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ORIGINAL ARTICLE

Shoulder stiffness following distal radius open reduction and internal fixation: Natural course and effect of structured postoperative exercise

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ABSTRACT

Objectives: This study aims to investigate the effect of a structured postoperative shoulder exercise program on shoulder range of motion (ROM) recovery and the development of postoperative shoulder stiffness following surgical fixation of distal radius fractures (DRFs).

Patients and methods: This non-randomized, time-based cohort study included a total of 64 patients who underwent volar plate fixation of DRF between October 2022 and March 2023. Patients were allocated into two groups based on calendar periods and basic demographic factors were evaluated. Group 1 (exercise group, n = 33) was educated on pre-designed shoulder exercise to prevent shoulder stiffness after surgical treatment. Group 2 (control group, n = 31) was instructed to use their shoulders freely without an arm sling. Shoulder ROM and Quick Disabilities of the Arm, Shoulder, and Hand (Q-DASH) scores were evaluated and compared at postoperative Weeks 2, 4, 8, 12, and 24. Shoulder stiffness was defined as passive ROM restricted by 30° or more compared to the contralateral side (or difference of two or more Constant-Murley scores in internal rotation) in two or more planes of movement.

Results: Of the patients, 12 were male and 52 were female with a mean age of 65.7 ± 8.9 (range, 42 to 85) years. The mean follow-up was 6.8 ± 1.6 months. Shoulder ROM markedly decreased between postoperative Weeks 2 and 4, but continuously improved until the final follow-up in both groups. A transient improvement in internal rotation at postoperative Weeks 4 and 8 was observed in Group 1 compared to Group 2. No significant difference in internal rotation was observed at the other time points. At the final follow-up, 7.8% of all patients continued to experience shoulder stiffness.

Conclusion: Structured shoulder exercise may facilitate earlier recovery of shoulder internal rotation after volar plate fixation of DRFs. However, this advantage can be transient and cannot be maintained beyond eight weeks postoperatively, suggesting that shoulder ROM often recovers spontaneously even in the absence of a routine rehabilitation protocol. Furthermore, secondary shoulder stiffness following DRF fixation peaks at approximately four weeks after surgery and subsequently resolves more rapidly than the typical natural history of primary frozen shoulder. These findings indicate that structured shoulder exercises may provide short-term benefits in postoperative recovery, while the long-term clinical significance of routine shoulder rehabilitation remains uncertain.

Keywords: Distal radius fracture, hand, quick disabilities of the arm, range of motion, shoulder, shoulder stiffness.

Distal radius fractures (DRFs) are common injuries which can lead to prolonged functional impairment.[1,2] Complications associated with DRFs and their treatments are closely related to patient outcomes.[3] Operative fixation is associated with various complications, including injuries to flexor/extensor tendons, inadequate reduction, subsidence, or collapse, improper intra-articular screw placement, nerve injury, and complex regional pain syndrome.[4,5]

Patients commonly experience shoulder stiffness after DRF fixation even without such surgical

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complications. This stiffness arises from the functional interconnectedness of the upper limb joints. To illustrate, reaching or even finger motion requires intricate coordination of movements involving the shoulder, elbow, and wrist.[6-8] Immobilization with a splint or cast after DRF fixation leads patients to intentionally avoid using the affected wrist, resulting in underutilization of the entire upper limb. An earlier study identified a strong correlation between duration of wrist immobilization and shoulder pain, and recommended including shoulder exercise in the rehabilitation program when immobilization exceeds 3.5 weeks.[7] Previous studies have also identified lower bone mineral density and injury to the non-dominant hand as distinct factors for developing shoulder stiffness after DRF surgery.[9]

The necessity of structured shoulder exercise following surgical fixation of DRFs remains unclear and, therefore, postoperative immobilization and shoulder rehabilitation protocols vary among surgeons. In the present study, we aimed to investigate the effect of a structured postoperative shoulder exercise program on shoulder range of motion (ROM) recovery and the development of postoperative shoulder stiffness following surgical fixation of DRFs.[10-13]

