RESEARCH ARTICLE

Orthotic Intervention with Custom-made Thermoplastic Material in Acute and Chronic Mallet Finger Injury: A Comparison of Outcomes

Erfan Shafiee, BSc/MSc OT, PT PhD; Maryam Farzad, BSc, MSc, PhD; Hadi Beikpour, MD

Research performed at Iran Hand Rehabilitation Center, Tehran, Iran

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Abstract

Objectives: To compare the effect of using custom-made orthosis on improving extension lag and reducing disability in acute and chronic mallet fingers.

Methods: We recruited 51 patients with acute or chronic Doyle type-1 mallet fingers, who were provided with a custom-made thermoplastic anti-mallet finger orthosis to wear full-time for 6 weeks and an additional 2 weeks at nighttime. The primary outcome, extension lag, was assessed at enrollment as well as six- and twelve-week follow-ups. Secondary outcomes included disability and satisfaction, which were evaluated using the Disability of the Arm, Shoulder, and Hand questionnaire at enrollment and 12 weeks, and a satisfaction scale at 12 weeks follow-up. Data analysis was conducted using univariate analysis of variance (ANOVA), one-way repeated measure mixed model analysis of covariance (ANCOVA), and independent sample t-test.

Results: A total of 43 participants, 25 acute and 18 chronic mallet fingers, completed the 12-week evaluation. The study found no significant difference between the two groups in terms of improvement in extension lag at either follow-up time point (P=0.21). Disability improved in both the acute and chronic groups at follow-up (P<0.05). Additionally, both groups expressed satisfaction with the treatment outcome, and no statistically significant difference was observed (t=0.173, P=0.51). We could not identify any clinically significant difference between the two groups in regard to extension lag, disability, or satisfaction at follow-up. Notably, 96% of the patients in the acute group and 88% of the patients in the chronic group demonstrated good to excellent outcomes.

Conclusion: Orthotic intervention with custom-made thermoplastic material in acute and chronic mallet fingers improved extension lag and disability, and both groups were satisfied with the treatment outcomes. The findings of our study indicated that patients with chronic mallet fingers benefited from orthotic interventions in the same way that patients with acute mallet fingers did.

Level of evidence: II

Keywords: Disability, Extension lag, Mallet finger, Orthotic intervention, Splint

Introduction

Mallet finger is a traumatic lesion in zone I of the hand extensor tendons, which results from a direct, forceful flexion or hyperextension to an extended finger. It leads to flexion deformity of the Distal Interphalangeal (DIP) joint due to the disruption of the extensor tendon at the DIP joint with or without bony avulsion. [1] Consequently, patients will not be able to extend their distal phalanx actively.

Different classifications based on radiological assessment are available for mallet fingers. However, no treatment algorithm is proposed based on the classifications. [2] Some researchers confirm immediate surgical interventions [3,4] since they allow an earlier return to work, while others suggest different timetables for immobilization, such as prolonged immobilization of the DIP joint in neutral or slight hyperextension. [5,6] Recently a decision algorithm

Corresponding Author: Maryam Farzad, University of Social Welfare and Rehabilitation Sciences, Tehran, Iran/ University of Western Ontario, London, Ontario, Canada

Email: mfarzad@uwo.ca

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suggested nonsurgical treatments of almost all mallet fingers and recommended surgical procedures in case of failure in the conservative management or fragment reduction. [7]

The effectiveness of the nonsurgical treatment with orthotic intervention on chronic conditions of the mallet finger is controversial in the literature. [7,8] To our knowledge, there is no prospective study to compare the effectiveness of the orthotic intervention on the outcomes in acute and chronic mallet fingers. [9]

This study aimed to compare the results of treatment of acute and chronic mallet fingers with a thermoplastic orthosis in terms of improving extension lag, disability, and satisfaction.

Materials and Methods

Design and participants

This study was a prospective cohort. The local ethical committee of our institution approved the study protocol. Between September 2018 and January 2019, patients with Doyle type-1 (closed injury ± avulsion fracture) mallet fingers diagnosed by an orthopedic hand surgeon were invited to participate in this study. Patients younger than 18 years old, those who presented with skin breakdown, a history of mallet finger surgery, and fixed flexion deformities in the affected finger, as well as those who did not consent to participate in this study were excluded. Patients were grouped into either acute/subacute (less than 28 days from injury) or chronic (more than 28 days from injury) based on the time passed from their injuries. [10,11]

After obtaining informed consent, patients provided demographic information, including age, gender, time passed from injury, dominant hand, injured finger, and the type of mallet finger injury (bony or tendinous). They also completed the Disability of the Arm, Shoulder, and Hand (DASH) questionnaire. An experienced occupational therapist measured the extension lag at the enrollment and fabricated a custom-made orthosis with thermoplastic material for all patients. Patients were asked to wear the orthosis full time for 6 weeks and continue to wear it for a further 2 weeks only at night. Finger range of motion (extension lag and total active motion) was also evaluated at 6- and 12-week follow-ups. Patients returned for a 12-week follow-up were asked to complete the DASH and satisfaction measure.

