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Early postoperative rehabilitation following surgical fixation of distal radius fractures: isokinetic and functional evaluation

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Abstract

Study aim: To assess hand function in patients after surgical repair of distal radius fractures using the open reduction and internal fixation (ORIF) method, compared with the contralateral (non-operated) limb serving as an internal control, following six months of early rehabilitation.
Material and methods: A prospective controlled study was conducted on 14 patients (8 women, 6 men; mean age 50.1 ± 9.3 years) treated surgically for distal radius fracture. The functional assessment included range of motion (ROM), grip strength, and isokinetic testing (Biodex System 4 Pro) of wrist flexion, extension, forearm pronation, and supination. Subjective outcomes were evaluated using the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire. Statistical analysis was performed using the Wilcoxon signed-rank test, with significance set at $p \leq 0.05$, and effect sizes (Cohen's d) were calculated.
Results: No significant differences were observed between operated and non-operated limbs for most functional parameters. Wrist flexion was reduced in the operated limb (50.3 ± 12.9° vs 60.4 ± 11.0°, $p = 0.008$, $d = 0.79$), and pronation torque was significantly lower at both angular velocities (90°/s: 4.73 ± 2.49 vs 7.00 ± 5.38 Nm, $p = 0.018$; 210°/s: 4.82 ± 2.56 vs 6.41 ± 3.96 Nm, $p = 0.028$). Normalization to body weight (PT/BW) confirmed that these differences were independent of body mass.
Conclusions: Early postoperative rehabilitation initiated 3–5 days after ORIF resulted in functional recovery comparable to the contralateral hand, except for reduced pronation strength. Targeted strengthening of the pronator muscles should be emphasized in early rehabilitation programs.

Keywords: Distal radius fracture – Early therapy – Exercise therapy

Introduction

Distal radius fractures (DRFs) commonly occur in young men who participate in sports. In the USA, out of 10,000 annual injuries, 67 are upper limb injuries and 25% are radius and ulna fractures. Typically, these injuries are high energy, resulting from falls while riding bicycles, motorcycles, and other such activities. In older individuals, DRFs account for 18% of all fractures and are three times more common in women (Nellans et al., 2012). In patients older than 50 years, these fractures are usually low energy, caused by falls from a standing position (Gehrmann et al., 2008). The type of fracture is determined by the magnitude of the force, the position of the hand and wrist, the rotation of the forearm, and the quality of bone tissue (Rundgren et al., 2020).

A fall in the upper limb with the wrist extended 40°–90° can cause Colles fractures (Hsu et al., 2022). Patients often experience pain, paresthesia, limited mobility in the radial-wrist and radial-elbow joints, intercarpal, carpometacarpal, and wrist-hand joints, and muscle weakness, even after the treatment period. Treatment of such fractures requires repositioning, followed by rehabilitation aimed at achieving the proper range of motion and restoring appropriate strength and muscle mass, which will allow the patient to become independent and improve the quality of life (S. Quadlbauer et al., 2020).

A key element of the study is the timing of rehabilitation, which is 3–5 days postoperatively. This time is based on information presented in the literature, such as excessive swelling, loosening of the fixation, or overloading, which may delay recovery. Because physiotherapy begins 3–5 days after surgery, tissues subjected to significant stress during the procedure have time to recover.