PATIENTS AND METHODS

This multicenter, non-randomized, time-based cohort study was conducted at the Departments of Orthopaedic Surgery of Yeson Hospital, Seoul National University Boramae Medical Center, and Nowon Eulji Medical Center between October 2022 and March 2023. Patients who underwent operative fixation of DRFs by three surgeons across three different centers in Republic of Korea were included. All surgical procedures were performed by experienced orthopedic hand surgeons who participated evenly during the given study period to prevent surgeon-related distribution bias. Inclusion criteria were as follows: unilateral acute DRF, surgical treatment using only a volar locking plate, and availability of complete clinical and radiological records. Exclusion criteria were as follows: open fractures; DRF combined with other ipsilateral arm injuries, including fractures or ligamentous injuries; concurrent instability of the distal radioulnar joint (DRUJ); arthritic changes; pre-existing shoulder pathology before the injury, such as rotator cuff tears or shoulder stiffness; symptomatic neuropathy confirmed by electromyography/nerve conduction velocity in the ipsilateral upper extremity; and a history of injury in the ipsilateral arm. Among the initial cohort, a total of 91 patients who met the inclusion criteria were recruited. A written informed consent was obtained from each participant. The study protocol was approved by the Nowon Eulji Medical Center, Eulji University School of Medicine Ethics Committee (Date: 07.11.2024, No: 2024-05-033). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patients meeting the criteria were assigned by calendar periods to prevent cross-contamination of rehabilitation protocol within the same clinical period. Those surgically treated from October to December 2022 were instructed to use their shoulders freely without an arm sling. Meanwhile, patients from January to March 2023 were educated to perform shoulder ROM exercise according to our rehabilitation protocol. The patients were classified into two different groups: Group 1 as the exercise group, and Group 2 as the control group. Patients postoperatively immobilized above elbow due to osteoporosis, severe comminution, or large bone defects were excluded, as their rehabilitation protocol differed from the standardized short-arm immobilization protocol applied in this study (exercise group, n = 4; control group, n = 5). Those who were lost to follow-up before six months (exercise group, n=6; control group, n = 7) and those with “Poor” or “Fair” compliance (exercise group, n = 3) were also excluded from this study. Two patients were excluded from the control group due to insufficient data. Finally, a total of 64 patients (Group 1 n = 33, Group 2 n = 31) were included in the study (Figure 1).

Outcome measures

All patients were evaluated for age, sex, hand dominance, fracture types and past medical history, including diabetes mellitus, hyperthyroidism, end stage renal disease on dialysis, and coronary artery obstructive disease. The ROM of the shoulder and Quick Disabilities of the Arm, Shoulder, and Hand (Q-DASH) scores were assessed between the two groups at postoperative Weeks 2, 4, 8, 12, and 24. Every ROM measurement was performed by two trained orthopedic surgeons or senior residents at each center who agreed on the same measurement protocol prior to the study. Average value measured by the two evaluators was used to reduce interobserver variability.

Shoulder stiffness

Passive ROM of the shoulder was assessed using standard goniometers for forward flexion,

