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Original Article

Physiotherapy Section

Effectiveness of Delorme versus Oxford Technique on Grip and Forearm Muscle Strength in Distal Forearm Fractures: An Experimental Study

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ABSTRACT

Introduction: Distal forearm fractures are among the most common musculoskeletal injuries, and are frequently associated with significant loss of hand function and impaired forearm muscle strength. Progressive Resistance Exercises (PRE) techniques, such as the Delorme and Oxford protocols, are established rehabilitation approaches for improving muscle function; their contrasting principles and comparative effectiveness remain understudied, thereby warranting this investigation.

Aim: To compare the effectiveness of the Delorme and Oxford techniques on grip strength and forearm muscle strength in patients with postoperative distal forearm fractures.

Materials and Methods: This experimental study was conducted at the Outpatient Department (OPD) of Krupanidhi College of Physiotherapy, Bengaluru, Karnataka, India from May 2024 to May 2025, after obtaining Institutional Ethics Committee approval. A total of 30 participants aged 18-40 years with distal forearm fractures, at least 6 weeks postoperative and with ≥80% normal range of motion, were included. Participants were randomly allocated into two groups: Group A followed the Delorme protocol (ascending resistance), and Group B followed the Oxford protocol (descending resistance). Both groups underwent a four-week intervention comprising supervised sessions three times per week along with a home exercise program. Outcome measures included grip strength and forearm muscle strength (wrist flexors, extensors, supinators, and pronators), assessed using the Lafayette Hand-Held Dynamometer. Statistical analysis was performed using SPSS version 23.0, with paired t-tests for within-group comparisons and unpaired t-tests for between-group comparisons. A p-value<0.05 was considered statistically significant.

Results: Baseline characteristics were comparable between the two groups (p>0.05). Within-group analysis showed significant improvements in both groups (p<0.01) across all the outcome measures. Between-group comparison revealed significantly greater post-intervention improvements in group A compared to group B. Grip strength was significantly higher in Group A than in group B, p<0.05. Similarly, wrist flexor strength, wrist extensor strength, supinator strength, and pronator strength were significantly higher in group A compared to group B, p<0.05.

Conclusion: Both the Delorme and Oxford training protocols were seen to be effective in improving the grip strength and forearm muscle strength in patients with postoperative distal forearm fractures. However, the Delorme technique was more effective than the Oxford technique in enhancing the forearm muscle strength and hand grip in this population.

Keywords: Exercise program, Hand strength, Muscle function, Resistance training, Wrist fractures

INTRODUCTION

Fractures of the forearm bones, involving one or both bones, are common injuries resulting from falls, direct trauma, or sports-related incidents, and they primarily affect the rotational movements of supination and pronation, as well as other wrist movements [1]. Fractures of the distal radius alone account for approximately 17% of all fractures worldwide, with an annual incidence of about 208 per 100,000 individuals. The incidence of distal forearm fractures is higher in children than in older adults, and in adolescents, it is approximately 17.5% [2].

There are three types of distal forearm fractures based on their structural pattern. Type 1 fractures are associated with low-energy trauma, such as falls, and most often occur in elderly patients, whereas types 2 and 3 typically result from high-impact sports or traumatic accidents and are more prevalent in younger individuals [3]. Treatment of forearm fractures may be either conservative or surgical, and the choice of treatment depends on the fracture type and the extent of associated injuries. Regardless of whether management is conservative or surgical, early and effective rehabilitation is essential to achieve optimal functional recovery. Incomplete recovery after rehabilitation may lead to complications such as radioulnar synostosis, restricted joint Range of Motion (ROM), or malunion [4].

In rehabilitation settings, to restore muscle strength, function, and normal ROM, emphasis is placed on isometric training, isotonic exercises, and isokinetic training, along with functional task-oriented strengthening and neuromuscular re-education [5]. Among these, resistance training remains a cornerstone of musculoskeletal rehabilitation, with Progressive Resistive Exercise (PRE) being one of the most commonly used approaches. This type of exercise is typically prescribed according to the Repetition Maximum (RM) principle, in which the exercise intensity is tailored to the maximum number of repetitions an individual can perform at a given resistance. Among the various PRE methods, the Delorme and Oxford techniques are two of the most widely applied programs in clinical and sports rehabilitation. The Delorme protocol employs a progressive loading strategy, beginning with lighter resistance that gradually increases to heavier loads. This approach is believed to adequately warm up the muscles, minimise soreness, and prepare the body to exert maximum effort during the final set [6].