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Treatments for DRF include conservative treatment and surgical treatment. Conservative treatment is used for fractures without displacement or with minimal displacement and involves immobilization in a circular cast or brace for five weeks or more. Surgical treatment is used for unstable fractures at the distal end of the radius and involves surgical alignment of the fracture with external or internal stabilization. Currently, the most popular surgical treatment is the open method with internal stabilization by a dorsal plate (ORIF), which helps maintain anatomical alignment and stability of fragments, and enables the patient to begin range-of-motion exercises much earlier, allowing them to return to their pre-injury state faster. This study included patients treated with the ORIF surgical method due to the possibility of almost immediate rehabilitation, i.e. 3–5 days after the surgery. Absolute indications for ORIF treatment include a confirmed joint gap of 2 mm in imaging studies (X-ray), computed tomography (CT), or magnetic resonance imaging (MRI) in patients under 65 years of age and displaced fractures with no possibility of reduction in patients older than 75 years of age (Mulders et al., 2017). The palmar plate has been shown to support a load of more than 300 N, while the stabilization of the K wire can support only about 150 N. During loading (such as riding a bicycle), the palmar plate shows less than a 1 mm displacement of the compound fracture, while stabilization of the K-wire shows a compound fracture displacement greater than 3 mm (Alluri et al., 2015). The closed method with internal stabilization, using intramedullary nails (minimally invasive), is used more frequently in pediatrics (Rafi & Tiwari, 2022).

A crucial element of treatment is postoperative rehabilitation. In the first phase of rehabilitation, controlling swelling, pain, and patient education are the most important. In the next stage, the goal is to restore the proper range of motion, strength, and function. In most cases, rehabilitation begins about 10–14 days after surgery. Rehabilitation results are evaluated using the DASH questionnaire [9] or its shortened version Quick Disability of the Arm, Shoulder and Hand Questionnaire (QDASH), the Patient-Rated Wrist Evaluation (PRWE) questionnaire, the Visual Analog Scale (VAS), the grip strength test, and wrist range of motion. The results of applied postoperative rehabilitation therapies are presented in the literature; however, there is no agreement on the effectiveness of early and late rehabilitation. In the study by Sørensen (2020) and Clementsen (2019) patients with early mobilization started within 1–2 days after surgery and patients in late mobilization started rehabilitation 2 weeks after surgery, while Quadlbauer (2016) reported that early mobilization started 1–2 days after surgery and late mobilization after 5 weeks. In their studies after 6 weeks of physical therapy, the results of the early intervention group were significantly better than those of the group that started mobilization later. In a long-term study (after 48 weeks), the differences were not as significant. However, in studies in which passive joint mobilization versus soft tissue massage was considered therapy, no significant differences were found in wrist extension and grip strength (Kay et al., 2000). It seems that early rehabilitation (before 2 weeks have passed) is significantly more beneficial for a patient after injury due to a faster return to daily and professional activities. Although long-term results were comparable in both therapies, the patients regained strength and range of motion and experienced reduced pain much faster.

The purpose of this study was to demonstrate the higher value of early rehabilitation over late rehabilitation by evaluating the hand function of patients who have undergone operative repair of distal radius fractures using the ORIF method, compared to their non-operated limb, after 6 months of early rehabilitation.

Material and methods

Participants

Fourteen subjects were included the study: eight women and six men. The control group in this case is the unoperated limb. The number of participants in the group is small, but it should be noted that the fracture type according to the AO classification is relatively uniform. Furthermore, all patients underwent surgery by the same hand surgeon, who holds a European Diploma in Hand Surgery and has been practicing in this field for 25 years. The same method was used, and the therapy was performed by a single therapist with 15 years of experience in hand therapy. The rehabilitation protocol for all patients studied is uniform and constitutes the internal protocol of the center where the therapy was performed. The examination method and the examiner were the same. Eight subjects sustained injuries to the left upper limb, and six subjects sustained injuries to the right upper limb. All patients were right-handed. The inclusion criteria were as follows: age range 18–67 years, distal radius fracture, ORIF procedure, and hand stabilization plate (Medartis), consent to participate in the study. The exclusion criteria included a delayed rehabilitation protocol and algodystrophy.

The research complied with the Declaration of Helsinki. Each participant signed an informed consent form for the study. The study was approved by Senate Research Ethics Committee at Józef Pilsudski University of Physical Education (SKE 01-56/2023). The trial was registered as NCT06258928.

