoulder, and Hand (*Quick*DASH) and Patient-Rated Wrist Evaluation (PRWE) questionnaire. Also, in some studies, the modified Green O´Brien (Mayo) Score is used. All three scores, DASH, *Quick*DASH and PRWE have shown evidence for reliability, validity and responsiveness [49–51].

Many studies investigating outcome after DRF focus on significant statistical differences and evaluate outcome solely on the basis of *p* values. Though the *p* value does not measure the magnitude of the effectiveness of treatment or clinical importance, strictly speaking, the *p* value is only the probability under a statistical model and is strongly influenced by the sample size. The larger the sample size the higher the probability of a significant *p* value, although the effectiveness of treatment may be small [52]. Thus, analyses and interpretation of results solely depending on the *p*-value do not account for clinical importance. Therefore, the use of minimal clinically important differences (MCID) in a study, for sample size calculation and interpretation of results is critical.

The MCID represents the lowest necessary difference in an outcome score that patients would perceive as beneficial or harmful [52, 53]. The literature quotes MCID for QuickDASH between 8 and 20 points [51], and DASH 3.9–20 points [54]. We agree with Chaudhry et al. [55] and consider a mean difference of 10 points as MCID after DRF, as both scores have not been evaluated specifically for DRF. The PRWE was evaluated for DRF and showed a MCID of 11.5 points [56] and grip strength 6.5 kg or 19.5% decrease [57]. To date, the Mayo score has not been researched for MCID.

Mobilization or immobilization after operatively treated distal radius fractures

Although biomechanical studies validated, that the available locking plate systems provide enough stability to allow

early mobilization, the literature only cites a few studies that focus on this topic and compare early mobilization to immobilization. There is still no unanimous consensus on whether or how long a wrist should be immobilized after operatively treated DRF [58–60].

As far back as 1814 Colles warned his colleagues about prolonged immobilization, which could potentially lead to impaired hand function [61]. Nevertheless, studies in long bone fractures have shown that the first 2 months of recovery significantly influence the outcome. Also, the axial load within 3 weeks after surgery has a significant impact on bone healing [62, 63]. Clinical studies on conservatively treated undisplaced DRF's suggested that shorter immobilization of three instead of 5 weeks lead to an improved short-term outcome and no increased risk of secondary redisplacement [64].

In 2015, the Cochrane Database review by Handoll and Elliott [65] on rehabilitation after DRF in adults confirmed the 2006 conclusions [66], that the effectiveness in various rehabilitation protocols is insufficiently evidence based.

A few case series report on early mobilization [42, 67–69] and only four prospective randomized trials [35, 58, 70, 71] compared the differences in functional outcome of early mobilization and immobilization. Even the standard guidelines do not routinely recommend early mobilization depending on the type of osteosynthesis and achieved stability [72, 73].

In their prospective study, Kwan et al. [68] evaluated 82 patients with DRF and angular stable plate fixation. Free active mobilization of the wrist was initiated immediately after surgery, but method and duration of physiotherapy was not reported. Two years after surgery, they showed in mean 57° in extension, 51° in flexion, 86° in supination and 80° in pronation. Grip strength was 83% compared to the uninjured hand and DASH a mean of 12 points. The radiological parameters showed no significant differences between surgery and final follow-up investigation.

Chung et al. [67] treated 87 patients with palmar locking plate and early mobilization. The patients were immobilized with a removable palmar splint for 6 weeks. One week after surgery, patients commenced structured active physiotherapy of the wrist on a weekly basis for 6 weeks. Strengthening exercises were only commenced at 6 weeks after surgery. After 12 months, ROM recovery compared to the uninjured side rated 83–115% and Michigan Hand Outcomes Questionnaire approached normal scores at 6 months after surgery. However, at the 12 month control, a significant decreased grip strength on the injured compared to the uninjured hand, but under the MCID [mean difference (MD) 3 kg], was noted. No statistical correction of grip strength for hand dominance was performed, which may account for the difference. No significant loss of reduction was seen with early physiotherapy.

The prospective case series by Osada et al. [42] documented 49 unstable DRF stabilized by palmar locking plate without bone grafting and follow-up of 1 year. Patients were only encouraged to use the injured hand for light daily activities from the first day after surgery. They also instructed the patients to actively move their wrist and forearm as frequently as possible. Physiotherapy was only indicated if ROM of the injured hand was less than half of the uninjured hand 3 weeks after surgery. The results after 12 months showed 48 (98%) "excellent" and "good" and one fair (2%) result in the modified Green O`Brien score with a mean DASH of 6 points. No significant indication of loss of reduction by an early mobilization was detected.