The Delorme method employs an ascending loading scheme across three sets, starting at 50% of the 10-RM, followed by 75%, and concluding with 100% of the 10-RM. Conversely, the Oxford protocol uses a descending loading regimen, in which greater effort is utilised initially when the muscles are rested, followed by progressively reduced resistance as fatigue develops. Thus, this approach applies a decreasing load over three sets, commencing at 100% of the 10-RM, then 75%, and concluding with 50% of the 10-RM [7].

Although both techniques are established to enhance muscle function, there is limited targeted research on their relative efficacy in postoperative rehabilitation, particularly among patients recovering from distal forearm fractures. Additionally, there is scarce evidence regarding which protocol yields superior clinical outcomes for grip and forearm muscle strength recovery in postoperative fracture cases.

Therefore, the present study aimed to compare the effectiveness of the Oxford and Delorme resistance training protocols on grip and forearm strength among patients following distal forearm fractures.

MATERIALS AND METHODS

This experimental study was conducted at the Outpatient Department of Krupanidhi College of Physiotherapy, Bengaluru, Karnataka, India, over a period of one year from May 2024 to May 2025.

Ethical approval for the study was obtained from the Institutional Ethics Committee of Krupanidhi College of Physiotherapy (IEC No. PT/UG/ETH-2024/012).

Sample size calculation: A sample size of 30 participants was calculated using G*Power, with an effect size of 1.304, an alpha level of 0.05, and a power of 0.90. The effect size of 1.304, derived from Abd El-Baky AM et al., was based on the mean difference and pooled standard deviation of grip strength outcomes (Cohen's d). This value, used in the G*Power sample-size calculation, was based on expected clinically meaningful differences in the primary outcome measures between the two groups (muscle and grip strength), as reported in relevant literature on forearm fracture and its rehabilitation [8].

This value corresponds to a large to very large standardised mean difference ($d \approx 1.3$), indicating that the anticipated treatment effect is expected to be substantially greater than the within-group variability. Given this magnitude of expected effect and the requirement for high power (0.90) at $\alpha = 0.05$, G*Power determined that a total sample size of n = 30 (15 per group) would be sufficient to detect such an effect with adequate statistical power.

Inclusion criteria: Patients of both genders, aged 18–40 years, who had completed 6 weeks post-surgery for distal forearm fracture (with bone healing confirmed on X-ray) and who demonstrated wrist flexion >45°, wrist extension ≥55°, radial deviation ≥15°, ulnar deviation ≥25°, forearm supination ≥81°, and pronation ≥78° (80% of normal ROM), were included. The ranges were measured using a standard universal goniometer [9].

Exclusion criteria: Eligible participants were identified and recruited from multiple orthopaedic clinics and hospitals (where the surgeries were performed) across Bengaluru through convenience sampling. Participants with multiple fractures in the same upper limb, recent surgeries involving the cervical spine or upper limb within the past six months, any neurological (e.g., neuropraxia, axonotmesis, neurotmesis) or vascular injury, or existing metabolic bone diseases (e.g., osteoporosis, osteomalacia) were excluded from the study.

Each individual reviewed the study procedures, and written informed consent was obtained prior to the commencement of the study. Participants were randomly allocated into two groups using Random Allocation Software version 2.0 (Informer Technologies). Group A underwent Delorme progressive resistance training [6], while Group B underwent Oxford progressive resistance training [7]. Before the intervention, baseline grip strength was assessed using a Lafayette hand-held dynamometer [10], while forearm muscle strength for the wrist flexors, wrist extensors, supinators, and pronators was assessed using a Lafayette dynamometer (manual muscle tester) [11].

Study Procedure

To establish the baseline training load, the 10-RM was determined for the wrist flexors, wrist extensors, forearm supinators, forearm pronators, and grip strength. To calculate the 10-RM for the forearm muscles, participants were first instructed to lift the maximum weight using a dumbbell, and the estimated 10-RM training load was derived from the measured 1-RM using accepted repetition–maximum conversion methods. As all participants were in the postoperative phase beyond 6 weeks, fracture healing had progressed to the remodelling stage, making controlled resisted loading clinically acceptable and safe [12]. The Brzycki prediction equation was subsequently used only as a conversion method to derive the corresponding estimated 10-RM training load required for the standardised Delorme and Oxford resistance training protocols. Based on the repetition–maximum relationship proposed by Brzycki and supported by Nuzzo JL et al., 10-RM is considered equivalent to 75% of 1-RM. Therefore, the 10-RM training load was calculated as 75% of the estimated 1-RM [13,14].