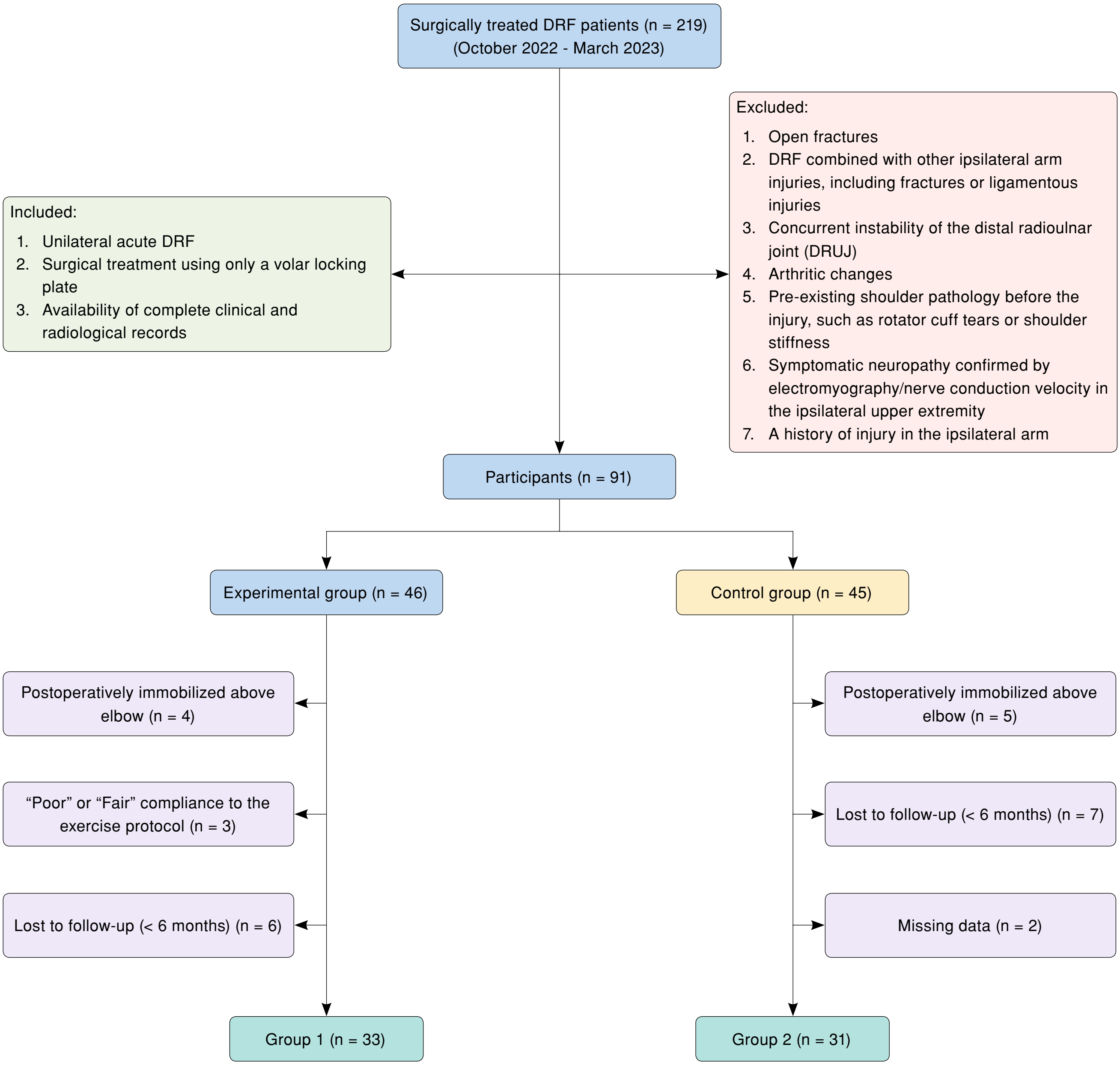

FIGURE 1. Study flowchart.
DRF, distal radius fractures.

abduction, and external rotation at postoperative Weeks 2, 4, 8, 12, and 24. Internal rotation was measured using a vertebral-level method and converted into a numerical scale from 0 to 10 using the Constant-Murley Score (CMS).[14] A limitation of 30° or more, or difference of two or more CMS scores in internal rotation compared with the contralateral side indicated ROM restriction in one plane. If ROM restriction occurred in two or more planes of movement with normal radiographic findings, it was defined as shoulder stiffness after DRF.[15,16] A ROM of less than 100° in forward flexion, less than 10° in external rotation, and less than four CMS scores (reaching below L5 vertebral level) in the internal rotation was classified separately as severe shoulder stiffness.[9,17] Patients with severe shoulder stiffness were planned to be withdrawn from the study and undergo additional exercise programs and physical therapy.