Duprat et al. [69] compared a two week splint immobilization to immediate mobilization after surgery in 72 patients after operatively treated DRF. They found no significant differences 3 months after surgery in ROM, grip strength and PROMs between the groups. Even though differences in PROM did not exceed the MCID (MD *Quick*DASH 2.2 points, PRWE 2.4 points). No sample size analysis was performed and patients were not assigned to supervised physiotherapy, but only performed a so called "self-rehabilitation". No complications like loss of reduction were observed in this study.

Lozano-Calderón et al. [35] compared wrist mobilization within two weeks after surgery and immobilization for six weeks in 60 patients in a prospective randomized trial. Both groups wore a removable forearm splint for 6 weeks. Follow-up examinations were conducted three and six months after surgery. The wrist mobilization group were taught how to remove the splint and perform active/active-assisted wrist motion exercises and mobilized the wrist during routine daily activities. In the control group, active wrist mobilization was only initiated after 6 weeks. No significant differences were found between the two groups 3 and 6 months after surgery regarding ROM, grip strength, pain, radiological parameters and PROMs. Hand therapists only taught the patients the specific wrist exercises, but no supervised physiotherapy was conducted. Both groups wore a splint for 6 weeks. In addition, patient´s compliance carrying out the recommended exercise program was not monitored. The immobilization group also only wore a removable splint, therefore, continuous monitoring of immobilization was not performed. Another limitation was that the authors sample size calculation was based on ROM in extension/flexion. As known from other studies ROM does not correlate with the DASH, which is the best outcome parameter after distal radius fractures. Therefore, the study may possibly not detect reliable differences in DASH and is therefore potentially underpowered [64]. Nevertheless, that sample size calculation was based on ROM, MDs in DASH were small at the 3 months (MD 2 points) as well as 6 months (MD 0.4 points) control and under the MCID. First check-ups were

performed only after three months, therefore, differences in the early rehabilitation phase were not covered in this study.

Watson et al. [70] investigated effects of immobilization of one, three and six weeks on hand function and pain after surgically treated DRF. After removal of the splint, all groups received physiotherapy at weekly intervals for 6 weeks including an education and exercise program. After 6 weeks, PRWE and DASH were significantly better, as well as wrist extension/flexion between the "1-week" and "3-week" group compared to the "6-week" group. Differences were over the MCID in the PRWE (14.8 points "1-week" vs. "6-week", 17.3 points "3-week" vs. "6-week") and DASH (15.1 points "1-week" vs. "6-week", 11.6 points "3-week" vs. "6-week"). Three months and 6 months after surgery no significant differences between the groups could be found and were under the MCID. As in the study by Lozano-Calderón et al. [35] sample size was calculated on wrist extension/flexion, therefore, this study may also be inconclusive.

Quadlbauer et al. [58] prospective randomized a small group of 30 patients and compared early mobilization versus immobilization after surgically treated DRF. Both groups received supervised physiotherapy, the early mobilization group from the first day after surgery, the immobilization group after cast removal 5 weeks post-surgery. ROM in extension/flexion and grip strength was significantly better up to 6 months, radial/ulnar deviation up to 9 weeks and supination/pronation up to 6 weeks in the early mobilization group compared to the immobilization group. Grip strength differed significantly between the early mobilization and immobilization group up to three months after surgery. *Quick*DASH and PRWE score was significantly better up to 6 weeks after surgery and Mayo Score up to 1 year after surgery. Only at the 6 week check were the differences over the MCID for PRWE (MD 13.2 points) and *Quick*DASH (MD 22.7 points) and up to 9 weeks for grip strength (MD 7.8 kg). Radiographs showed no loss of reduction. Sample size was small, and prior to conducting the study, no sample size calculation was performed. Therefore, the study is potentially underpowered and differences at the later follow-up intervals may not be detectable.