All participants were initially diagnosed with a distal radius fracture (intra-articular, multi-fragment). Surgical treatment was indicated based on the severity of the injury according to the AO classification (6 subjects 2R3C1, 8 subjects 2R3C2, 5 subjects 2R3C3). DRF was classified according to the AO classification – location, type, and morphology of the fracture, type A: extraarticular fractures, type B – partial intraarticular fractures, and type C – complete intra-articular fractures (Jayakumar et al., 2016; Sander et al., 2020). A detailed characterization of the group is presented in Table 1.

Table 1. Demographic data of participants

Group	*n*	Age [years] $x \pm$ SD, range	Body height [cm] $x \pm$ SD, range	Body mass [kg] $x \pm$ SD, range
Participants	14	50.14 ± 9.3 35–67.	171.64 ± 8.84 158–189	77.21 ± 14.35 55–100

Surgical treatment

All patients underwent ORIF and stabilization of the hand plate. A radial incision was made in the area of the styloid process of the radius bone. The radial nerve was visualized and secured. The pronator quadratus muscle (PQ) was dissected distally. Fragments were removed, a preliminary reduction was performed, and the hand plate was stabilized on the shaft of the radius bone. The reduced fragments were temporarily stabilized with Kirchner wires. Then, under X-ray control, the joint surface fragments were stabilized with screws inserted into the distal part of the plate. Arthroscopy was performed again, which confirmed that the bone fragments were not dislocated on the surface of the joint. The PQ and wound were sutured. After the operation, the operated limb was immobilized in a wrist-forearm-hand splint.

Rehabilitation protocol

The physiotherapy protocol for surgically treated radial fractures is an internal protocol of the center where the research was conducted. Patients participated in rehabilitation at the center three times a week for the first month of therapy, then twice a week until the desired range of motion and function of the hand were achieved. The rehabilitation protocol is standard at the center, where the therapist and the attending physician work. This allowed patients to be under the constant supervision of the attending physician and the physiotherapist. The rehabilitation process started 3–5 days after the procedure was performed. The cast was removed from the hand. The main goal in the first days was to reduce swelling. The patient was asked to elevate the limb and hold this position as long as possible during the day. The first step in the implementation of exercises was passive and active mobilization of the elbow and finger joints and glide exercises of the hand tendon. In the next stage of the early therapeutic intervention, active and passive wrist exercises were introduced. After the first therapy, the patient received home recommendations to systematically activate joint structures and soft tissues. This included passive and active wrist range-of-motion exercises—flexion, extension, supination, pronation, and radial and ulnar deviation—performed every hour for 5 repetitions in each direction. If there were postoperative hematomas in the hand and forearm area, therapy was used to remove the hematomas faster. Therapy and self-massage were always performed with special attention to the surgical field and in the cranial direction. During the 3–6-week period, the patient was required to continue with active and passive range of motion exercises on the wrist, hourly home conditions, and anti-swelling measures. Exercise in daily activities, exercises to improve the range of motion of the equipment and exercises with a small load of 0.5–1.5 kg were gradually introduced according to the condition and ability of the patient. At 6–8 weeks, the patient was instructed to continue performing home exercises. Strengthening grip strength exercises, strengthening forearm muscle strength exercises, and exercises with equipment such as Theraband, medical play-dough, etc. were introduced. 9–12 weeks after surgery, while continuing strengthening exercises, the patient returned to normal daily activities. After confirmation of healing on the X-ray image and checking with the attending physician, a return to sport was possible.