Rehabilitation protocol

The wrist was immobilized in a short arm splint or cast for four weeks after surgery. All patients were told to begin active ROM exercise of the fingers postoperatively. Group 1 was instructed to follow a structured shoulder exercise protocol at home. The exercise protocol was adapted from a previous study[10] and was performed three times a day. It consisted of the following components. First, a pendulum warm-up exercise was performed in which the patient relaxed the affected arm and allowed it to hang freely toward the floor while stabilizing the body with the contralateral arm, gently swinging the arm in a pendulum-like motion. Second, forward flexion was performed in supine position by holding the affected wrist with the opposite hand and elevating the arm to the maximal tolerable range, maintaining the position for 5 sec. Third, external rotation was also performed in supine position with both elbows flexed at 90°, using a stick or towel to assist the movement while the contralateral arm guided the affected arm into external rotation and held the position for 5 sec. Finally, internal rotation was performed by supporting the affected wrist with the opposite hand behind the back and gently pushing the wrist upward to the maximal tolerable range, maintaining the position for 5 sec. Each exercise was repeated 30 times per session and was performed within a pain-free ROM. Group 2, instead of being asked to perform a structured exercise, was told to use shoulders freely during daily living activities throughout the same period.

Patient compliance of Group 1 was monitored by providing an exercise log and asking the patients to record daily exercise frequency. Based on the log, patient compliance was graded as "Poor" (less than 60% of the days completed throughout the study), "Fair" (between 60% and 80% number of days), and "Good" (between 80% and 100% number of days). They were, then, asked to demonstrate the exercises in front of the educator at the second postoperative visit to confirm adherence. Those who showed "Poor" or "Fair" compliance or insufficient adherence were excluded from the final analysis.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 29.0.1.1 software (IBM Corp., Armonk, NY, USA). Continuous data were presented in mean ± standard deviation (SD) or median (min-max), while categorical data were presented in number and frequency. Repeated measures analysis of variance (RM-ANOVA) was used to compare shoulder ROM and Q-DASH scores at each postoperative time point between the two groups. In addition, to account for within-subject correlation across repeated measurements, a linear

TABLE I
Demographic characteristics

	Group 1 (n = 33)				Group 2 (n = 31)				
Characteristics	n	%	Mean ± SD	Range	n	%	Mean ± SD	Range	*p*
Age (year)			67.0 ± 7.4	47-83			64.3 ± 10.2	42-85	0.23
Sex									0.24
Female	25	75.8			27	87.1			
Dominant hand fractured	15	45.5			14	45.2			0.98
Types of fractures (AO/OTA)									0.94*
A2	4	12.1			4	12.9			
A3	2	6.1			1	3.2			
B1	1	3.0			0	0			
B2	3	9.1			2	6.5			
C1	6	18.2			8	25.8			
C2	15	45.5			15	48.4			
C3	2	6.1			1	3.2			
Underlying medical conditions									
DM	6	18.2			4	12.9			0.51
Hyperthyroidism	0	0			1	3.2			0.31
ESRD on dialysis	4	12.1			3	9.7			0.71
CAOD	6	18.2			5	16.1			0.84

SD, standard deviation; AO/OTA: Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association; DM, diabetes mellitus; ESRD, end stage renal disease; CAOD, coronary artery obstructive disease. * Fisher exact test was used to compare overall fracture type distribution.