Andrade-Silva et al. [71] evaluated pain and functional outcome of DRF after palmar locking plate stabilization. Patients were randomized into two groups, one with no immobilization and the other was immobilized for 2 weeks by a palmar splint. No supervised physiotherapy was performed in the mobile group, the functional rehabilitation at home was described by physiotherapists. After 2 weeks, both groups were referred to physiotherapists. Within the first 24 weeks, no significant differences were found in pain according to the visual analogue scale (VAS) and the patients with no immobilization required no more pain killers than the immobilized patients. No significant differences could be found in ROM and PROMs. Mean differences in DASH were under the MCID 6 weeks (MD 3.9 points), 3 months (MD 8.2 points) and 6 months (MD 4.1 points) after surgery.

The different study designs and especially the various rehabilitation protocols (from none to supervised physiotherapy) and immobilization durations makes a direct comparison of the results problematic. Each study has shown their limitations including sample size calculation based on ROM (which is known not to correlate with PROMs), or no sample size calculation. Therefore, the studies may have too few participants and are potentially underpowered. Due to this, significant differences at a later follow-up may not be obvious. Besides these limitations, differences in PROMs were under the MCID at the later follow-up. Consequently, a notable benefit for the patients in long-term outcome is doubtful.

But the gist of these studies suggest that immobilization after operatively treated isolated DRF by palmar locking plate is not necessary. The patients benefit significantly and clinical important by an immediate wrist mobilization in the early rehabilitation phase at least up to 3 months after surgery. Additionally, early active wrist mobilization has no correlation to increased pain risk, loss of reduction or complications. Table 1 summarizes the current studies concerning the impact of immobilization/mobilization after operatively treated DRF.

The impact of physiotherapy on the functional outcome after distal radius fractures

Patients are often referred to physiotherapy after upper limb injuries and especially after DRF to manage pain, improve ROM, grip strength and regain full functionality [74]. It is well known that physiotherapy is beneficial in restoring mobility to impaired extremities [75], but the impact of supervised physiotherapy and active wrist exercises after operatively treated DRF is still not fully clarified in the literature. Several studies investigating additional supervised physiotherapy versus a prescribed home exercise programme showed no conclusive evidence that upper limb function really benefited with the supervised treatment compared to a sole home exercising programme [74, 76–78].

Krischak et al. [37] and Souer et al. [79] even showed that the independent home exercises resulted in superior functional outcomes versus supervised physiotherapy. Krischak et al. [37] prospectively randomized 48 patients with DRF and compared 12 sessions of physiotherapy for 6 weeks to a home exercise alone regime. Therapy of both groups was initiated one week after surgery with a 2-week immobilization of the wrist. After 6 weeks, a reduced upper limb function and increased impairment in the supervised physiotherapy group was reported. But no standardized therapy protocol

Table 1 Summary of studies focusing on immobilization/mobilization after operatively treated distal radius fractures

Study	*N*	Study design	Immobilization	Start active wrist exercises	Postoperative rehabilitation	Outcome measures
Chung et al. [67]	87	Prospective Case Series	Removable palmar splint for 6 wks	within 1 wk after surgery, only with physiotherapy	Once-a-week structured hand therapy program: active wrist motion exercises active and passive finger range of motion. Strengthening exercises only until six wks after surgery	FU: 3 mo, 6 mo, 1a Pain, ROM, grip strength, lateral pinch, Jebsen-Taylor, MHQ, radiographs
Osada et al. [42]	49	Prospective Case Series	No immobilization (except 3 patients)	Immediately after surgery	Instructed to actively move their wrists as frequently as possible and encouraged to use the injured hand for light daily activities, lifting weight max 0.4 kg until fracture union Referred to physical therapy 21 days after surgery, if the range of motion was 50% of the healthy wrist	FU: 5wk, 3mo, 6mo,1a Pain, ROM, grip strength, Gartland and Werley Score, Mayo Score, DASH, radiographs
Kwan et al. [68]	82	Prospective case series	No immobilization	Immediately after surgery	NA	FU: 2 wks, 3mo, 6mo, 1a, 2a Pain, ROM, grip strength, Gartland and Werley functional scores, Mayo Score, DASH, radiographs
Duprat et al. [69]	72	Prospective Cohort Study	Group I ($n=36$): Splint 30° wrist extension Group II ($n=36$): No immobilization	Group I: After 2 wks Group II: Immediately after surgery	Group I: After 2 wks self-rehabilitation Group II: NA	FU: 3 mo Pain, ROM, grip strength, *Quick*DASH, PRWE, radiographs
Lozano-Calderón et al. [35]	60	RCT	Early ($n=30$) and Late ($n=30$) motion: Removable thermoplastic palmar splint for 6 wks	Early Motion: Immediately after surgery (splint was taken off only for exercises) Late motion: 6 wks	Early motion group: Were taught to remove the thermoplastic splint and perform active and active-assisted wrist exercises. Encouraged to perform wrist exercise during activities of daily living without splint Late motion group: Wrist motion exercises were initiated 6 wks postoperative	FU: 3, 6 mo Pain, ROM, Grip strength, Modified Gartland and Werley score, Mayo Score, DASH, Radiographs