Research methods

The research method consisted of collecting baseline characteristics, including age, sex, body mass, and body height. After 12 weeks of treatment, the following were measured: ranges of motion (ROM) such as flexion, extension of the wrist, supination and pronation of the forearm using a 15 cm stainless steel Saehan finger goniometer, using the SFTR method described by Zembaty (2002), grip strength using a hydraulic handgrip dynamometer by Saehan according to the procedure to measure grip strength (Lee et al., 2020), isokinetic evaluation of force moments of the biceps and triceps, and the muscles responsible for supination and pronation of the forearm using the Biodex System 4 Pro (Biodex, USA) dynamometer. The evaluation was performed at angular speeds of 90 and 210°/s in isolated positions. The non-operated limb served as an internal control for each participant, representing individual baseline values of functional and strength capacity. Additionally, the obtained peak torque (PT) values were normalized to body weight (BW) to calculate the PT/BW ratio (expressed in Nm/kg), allowing for more objective interindividual comparison of results independent of muscle mass. At each angular velocity, the peak torque (maximum moment of force, Nm) was recorded for wrist flexion, extension, forearm pronation, and supination. Isokinetic evaluation of force moments means the assessment of biomechanical parameters of muscle force (force moments) during movement with constant angular velocity. It is a physical quantity defining the ability of muscles to generate rotational force around the axis of a joint. A functional and subjective evaluation of the upper limb was performed using the DASH questionnaire (Czarnecki et al., 2015). The DASH questionnaire assesses upper limb disability and consists of 30 questions in the general section and an additional work module with 4 questions and a sport/instrument playing module with 4 questions. It assesses symptoms and the inability to perform certain activities based on health status. The result is obtained by calculating the DASH score = $\left[\left(\frac{\sum \text{of ansvers}}{n}\right) - 1\right] \times 25$. The interpretation of the results ranges from 0 to 100, where 0 is the best result and 100 is the worst. A score of less than 15 is considered good and is referred to as "no problem", 16–40 is average or indicates "a problem but able to work," and above 40 is poor or "unable to work" (Angst et al., 2011).

Statistical analysis

The sample size ($n = 14$) was determined based on a power analysis for the Wilcoxon signed-rank test, assuming a significance level of $\alpha = 0.05$, a power of 0.80, and a medium expected effect size. Descriptive statistics were computed, including the mean and standard deviation, as well as the median, the lower quartile (Q1), and the upper quartile (Q3) The level of significant was $p < 0.05$.

Statistical analysis was performed using STATISTICA v. 13.0 (StatSoft USA). The normality of the data was evaluated using the Shapiro-Wilk test. The distributions of the analyzed data did not have normal distributions; therefore, the significance of the differences between the operated and non-operated limbs was assessed using the Wilcoxon signed rank test. The level of significance was established at $p \leq 0.05$. The interdependence between the examined features was also analyzed using the Spearman correlation. Also calculated for statistically significant differences, the effect size (Cohen's d) was determined by calculating the mean difference between two groups and then dividing the result by the pooled standard deviation. Cohen's $d = (M_2 - M_1)/SD_{pooled}$. For biomechanical comparison, peak torque values were also normalized to body weight according to the following formula: PT/BW = peak torque (Nm)/body weight (kg). This normalization enables adjustment for intersubject differences in muscle mass and body composition. The effect size (Cohen's d) was interpreted according to Cohen's guidelines: $d = 0.2$ – small effect, $d = 0.5$ – medium effect, $d \geq 0.8$ – large effect. For non-normally distributed data, Glass's delta values were also computed and interpreted using the same thresholds.

Results

The range of motion of wrist flexion was significantly different in the operated and non-operated limb (50.28 ± 12.9, 60.38 ± 11.0, $p < 0.01$, respectively, Cohen's $d = 12.9$, Glass's delta = 78.3). The remaining range of motion did not differ significantly between the limbs. The non-operated limb served as the control group in all comparisons, representing baseline physiological values for each participant.

Table 2. Baseline measures of participants for range of motion (mean ± SD)

Parameters	Operated limb [°]	Nonoperated limb [°]	p	Effect size (Cohen's d)
Flexion	50.28 ± 12.9	60.38 ± 11.0	0.0079	0.79 (large)
Extension	63.57 ± 10.08	67.14 ± 8.48	0.1083	–
Supination	57.86 ± 16.84	60.36 ± 15.87	0.7221	–
Pronation	53.57 ± 13.93	58.57 ± 13.65	0.2621	–

Note: Statistical analysis was performed using the Wilcoxon test; $p < 0.05$.