TABLE II
Shoulder ROM between the Group 1 and 2

Shoulder ROM	Group 1 FF	Group 2 FF		Group 1 ABD	Group 2 ABD	
	Mean ± SD	Mean ± SD	*p*	Mean ± SD	Mean ± SD	*p*
Preoperative	170.43 ± 9.7	167.56 ± 11.7	0.656	173.9 ± 9.5	173.5 ± 7.4	0.653
Postoperative						
Week 2	160.3 ± 10.8	158.6 ± 6.9	0.185	162.2 ± 9.5	161.4 ± 7.4	0.052
Week 4	162.4 ± 14.6	159.6 ± 14.0	0.673	163.1 ± 12.1	160.2 ± 10.8	0.125
Week 8	164.7 ± 15.8	161.4 ± 13.5	0.822	165.2 ± 11.5	163.1 ± 13.5	0.996
Week 12	168.3 ± 12.2	164.8 ± 9.6	0.007	171.8 ± 9.6	167.2 ± 14.9	0.803
Week 24	171.2 ± 12.0	170.4 ± 10.4	0.718	173.6 ± 12.9	171 ± 17.7	0.373
Shoulder ROM	Group 1 ER	Group 2 ER	*p*	Group 1 IR	Group 2 IR	*p*
Preoperative	68.4 ± 13.6	71.2 ± 14.8	0.429	7.4 ± 1.8	7.1 ± 1.5	0.487
Postoperative						
Week 2	65.6 ± 14.6	67.3 ± 11.8	0.590	6.4 ± 1.5	5.4 ± 1.6	0.021
Week 4	63.2 ± 17.8	66 ± 14.3	0.427	7.2 ± 1.4	5.2 ± 1.7	< 0.001
Week 8	67.3 ± 14.5	68.4 ± 13.4	0.817	7.7 ± 1.4	5.7 ± 1.4	< 0.001
Week 12	73.2 ± 13.0	71.4 ± 9.5	0.585	7.8 ± 1.7	6.7 ± 1.4	0.006

ROM, range of motion; FF, forward flexion; ABD, abduction; SD, standard deviation; ER, external rotation; IR, internal rotation. FF, ABD, ER were measured in degrees while IR was measured in vertebral-level method and converted into a numerical scale based on the Constant- Murley score.

mixed-effects model with fixed effects for group, time, and their interaction, and a random intercept for each participant was applied. The Kaplan-Meier survival estimation was performed to calculate the survival rates of the two groups concerning shoulder stiffness over time and provide a visual representation of survival probabilities using a step function plot. A p value of < 0.05 was considered statistically significant.

RESULTS

Of a total of 64 patients included in the study, 12 were male and 52 were female with a mean age of 65.7 ± 8.9 (range, 42 to 85) years. The mean follow-up was 6.8 ± 1.6 months. There were no statistically significant baseline differences between the two groups ($p > 0.05$) (Table I). Union was confirmed in all cases during the follow-up period. None of the patients experienced major complications, such as infection or collapse, requiring reoperation.

Passive shoulder ROM and Q-DASH scores were compared between the two groups (Tables II and III, Figure 2). There were progressive improvements of all shoulder ROM parameters and Q-DASH scores by time in both groups. Comparing at each

TABLE III
Q-DASH scores of the Group 1 and 2

	Group 1 (n = 33)	Group 2 (n = 31)	
Q-DASH scores	Mean ± SD	Mean ± SD	*p*
Preoperative	45.30 ± 19.9	55.23 ± 25.2	0.084
Postoperative			
Week 2	53.5 ± 18.9	56.9 ± 19.1	0.487
Week 4	38.5 ± 18.9	45.5 ± 19.1	0.148
Week 8	30.0 ± 20.0	32.1 ± 21.9	0.711
Week 12	18.1 ± 15.0	19.3 ± 14.0	0.727
Week 24	10.5 ± 10.7	8.7 ± 8.7	0.434

Q-DASH, quick disabilities of the arm, shoulder, and hand; SD, standard deviation.