Table 1 (continued)

Study	*N*	Study design	Immobilization	Start active wrist exercises	Postoperative rehabilitation	Outcome measures
Quadlbauer et al. [58]	30	RCT	Mobilization: 1wk removable forearm thermoplastic splint Immobilization: 5 wks forearm plaster cast	Mobilization: Immediately after surgery Immobilization: 5 wks	Early Mobilization: Immediately after surgery active wrist exercise, supervised physiotherapy and home exercises Immobilization: first 5 wks: Supervised physiotherapy for shoulder, elbow and fingers, thereafter: same as early mobilization	FU: 6, 9 wks, 3, 6 mo, 1a ROM, pain, grip strength, DASH, PRWE, Mayo Score, radiographs
Watson et. al [70]	133	RCT	1 wk ($n=46$): palmar splint 3 wks ($n=41$) and 6 wks ($n=46$): forearm cast	1, 3 or 6 wks	Standardized physiotherapy education and home exercise program weekly for 6 weeks after cast removal	FU: 6, 12, 26 wks Pain, ROM, grip strength, DASH, PRWE
Andrade-Silva et al. [71]	39	RCT	No splint group: No immobilization Splint group: palmar plaster splint for 2 wks	No splint group: Immediately after surgery Splint group: 2 wks	No splint group: physiotherapist described wrist exercises to be performed at home. After 2 wks referred to a physiotherapist Splint group: After 2 wks patient were referred to a physiotherapist	FU: 2, 6 wks, 3, 6 mo Pain, rates and doses of tramadol, ROM, DASH, patient satisfaction

N number, *FU* follow-up, *Quick*DASH shortened disabilities of the arm, shoulder and hand questionnaire, *DASH* disabilities of the arm, shoulder and hand questionnaire, *PRWE* patient-rated wrist evaluation, *Mayo score* modified green O´ brien (Mayo) wrist score, *RCT* prospective randomized trial, *wk* weeks, *wks* weeks, *mo* month, a year, *ROM* range of motion, *NA* not applicable

Table 2 Summary of studies comparing different physiotherapy rehabilitation protocols

Study	*N*	Study design	Immobilization	Start active wrist exercises	Postoperative rehabilitation	Outcome measures
Kay et al. [81]	56	RCT	Exp ($n=22$) and Con ($n=28$): plaster cast	6 wks after injury	Exp = one session of instruction to perform home exercise program Con = No physiotherapy intervention—natural recovery	FU = 0, 3, 6 wks (removal plaster cast) ROM, grip strength, PRWE, *Quick*DASH
Krischak et al. [37]	48	RCT	Exp ($n=23$) and Con ($n=23$): forearm splint, removed for therapy	Exp and Con: 1 week after surgery	Exp = 12 sessions supervised physiotherapy, 20 to 30 min each, over a 6 wks period and home exercise program Con = Instructed home exercise program alone. 2/day a 20 min for 6 wks	FU: Follow-up = 1, 7 wks after surgery ROM, grip strength, PRWE
Souer et al. [79]	94	RCT	Exp ($n=46$): NA Con ($n=48$): Wrist splint until free finger and forearm motion	Exp: NA Con: Until free finger and forearm motion	Exp = Exercises under supervised by OT and home exercise program. Content, frequency and duration of OT program at discretion of OT Con = Instructions to perform home exercise program. Frequency: at least 3–4/day a 30 min	FU: 3, 6 mo Pain, ROM, grip strength, DASH, Gartland and Werley, Mayo wrist score, Radiographics
Valdes et al. [80]	50	RCT	Exp ($n=22$) and Con ($n=28$): NA	Exp and Con: NA	Exp = received therapy under the supervision of a CHT. Frequency: 2x/wk a 30 to 60 min (mean 16 visits). Additional home exercise program Con = home exercise program alone, instructed and monitored by a CHT. Frequency: wk 1 to 6: 5 exercises, 5 sets × 10 repetitions. Stretching exercises additionally in wk 6 (2x/day)	FU = 2, 4, 8, 12 wks; 6mo Pain, ROM; Grip strength, PRWHE
Bruder et al. [77]	33	RCT	Exp ($n=19$) and Con ($n=14$): plaster cast for 6 wks	6 wks after injury	Exp: Progressive exercise and structured advice implemented over three consultations over 6 wks by a physiotherapist Con: structured advice only as Exp, delivered by a physiotherapist over three consultations over 6 wks	FU = 7 wks (post intervention), 6 mo Pain, ROM, grip strength, *Quick*DASH, PRWE
Clementsen et al. [82]	119	RCT	Exp (57): plaster splint 2–3 days Con (62): dorsal splint 2 weeks	Exp: 2 – 3 days Con: 2 weeks	Exp: Supervised physiotherapy once a week for 3 months and home exercise program (4x/day) Con: Once demonstrated home exercise program by physiotherapist as Exp	FU: 6 wks, 3mo, 1a, 2a