Dynamometric evaluation of grip strength and the isokinetic evaluation of the muscles responsible for wrist flexion, extension, supination and pronation of the forearm at angular velocities of 90 and 210°/s are presented in Table 3. The grip strength was 32.71 ± 13.96 kg on average in the operated limb and higher in the non-operated limb, 36.57 ± 14.26 kg; however, this difference was not statistically significant. The force moments of the muscles responsible for hand flexion and forearm supination showed similar results. Differences in extensor muscle force moments were observed at a speed of 90°/s, 7.67 ± 4.09 Nm in the operated limb and 9.08 ± 6.13 Nm in the non-operated limb, and at a velocity of 210°/s in similar ranges, but no statistically significant differences were observed at these moments. The Wilcoxon signed rank test showed statistically significant differences in the moments of the muscles responsible for pronation of the forearm at both speeds. For pronation at 90°/s, $p = 0.0179$, Cohen's $d = 0.54$ (moderate effect), Glass's delta = 0.91 (large effect); for pronation at 210°/s, $p = 0.0284$, Cohen's $d = 0.48$ (moderate effect), Glass's delta = 0.62 (moderate effect).

To account for body mass influence, normalized values of peak torque to body weight (PT/BW, Nm/kg) were also calculated. The patterns of differences between operated and non-operated limbs remained consistent after normalization, confirming that observed variations in pronation strength were not solely attributable to body mass differences. Mean PT/BW ratios were lower in the operated limb for pronation at both 90°/s and 210°/s, while other movement directions showed comparable normalized values.

Table 3. Dynamometric evaluation of grip strength and isokinetic evaluation of muscles at angular velocities of 90 and 210°/s in isolated positions

Parameters	Operated limb	Nonoperated limb	*p*	Effect size (Cohen's *d*)	PT/BW [Nm/kg]
Grip strength [kg]	32.71 ± 13.96	36.57 ± 14.26	0.0464	0.28 (small)	–
Peak flexion torque 90 [Nm]	12.92 ± 7.37	12.42 ± 6.53	0.7597	–	0.167 ± 0.095 / 0.161 ± 0.085
Peak extension torque 90 [Nm]	7.67 ± 4.09	9.08 ± 6.13	0.2411	–	0.099 ± 0.053 / 0.118 ± 0.079
Peak supination torque 90 [Nm]	8.09 ± 4.35	8.08 ± 4.78	0.5076	–	0.105 ± 0.056 / 0.105 ± 0.062
Peak pronation torque 90 [Nm]	4.73 ± 2.49	7.00 ± 5.38	0.0179	0.54 (moderate)	0.061 ± 0.032 / 0.091 ± 0.070
Peak flexion torque 210 [Nm]	13.25 ± 5.94	13.08 ± 5.91	0.2845	–	0.172 ± 0.077 / 0.169 ± 0.076
Peak extension torque 210 [Nm]	7.92 ± 3.37	9.08 ± 6.02	0.6834	-	0.103 ± 0.044 / 0.118 ± 0.078
Peak supination torque 210 [Nm]	7.82 ± 3.79	7.58 ± 3.09	0.8886	–	0.101 ± 0.049 / 0.098 ± 0.040
Peak pronation torque 210 [Nm]	4.82 ± 2.56	6.41 ± 3.96	0.0284	0.48 (moderate)	0.062 ± 0.033 / 0.083 ± 0.051

Legend: Wilcoxon test, $p < 0.05$.
PT/BW = peak torque/body weight (Nm/kg).

Disability of the operated upper limb was also assessed using the DASH questionnaire. The patients scored well in the general and work modules, but had an average score in the sport module. This result may be due to the diversity of sports activities conducted at different age levels.

Table 4. Upper limb disability questionnaire (DASH)

Parameters	Operated limb
DASH generally	11.95 ± 18.44
DASH work	10.71 ± 21.01
DASH sport	19.64 ± 30.99

Discussion

This study demonstrates that an early rehabilitation protocol following distal radius fracture fixation can deliver comparable functional outcomes in range of motion (ROM) and hand grip strength between operated and non-operated limbs after six months. The only domains where statistically significant deficits were observed on the operated side were wrist flexion and forearm pronation, which were affected primarily by pain, tissue contracture, and surgical disruption to musculature. Importantly, early rehabilitation did not negatively affect scar healing, implant stability, or clinical recovery.