Forearm muscle strengthening exercises were prescribed for wrist flexion, wrist extension, forearm supination, and forearm pronation using dumbbells [15]. For grip strength training, an adjustable heavy-grip hand gripper was used to determine the 10-RM [16]. Participants were seated in a comfortable position with the forearm relaxed on the tabletop and were instructed to perform 10 squeezes with the hand gripper. The maximum weight (kg) that the participant was able to squeeze for 10 repetitions was recorded as the 10-RM for grip training.

To progress the training protocol, 10-RM assessments were conducted at the beginning of each week in the same manner for both grip and forearm muscle groups [Table/Fig-1]. The revised load was then used to systematically progress training intensity each week throughout the 4-week protocol [17]. Both groups underwent supervised physiotherapy treatment three times per week for a period of four weeks.

Each session began with a five-minute warm-up, followed by the main exercise programme, and ended with a five-minute cool-down. The main exercise programme consisted of 10 repetitions across three sets, with a 2-minute rest interval between sets, and the intensity was adjusted according to the weekly 10-RM (as explained above) [17,18]. Group A received Delorme training, which involved weekly increases in load, whereas group B received Oxford training with descending load progression within each session (100%, 75%, 50% of the updated weekly 10-RM), as explained in [Table/Fig-1] [19]. The intervention was discontinued immediately if participants reported sharp pain, crepitus, or sudden onset of weakness during the exercise session.

A structured home exercise program was implemented, consisting of static stretching exercises for the wrist flexors and extensors,

Week	Delorme protocol	Oxford protocol
Week 1	3 sets: 10 reps at 50% of 10RM, 10 reps at 75% of 10RM, 10 reps at 100% of 10RM.	3 sets: 10 reps at 100% of 10RM, 10 reps at 75% of 10RM, 10 reps at 50% of 10RM.
Week 2	3 sets: 10 reps at 50% of 10RM, 10 reps at 75% of 10RM, 10 reps at 100% of 10RM	3 sets: 10 reps at 100% of 10RM, 10 reps at 75% of 10RM, 10 reps at 50% of 10RM
Week 3	3 sets: 10 reps at 50% of 10RM, 10 reps at 75% of 10RM, 10 reps at 100% of 10RM	3 sets: 10 reps at 100% of 10RM, 10 reps at 75% of 10RM, 10 reps at 50% of 10RM
Week 4	3 sets: 10 reps at 50% of 10RM, 10 reps at 75% of 10RM, 10 reps at 100% of 10RM	3 sets: 10 reps at 100% of 10 RM, 10 reps at 75% of 10RM, 10 reps at 50% of 10RM

[Table/Fig-1]: Delorme vs Oxford Method-Weekly Training Plan [19].

active range of motion exercises for the wrist and forearm, and cryotherapy applied for 10 minutes following each exercise session to help control inflammation. Participants were instructed to maintain a home exercise adherence log throughout the intervention period. These logs were reviewed regularly by the investigator to monitor compliance with the prescribed exercise protocol. At the end of the four-week intervention period, grip and forearm strength were reassessed and recorded using the same procedures as those employed at baseline.

STATISTICAL ANALYSIS

Data were analysed using Statistical Package for Social Sciences (SPSS) version 23.0. The Chi-square test was used to examine gender distribution across groups, and the Independent t-test was used to analyse age differences between the groups. The dependent t-test was used to analyse within-group comparison in grip and forearm muscle strength and the independent t-test was used to analyse the between-group comparison. A p-value of <0.05 was considered statistically significant.

RESULTS

Baseline demographic characteristics were comparable between the two groups. As seen in [Table/Fig-2], there was no statistically significant difference in gender distribution (χ^2=1.22; p=0.269), similar to [Table/Fig-3], which demonstrates that the mean age also did not statistically differ significantly between group A and group B (p=0.745), confirming demographic homogeneity.

S. No.	Gender	Group A (Delorme) (n=15)	Group B (Oxford) (n=15)	Chi-square test
1	Male	10	7	1.22 (p=0.269)
2	Female	5	8	

[Table/Fig-2]: Gender distribution among the groups of distal forearm fracture.

Age distribution	Mean±SD	Min-Max	Independent t-test
Group A (Delorme)	33±4.5	25-40	t= 0.329 p= 0.745
Group B (Oxford)	32±6.4	18-40	

[Table/Fig-3]: Age distribution among the groups of distal forearm fracture.