N number, *Exp* experimental group, *Con* control group, *FU* Follow-up; *Quick*DASH shortened disabilities of the arm, shoulder and hand questionnaire, *DASH* disabilities of the arm, shoulder and hand questionnaire, *PRWE* patient-rated wrist evaluation, *Mayo score* modified Green O´Brien (Mayo) Wrist Score, *RCT* prospective randomized trial, *OT* occupational therapy, *wk* weeks, *wks* weeks, *mo* month, *a* year, *ROM* range of motion, *NA* Not applicable, *CHT* certified hand therapist

was defined in this study. Type of therapy was based on the evaluation of the treating therapists. Souer et al. [79] found significantly better results in ROM, grip strength and Mayo Score up to 6 months in the independent home exercises group compared to the supervised physiotherapy patients. Similar to Krischak et al.'s [37] study, supervised occupational/physiotherapy therapy was not performed according to a standardized program, or more precisely each occupational therapist decided about content, frequency and duration of the rehabilitation program. Monitoring of the intervals of the performed exercises and length of immobilization (inclusion criteria: within 4 weeks after surgery) was not documented in this study. The inferior outcome after supervised therapy, could be attributed to the confounding factors which may have biased the results of this study.

Valdes et al. [80] compared supervised physiotherapy with therapist instructed home exercises after operatively treated DRF in a prospective randomized trial. Supervised physiotherapy was performed on a biweekly basis for an average of 16 treatments. They found no significant differences in ROM, PRWE and grip strength at three, or six months after surgery. Frequency and adherence to the prescribed exercises at home were not monitored by the authors. Kay et al. [81] compared an advice and exercise program with natural recovery without physiotherapy. In the advice and exercise group, physiotherapy was commenced 6 weeks after surgery (1.6 weeks after cast removal). They found a significantly better *Quick*DASH and pain at the 3- and 6-week control between the groups in favour of the advice and exercise program group. Similarly, Bruder et al. [77] in a prospective randomized trial found no significant differences, up to 24 weeks after starting therapy, when comparing a progressive exercise and structured advice program to a structured advice program alone. Interestingly, all the patients were immobilized with a mean of 6 weeks and then only commenced physiotherapy. Radiological outcomes were not reported or analyzed. Therefore, differences in radiological results could account for missing differences, and therefore, cannot be excluded as biasing factors. In addition, the 6-week immobilization may also have influenced the results. Clementsen et al. [82] randomized 119 patients with extra-articular operatively treated DRF in an early mobilization group with supervised physiotherapy plus home exercises, and a late mobilization group with only home exercises. The patients in the late mobilization group received the same home exercise program as the early mobilization group. Significant differences in favor for the early mobilization group could only be found 6 weeks after surgery in *Quick*DASH (MD 5.8 points) and 6 weeks (MD 3.7°), respectively 3 months (MD 3.5°) after surgery in pronation. However, these differences didn´t pass MCID. At later follow-up examinations, no significant differences could be found between the groups. Equally, no significant differences in complication rates were reported between the groups. Radiological parameters were not analyzed in this study. Therefore, radiological differences between the groups biasing the functional outcome cannot be excluded. Attendance to the home exercise program, which was a once-off instruction, was not monitored. Thus, no definitive statements regarding frequency or quality of the performed home exercises can be made.