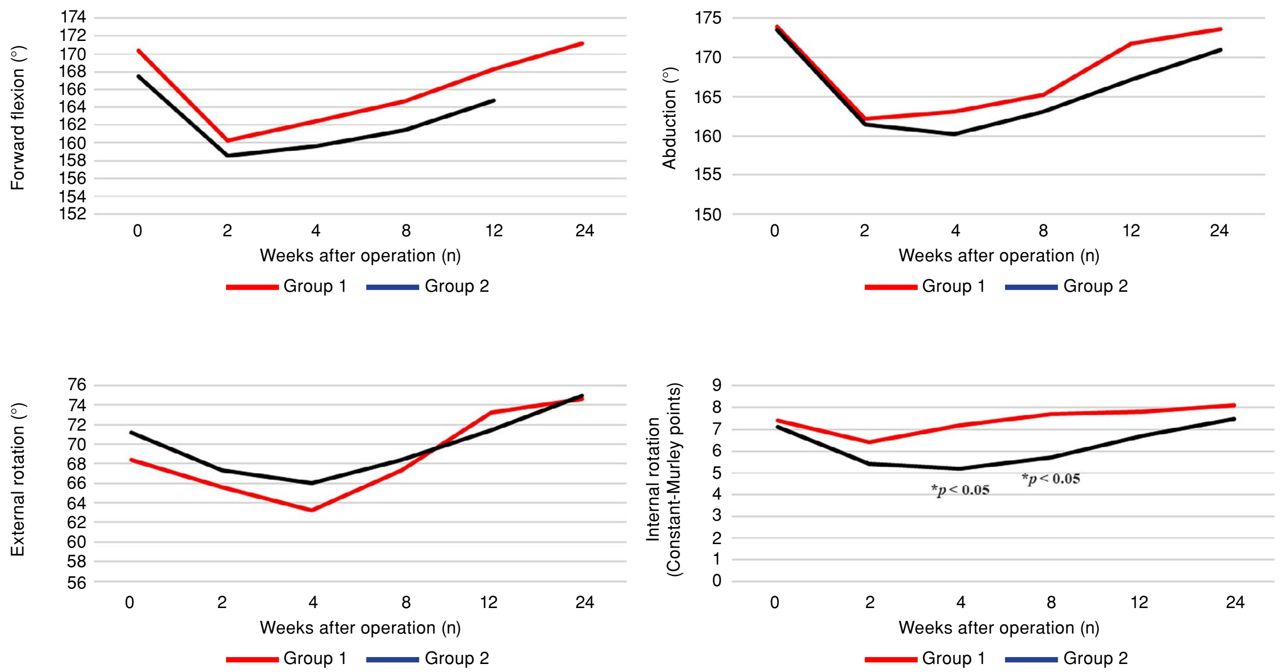

FIGURE 2. Shoulder ROM of the Group 1 and 2.
ROM, range of motion.

postoperative time point, internal rotation of patients in Group 1 showed significantly greater improvement at postoperative Weeks 2, 4, 8, and 12 (all $p < 0.05$). However, there were no significant differences between the two groups for forward flexion, abduction, external rotation, and Q-DASH scores at any given time point ($p > 0.05$).

Additional analyses using linear mixed-effects model were performed to account for within-subject correlations due to repeated measurements (Table IV). Comparable to the results of RM-ANOVA analyses, a significant main effect of time was observed for forward flexion, abduction, internal rotation, and Q-DASH scores, indicating overall functional recovery. However, no significant group and time interaction was identified for forward flexion, abduction, external rotation, or Q-DASH scores. In contrast, internal rotation demonstrated a significant group and time interaction ($p = 0.002$), suggesting a different recovery pattern between the two groups over time. Post-hoc comparisons indicated that the exercise group showed significantly greater internal rotation at postoperative Weeks 4 ($p = 0.002$) and 8 ($p = 0.002$), while no significant differences were observed at later follow-up points.

TABLE IV
Linear mixed-effects model analysis of shoulder ROM and Q-DASH scores

	Group	Time	Group × Time
Outcome	*p*	*p*	*p*
Forward flexion	0.685	< 0.001	0.094
Abduction	0.728	< 0.001	0.156
External rotation	0.410	0.056	0.361
Internal rotation	0.447	0.007	0.002
Q-DASH	0.028	< 0.001	0.065

ROM, range of motion; Q-DASH, quick disabilities of the arm, shoulder, and hand.