The pre-intervention values of the muscle strength in both groups, along with their post-intervention readings, are depicted in [Table/Fig-4]. Both groups were comparable, as the p-values were statistically insignificant (p>0.05) when pre-intervention measures were compared, thereby establishing baseline equivalence between the two groups. Group A showed greater improvement in wrist flexor strength (p<0.001), extensor strength (p=0.006), supinator strength (p=0.003) and pronator strength (p<0.001), with a statistically significant p-value <0.05 for all the outcome measures.

The comparison of grip strength between the two groups demonstrated a baseline comparability p-value of 0.877 [Table/Fig-5]. Post-intervention, group A showed better results, with a mean of 27.26 compared to group B at 25.26, indicating greater improvement (p=0.013).

Overall, while both the progressive resistance protocols produced statistically significant improvements within groups (p<0.001), the between-group comparisons presented in [Table/Fig-4,5] clearly indicate that the Delorme protocol yielded comparatively greater improvements in both the forearm muscle strength and grip strength.

DISCUSSION

The present study aimed to compare the effectiveness of the Delorme and Oxford resistance training techniques in improving grip strength and forearm muscle strength in patients recovering from postoperative distal forearm fractures. Both groups demonstrated statistically significant improvements (p<0.05) across all outcome measures, indicating that both methods were effective. However, in the inter-group comparison, the Delorme training (group A) resulted in greater improvement in forearm muscles strength, including flexors, extensors, supinators, pronators, as well as grip strength, compared with Oxford training (group B), with a statistically significant difference (p<0.05,), indicating that the Delorme protocol is more effective in enhancing muscle strength in postoperative distal forearm fracture patients. The findings of the current study support the superiority of the Delorme, as participants demonstrated smoother progression

Outcome measure	Group A (Delorme)	Group B (Oxford)	Independent t-test	p-value	df	Cohen's d	95% CI for mean difference	
	Mean±SD	Mean±SD					Lower	Upper
Pre- wrist flexors (N)	48.51±5.7	46.24±5.0	1.146	0.261	28	0.419	-1.789	6.336
Post- wrist flexors (N)	69.21±2.4	60.65±3.5	7.743	<.001*	28	2.827	6.295	10.825
Dependent t-test	t= -18.65	t= -23.90						
p-value	<0.001	<0.001						
df	14	14						
Cohen's d	-4.816	-6.172						
Pre wrist extensors (N)	53.01±3.1	52.66±4.7	0.236	0.815	28	0.086	-2.661	3.355
Post wrist extensors (N)	68.67±2.4	65.06±3.9	2.996	0.006*	28	1.094	1.143	6.084
Dependent t-test	t= -29.64	t= -39.27						
p-value	<0.001	<0.001						
df	14	14						
Cohen's d	-7.655	-10.141						
Pre-supinators (N)	46.60±7.0	45.51±5.4	0.498	0.622	28	0.182	-3.566	5.859
Post-supinators (N)	64.24±4.9	58.89±3.9	3.25	0.003*	28	1.187	1.977	8.716
Dependent t-test	t= -10.04	t= -24.74						
p-value	<0.001	<0.001						
df	14	14						
Cohen's d	-2.593	-6.389						
Pre-pronators (N)	40.53±4.5	43.74±4.6	-1.91	0.066	28	-0.698	-6.659	0.232
Post-pronators (N)	64.56±3.8	59.52±3.4	3.764	<.001*	28	1.375	2.3	7.793
Dependent t-test	t= -15.90	t= -20.61						
p-value	<0.001	<0.001						

df	14	14
Cohen's d	-4.106	-5.322

[Table/Fig-4]: Comparison of forearm muscle strength before and after four weeks of intervention among Group-A and Group-B.
N: Newton, *Significant p-value

Outcome measures	Group A (Delorme)	Group B (Oxford)	Independent t-test	p-value	df	Cohen's d	95% CI for mean difference	
	Mean±SD	Mean±SD					Lower	Upper
Pre-grip strength	19.60±2.5	19.73±2.2	-0.156	0.877	28	-0.057	-1.8	1.6
Post-grip strength	27.26±2.2	25.26±1.8	2.647	0.013*	28	0.967	0.45	3.58
Dependent t-test	t = -25.26	t = -23.40						
p-value	<0.001*	<0.001*						
df	14	14						
Cohen's d	-6.52	-6.04						

[Table/Fig-5]: Comparison of grip strength following four weeks of intervention among group A and group B.
*Significant p-value

in grip and forearm muscle strength, maintained consistency throughout the protocol and appeared to demonstrate better tolerance to exercise progression. Shin HK et al., evaluated the EMG findings of Delorme progressive resistance training after 12 weeks and inferred similar findings i.e., statistically significant improvement ($p<0.05$) in gradual motor unit recruitment, enhanced neuromuscular control, reduced premature fatigue, steady gains in muscle strength and better tolerance [20].