Fig. 1 Postoperative thermoplastic splint for one week, which is removed during physiotherapy and home exercises. The patients are also permitted to remove the splint for light daily activities

Several explanations are probable, why supervised physiotherapy has shown no superior results when compared to home exercises in the aforementioned studies. Firstly, the prescribed exercises may not be as effective in optimizing hand function, that cannot be achieved anyway by routine daily activities. Also, the frequency of physiotherapy treatments administered in these studies is probably insufficient to remodel soft tissue and improve upper limb function versus the normal use of the hand [74]. To increase joint ROM and improve soft tissue extensibility, a daily exercise programme of at least 30 min is essential. To improve muscle strength, specific exercises to the afflicted muscles should be performed with an intensity of 60–70% of one repetition maximum. Both are often problematic and not applicable in upper limb fractures [23, 75]. Alternatively, patients may benefit more from an active and self-reliant approach after surgery with an independent home exercise program. In addition, therapists might be overprotective during therapy, advising the patient to work up to pain threshold, but not beyond. By adhering solely to home exercise program, patients are more likely to go to their limits and, therefore, achieve quicker improvement in upper limb function [79].

In a systematic review, Bruder et al. [74] concluded, that shorter immobilization combined with early mobilization has positive effects on increasing participation and activity level and reducing of impairment. Active mobilization and