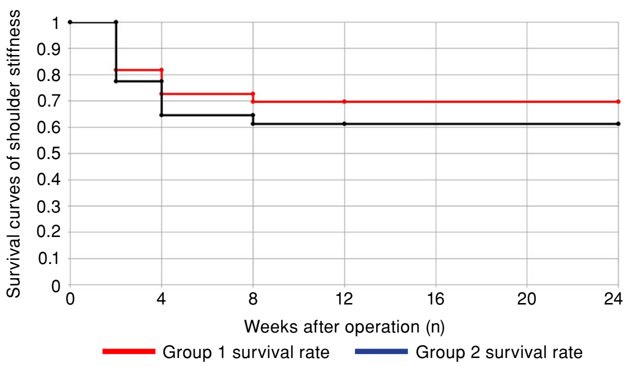

FIGURE 3. Kaplan-Meier survival analysis of shoulder stiffness.

In the Kaplan-Meier survival analysis regarding shoulder stiffness, the survival rate at the final follow-up (postoperative Week 24) was 0.697 in Group 1 and 0.613 in Group 2. The Kaplan-Meier survival curves indicated that shoulder stiffness occurred within postoperative Week 8 in both groups (Figure 3).

The prevalence of shoulder stiffness was assessed at postoperative Weeks 2, 4, 8, 12, and 24 weeks in both groups (Table V). It peaked at postoperative Week 4 weeks, with 24.2% in Group 1, 32.3% in the Group 2, and 28.1% among all patients. At the final follow-up, 6.1% of Group 1, 9.7% of the Group 2, and 7.8% of all patients still experienced shoulder stiffness. No patients were diagnosed with severe shoulder stiffness requiring additional treatment during the study.

DISCUSSION

In the present study, we investigated whether structured shoulder exercise had a preventive effect on shoulder stiffness after volar plate fixation of DRF. The primary finding of this study was that although following the shoulder rehabilitation protocol resulted in transient superiority in recovery of internal rotation, the program did not produce a sustained advantage in overall shoulder ROM recovery compared to unrestricted shoulder use in daily living activities. The mixed-effects model showed that the difference in internal rotation between the two groups was not maintained beyond postoperative Week 8. These findings suggest that shoulder exercise may facilitate earlier restoration of internal rotation, but does not substantially change the overall recovery trajectory of shoulder ROM after wrist surgery.

The transient superiority of Group 1 observed only in internal rotation may be attributed to several factors. Even when instructed to use their shoulders freely, patients tend to avoid placing the operated wrist behind their backs. As a result, internal rotation may be particularly susceptible to temporary disuse, whereas forward flexion, abduction, and external rotation are commonly used during routine daily living activities even when the wrist is immobilized. Another possible explanation is that reduced shoulder motion after wrist immobilization may lead to temporary posterior capsule tightness which preferentially restricts internal rotation compared with other shoulder movements.[18-24]

This study also demonstrated a temporal pattern of secondary shoulder stiffness. A stiff shoulder usually refers to a patient presenting with a restricted ROM due to both primary and secondary causes.[17] The commonly known "frozen shoulder" specifically represents primary stiff shoulder, characterized by idiopathic development and the three phases of freezing, frozen, and thawing.[25,26] Cases with identifiable causes are classified as secondary stiff shoulder.[16,17] The duration of symptoms in untreated cases of frozen shoulder is commonly reported to last approximately 15 months.[27] In contrast, the duration of symptoms in our study was shorter. Shoulder stiffness following surgical fixation of DRF peaked at postoperative Week 4 to 8 and improved afterwards, suggesting a relatively short and self-limiting natural course of secondary stiff