The protocol for early rehabilitation after surgery remains controversial, with ambiguous results in recent literature (Bruder et al., 2013; Christersson et al., 2018; Davis & Buchanan, 1987). Many fear that early activation may increase pain, impair scar healing, risk implant loosening, or result in loss of reduction and stability. However, as reported in the review by Østergaard et al. (2021), analysis of fifteen studies found no significant difference in outcomes between early and delayed mobilization groups for ROM, grip strength, pain, and PRWE scores. Despite heterogeneous findings, this study – supported by Deng et al. (2021) and Watson et al. (2018) – shows that early mobilization after distal radius fracture surgery can accelerate return to functional fitness and reduce pain during rehabilitation compared to delayed protocols (Deng et al., 2021; Watson et al., 2018). Early pain in rehabilitation may be controlled by graded exercises and limiting activities to pain-free ranges. Importantly, patient engagement in light daily activity enhances discipline, motivation, and overall outcomes.

Although some studies – including the present one – found significantly better short- and medium-term outcomes in early rehabilitation groups (Tomruk et al., 2020), others did not observe notable differences in function or pain at long-term follow-up (Huh et al., 2012; Østergaard et al., 2021). Limitations of this study include a small sample size and limited diversity of fracture types and surgical approaches. The persistent deficit in flexion and pronation may relate to both postoperative pain and intraoperative disruption of the pronator quadratus muscle, a factor similarly noted by Huh et al. (2012).

Most authors emphasize the importance of rapid restoration of hand function and professional efficiency after surgery for both individual and economic reasons. The results of this study support the rationale for early patient activation (3–5 days after surgery) following ORIF for distal radius fracture, with continued attention to fracture stability, edema, pain control, and scar management.

Early rehabilitation following distal radius fracture surgery appears safe and effective in most domains and can facilitate faster return to daily and professional activities. Future research should address long-term outcome variability, investigate optimal exercise protocols for flexion and pronation deficits, and explore patient-centered strategies for sustained engagement and functional restoration.

Lack of consensus on the effectiveness of therapy: there is disagreement on the effectiveness of early and late rehabilitation. Some studies have shown that after 6 weeks of physical therapy, the early intervention group had better results, but long-term outcomes (after 48 weeks) were not significantly different (Sørensen et al., 2020).

The results of studies examining early versus delayed rehabilitation are inconsistent (Christersson et al., 2018; Østergaard et al., 2021). A systematic review (Østergaard et al.) found no significant differences in favor of either rehabilitation protocol (early or delayed) (Mulders et al., 2017). Although other studies indicate benefits in the short/medium term, there is no complete consensus in the literature (Deng et al., 2021; Watson et al., 2018).

Another limitation is the effect of PQ muscle damage on pronation. The significantly reduced pronation observed in the operated limb in this study is directly related to the specific surgical technique (ORIF), where the pronator quadratus (PQ) muscle is separated for volar plate placement. This finding, while clinically significant, reflects a limitation of the procedure, not just the rehabilitation itself, and may be due to scar tissue formation at the site of the separated muscle.

No correlation between DASH and isokinetic measurements: Other studies cited in the discussion found no correlation between DASH scores and isokinetic measurement, suggesting that subjective assessment does not always correlate with objective muscle strength (Huh et al., 2012).

Conclusions

The conclusions from the study are preliminary due to the small number of participants.

1. There were no differences in hand functionality (most of the analyzed parameters) between the operated and non-operated hand 12 weeks after treatment for a distal radius fracture in patients who underwent early postoperative therapy (3–5 days).
2. The worst results were obtained in the return of muscle strength responsible for pronation of the forearm, so special attention should be paid to exercises of this muscle group.

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