In contrast to the present study, Gulunjkar P et al., when compared Delorme with another established training program (the McQueen technique), did not find any statistically significant difference ($p>0.045$) in the outcomes, thereby inferring no noteworthy superiority of Delorme in improving strength [21]. However, the evidence provided by Kale S et al., further supports the findings of the present study, as they demonstrated that progressive neuromuscular loading, as emphasised in the Delorme approach, yields greater rehabilitation benefits with a significant increase in muscle strength ($p<0.01$) [22]. With respect to Oxford training, the present study demonstrated statistically significant improvements in forearm muscle strength (flexors, extensors, supinators, pronators) and grip strength ($p<0.001$). Knight KL conducted a study focusing on the Oxford technique that reported a statistically significant improvement in strength ($p<0.05$) in orthopaedic and post-injury rehabilitation, achieving rapid initial strength gains [23]. Razmjou S et al., also reported that the Oxford technique showed significantly greater improvement in biceps curl strength ($p=0.04$) in healthy untrained women after six weeks of strength training [24]. Furthermore, the current study also found that the subjects experienced initial difficulty during the early sessions of Oxford and required supervision, motivation, and continuous encouragement to overcome fatigue. By the third week, adherence had improved, indicating that even Oxford can be effective, aligning the present study with the existing literature.

The present study demonstrated greater improvement in forearm and grip strength ($p<0.05$) in post-surgical cases of forearm fracture following Delorme training compared to Oxford, which was contrary to the findings reported in the literature regarding comparative studies of Delorme and Oxford techniques in non operative conditions. Pereira R et al., compared the effects of the Delorme and Oxford training protocols on quadriceps strength in healthy individuals and reported no statistically significant difference ($p> 0.05$) in strength improvement between the two training programs [25]. Similarly, Silva DP et al., in moderately active individuals undergoing resistance training, also found statistically insignificant ($p>0.05$) difference between these two protocols in the quadriceps' strength, thus implying that neither of the methods has consistent statistical superiority [26]. However, the present study reflected the superiority of Delorme's ($p<0.05$) over Oxford in all outcome measures in postoperative cases of distal forearm fracture. This may be attributed to the ascending progression in Delorme training, starting with lighter loads and gradually increasing the weight with each set, in contrast to the Oxford method, which uses a descending progression, beginning with heavier loads and tapering down. This structured progression of load in the former would reduce fatigue and enhance the motor unit recruitment, which is necessary in postoperative fracture cases to provide loading of the bone gradually in accordance with Wolff's law, thus potentially facilitating functional recovery through gradual loading principles [27]. Monteiro AG et al., proved that in less-trained or clinical populations, the ascending progression i.e., Delorme, offers better fatigue management, higher patient compliance, and more consistent muscle strength gains ($p=0.02$) [28]. Deci EL and Ryan RM stated that the gradual progression in exercise, as implemented in Delorme training, also plays a key role in enhancing motivation, confidence, and adherence during rehabilitation, as supported by the psychological theory of self-determination, which may explain the improved results [29]. Hence, it can be concluded that in post-surgical cases, the ascending loading pattern proved beneficial in reducing early fatigue, allowing gradual adaptation, and enhancing patient confidence during initial rehabilitation sessions.

Limitation(s)

The present study has a small sample size that limits the generalisability of the findings, and the short follow-up duration restricts the ability to determine long-term effects of the intervention. The absence of blinding and the use of convenience sampling may increase the possibility of measurement and observer bias. The study is limited by the fact that participants were recruited from a single geographical location (Bengaluru). The generalisability of the findings could be affected, especially if there are regional differences in patient populations or treatment approaches. Also, 10-RM was estimated from 1-RM, which may overestimate true capacity and introduce error. The incorporation of Electromyography (EMG) could provide more detailed insights into neuromuscular activation patterns with a longer follow-up period.

CONCLUSION(S)

Both Delorme and Oxford training protocols are effective in improving grip strength and forearm muscle strength among postsurgical distal forearm fracture cases. However, the Delorme protocol demonstrated a statistically greater improvement in the present study, suggesting that it may be the more beneficial option for postoperative cases. Ascending load progression is a more efficient method of muscle strengthening than descending load training, particularly in postoperative fracture cases; however, replication with larger samples is needed.

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