TABLE V
Point prevalence of shoulder stiffness after surgical treatment of DRF

		Week 2		Week 4		Week 8		Week 12		Week 24	
Prevalence of shoulder stiffness	n	n	%	n	%	n	%	n	%	n	%
Group 1	33	6	18.2	8	24.2	4	12.1	4	12.1	2	6.1
Group 2	31	7	22.6	10	32.3	7	22.6	4	12.9	3	9.7
Total	64	13	20.3	18	28.1	11	17.2	8	12.5	5	7.8

DRF, distal radius fractures.

shoulder. These results indicate that stiff shoulder caused by wrist immobilization after DRF does not follow the typical clinical three-phase progression observed in primary frozen shoulder.

Another notable finding was that the results of this study differed from a previous study with a similar design. Cha et al.[9] evaluated patients who underwent operative fixation for DRF from postoperative Week 4 to 12 and reported that approximately 34.1% of patients were classified into the stiff shoulder group. The prevalence of stiff shoulder in our study was comparably lower: 28.1% at postoperative Week 4, 17.2% at Week 8, and 12.5% at Week 12. Furthermore, Cha et al.[9] defined "shoulder stiffness" as an ROM of less than 100° in forward flexion, less than 10° in external rotation, and less than the fifth lumbar vertebra (L5) level in internal rotation, indicating that more stringent diagnostic criteria were applied than in this study. Therefore, if the same criteria were applied in our cohort, the difference in prevalence would likely be even greater. This could have been attributed to two possible factors. First, wrist immobilization was limited to four weeks in our study, in contrast to six-week immobilization in the previous study. Second, while patients were instructed to use an arm sling in the previous study, patients in this cohort were told to freely use their shoulders for daily living activities without a sling.

Nonetheless, this study has several limitations. First, a non-randomized, time-based cohort study design was selected to prevent cross-contamination of the exercise protocol within a given period in a clinical setting. Although baseline demographic characteristics were comparable between the two groups, time-dependent bias might have been introduced. Second, approximately 30% of initially eligible patients were excluded in the final analysis, potentially limiting external validity. This was primarily due to exclusion of patients requiring above-elbow immobilization because the scope of this study was limited to surgically treated DRF patients immobilized with short arm splint or cast. Third, although ROM measurement was standardized across centers, formal interobserver reliability testing was not performed, and minor variability cannot be excluded. In addition, six-month follow-up may be considered short relative to the natural course of primary stiff shoulder. However, this study focused on secondary stiffness after wrist immobilization, which in our cohort peaked within four weeks and improved thereafter. Longer-term follow-up was deemed unnecessary for a simple DRF case but could have been helpful for confirming durability. Finally, exercise compliance was assessed through patient self-reporting, which may have introduced reporting bias and the actual adherence to the exercise protocol could not be objectively verified.

In conclusion, our study results suggest that structured shoulder exercise may facilitate earlier recovery of shoulder internal rotation after volar plate fixation of DRFs. However, this advantage can be transient and cannot be maintained beyond eight weeks postoperatively, suggesting that shoulder ROM often recovers spontaneously even in the absence of a routine rehabilitation protocol. Furthermore, secondary shoulder stiffness following DRF fixation peaks at approximately four weeks after surgery and subsequently resolves more rapidly than the typical natural history of primary frozen shoulder. Taken together, these findings indicate that structured shoulder exercises may provide short-term benefits in postoperative recovery, while the long-term clinical significance of routine shoulder rehabilitation remains uncertain. Further randomized studies with larger sample sizes are warranted to confirm these findings and identify patients who are most likely to benefit from targeted rehabilitation.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: J.L., Y.L.: Idea/concept; J.L.: Design; S.C.: Control/supervision; J.L., Y.L., D.L., Y.S., S.C.: Data collection and/or processing; Y.S., S.C.: Analysis and/or interpretation; Y.L., Y.S.: Literature review; Y.S., D.L., S.C.: Writing the article; D.L., S.C.: Critical review; S.C.: References and fundings; J.L., D.L.: Materials.

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