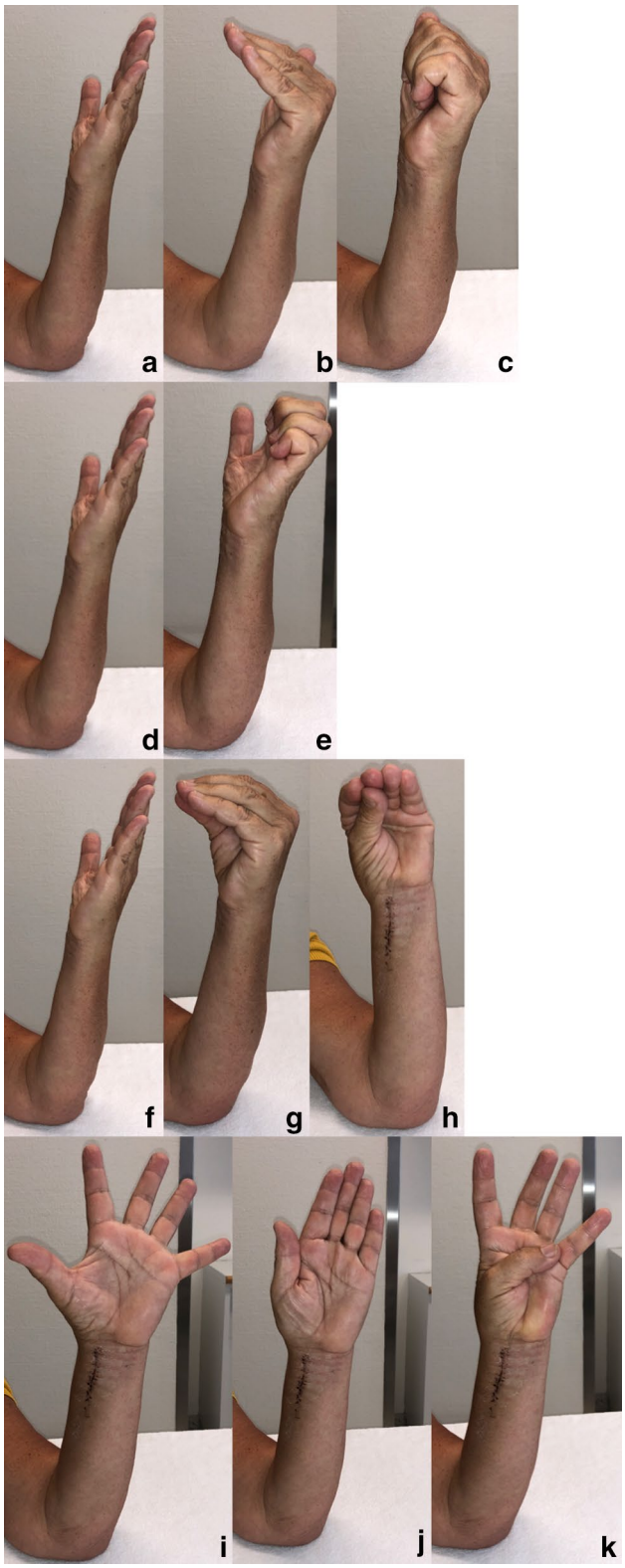

Fig. 2 **a**–**k** Active exercises for thumb and fingers from the first ▶ day after surgery. **a**, **b** Intrinsic plus position: Wrist is positioned in 20–30° dorsal extension. All fingers except for the thumb are flexed in the metacarpophalangeal (MCP) joints and stay extended in the proximal (PIP) and distal interphalangeal (DIP) joints. **c** Fist closure exercises: The fingers are gently bent until the tips touch the palm of the hand. **d**, **e** MCP joints remain straight and PIP and DIP joints are flexed. The fingers are closed until the base of each is reached (claw stretch), **f**–**h** Thumb and fingers are only flexed in the MCP joints, and the thumb moves to the index and middle finger. **i**, **j** Finger adduction and adduction, **k** Thumb opposition—the tip of the thumb moves to touch the base of the little finger and then back to original position

shorter immobilization duration help to reduce pain, swelling and edema that possibly cause scar tissue and decreased ROM. Therefore, immobilization period is likely to play an important role in recovery rate for the short-term activity after DRF. Decreasing immobilization enables patients to use both hands for daily activities, improving life quality and lengthening exercising time due to a normal use of the hand. Table 2 presents the current studies comparing the various physiotherapeutic rehabilitation protocols.

Conclusion

Fractures of the distal radius are one of the most common fractures in the upper extremities and incidence will rise due to an increased life expectancy. Therefore, optimizing treatment methods as well as post-operative rehabilitation remain current in the literature. As DRF potentially lead to restricted hand function due to the involvement of the radiocarpal joint, rehabilitation plays an important role to reduce impairment, recovery time as well as socio-economical costs such as limiting the time off work.

Immobilization after palmar stabilized DRF by locking plate appears not to be imperative, although significant and clinically important improvements were only documented in the early rehabilitation phase. To date, the literature shows no differences in functional outcome after three months post-surgery between the varying immobilization periods. But active wrist mobilization directly after surgery is not associated with an increased risk in loss of reduction, pain or complications. Duration of immobilization has to be adapted to the patient´s needs and compliance to the post-surgical restrictions.

Currently evidence remains lacking whether physiotherapy, supervised or not, leads to an improved outcome versus an independent home exercise program. But supervised physiotherapy is better than natural recovery with no physiotherapy. Further prospective randomized studies are necessary to specifically evaluate the post-surgical impact of a combination of immediate mobilization with no immobilization and supervised physiotherapy.

In our institution, all patients under 75 years of age with operatively treated isolated DRF using palmar locking plate fixation commence active wrist mobilization in a supervised group physiotherapy plus home exercise program from the

Fig. 3 **a**–**k** Postoperative physiotherapy program of the wrist for isolated distal radius fractures from the first day after surgery for. Prior to the specific wrist exercises, active shoulder and elbow exercises are performed. Using both hand simultaneously, all exercises are carried out until pain threshold. **a–f** Wrist extension and flexion. The wrist lies on a surface in neutral position, thereafter gently bend it in both palmar and dorsal directions, without gravity (**a**–**c**). The arm is positioned with the hand face down free over the edge of the table, and then lifted and lowered from the wrist joint against gravity (**d–f**). **g–i** Windshield wiper—the hand is placed with the palm flat on the table and then slowly wiped to the radial and ulnar side. **j**, **k** Palm up, Palm down—the elbows are flexed 90° and pressed to the chest. The wrist is moved so that the palm faces up and down

first day after surgery. The patients receive a removable thermoplastic forearm splint for 1 week, which is removed during supervised physiotherapy and home exercises as well as light daily activities [58]. Figure 1 shows the thermoplastic splint and positioning of the hand after surgery to reduce swelling and edema. Physiotherapy is performed in our outpatient department twice a week for 30 min. Additionally, we recommend the patients to do the exercises several times a day at home without the splint. Figures 2 and 3 present the supervised and home exercises for the fingers and wrist in the first 5 weeks. Patients over 75 years are immobilized for 5 weeks. Thereafter, they receive active wrist mobilization in a supervised physiotherapy and home exercise program.

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Conflict of interest The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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