Intervention

A custom-made orthosis with thermoplastic tape (Orficast, Orfit Industries, Belgium) was fabricated for all participants to immobilize the DIP joint in slight hyperextension [Figure 1a]. Patients were instructed to take off their orthosis for hygiene (while keeping the DIP joint in hyperextension with their other hand). We monitored the orthosis weekly to ensure that the position of immobilization had not been changed due to the edema reduction [Figure 1b]. We reshaped the orthosis for patients whose orthosis became loose or failed to keep the finger immobilized in the proper position. At 6 weeks, patients were asked to stop wearing the orthosis during the day but continue using it during the nighttime for 2 weeks. Patients were allowed to start light daily activities after removing the orthosis at 6 weeks. The flexion exercises with therapeutic putty were started at 8 weeks to recover their missed flexion range of motion. We recorded any complications, such as skin irritation or pain, during the period of using the orthosis.

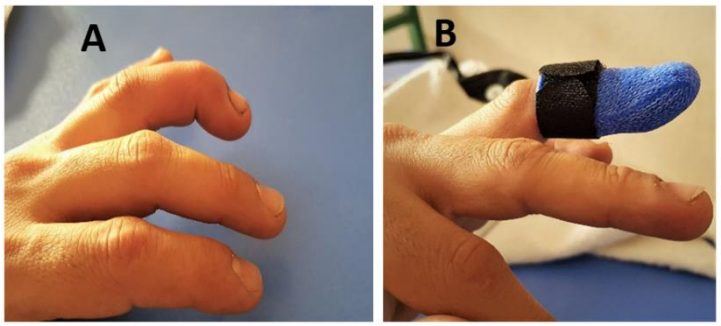

Figure 1. Anti-mallet finger orthosis. This figure demonstrates the use of thermoplastic material for orthotic intervention in patients with mallet fingers. Figure 1A is a patient with a mallet finger at baseline, and Figure 1B is a patient wearing the thermoplastic anti-mallet orthosis

Evaluation and outcome measures

A handheld goniometer (JAMAR) was used to measure extension lag and the flexion range of motion of the finger. We measured extension lag with the goniometer on the dorsum of the DIP joint with the patient's wrist and forearm in mid-position and all fingers in full extension. Residual extension lag was interpreted by modified Miller's criteria as 0: Excellent; 5-10: Good; 11-45: Fair; and > 45: Poor. [10]

To measure flexion loss in the affected finger, total active motion (TAM) was calculated using the following formula: TAM = (PIP+DIP flexion) – (PIP+DIP extension lag). The total amount of TAM was interpreted as Excellent (150<TAM<175), Good (125<TAM<149), Fair (90<TAM<124), and Poor (TAM<90). [11]

The DASH questionnaire was used to evaluate disability at the baseline and 12 weeks. The DASH is a 30-item self-report outcome measure that assesses functional limitations in daily activities. [11] Each item is scored on a 5-point Likert scale, and the total score ranges from 0-100 with higher scores indicating a greater level of disability. We used the Persian version of the DASH in this study. [12]

Satisfaction with the treatment outcomes was measured on a 0 to 10 ordinal scale at 12 weeks with higher scores representing higher satisfaction levels. [13]

To grade the overall outcome of the patient, we used the Crawford criteria at 12-week follow-up. [14] Based on the Crawford criteria, patients were rated as: 1) Excellent: with full extension, full flexion; 2) Good: with 0-10 degrees extension lag, full flexion; 3) Fair: with 10-25 degrees extension lag, any flexion loss; and 4) Poor: with extension lag of > 25 degrees and persistent pain.

Statistical analysis

A post hoc power analysis indicated that a sample of 42 would provide 80% statistical power (β=0.20 and α=0.05) and a large effect size (0.8). To account for a dropout rate of 20%, we enrolled 26 patients in each group.

To confirm the comparability of the groups, we performed

univariate analysis using independent sample t-tests for continuous variables (age, baseline extension lag, DASH) and Fisher's exact test for categorical variables (gender, dominant hand, injured hand, injured finger, and the type of injury).

A one-way repeated measure mixed model analysis of variance (ANOVA) was used to compare the residual extension lag between the groups at the baseline as well as 6 and 12 weeks. It was also utilized to determine the changes in extension lag within each group over time. A post hoc pairwise comparison using the Bonferroni correction was used to determine the significant difference between the two groups.

Univariate analysis of covariance (ANCOVA) was performed to detect within-subject variation by considering the baseline extension lag as a covariate. F statistic magnitude was used to evaluate the significance level. Partial eta squared effect size from ANCOVA is a method to measure the treatment effect size and was interpreted as small (0.01), medium (0.06), and large (≥0.14). [14]

To compare the DASH and satisfaction score between patients with acute or chronic mallet fingers, we used an unpaired Student's t-test. A paired t-test was applied to evaluate the DASH change scores between the baseline and 12-week follow-up in each group. Data was evaluated using the SPSS23.0 software for Windows.

Results

A total of 51 patients (26 acute and 25 chronic) were invited to participate in this study. Six patients declined to complete follow-ups, and two did not use the orthosis continuously. Twenty-five patients in the acute/subacute group with a mean age of 38.0 (±15.8) years and 18 patients in the chronic group with a mean age of 38.3 (±2.2) years completed 12-week follow-up. None of the patients reported any complications during the eight-week period of wearing the orthosis. Eleven participants presented with a bony mallet and 32 patients with a tendinous mallet. The mean of extension lag at the baseline was 23.6 (±12.2), ranging from 5 to 55 in the acute group, and 23.0 (±8.4) ranging from 10 to 40 in the chronic group (t=0.163, P=0.87) [Table 1].

At baseline, using independent sample t-test and Fisher's exact test, there was no significant difference between the two groups in terms of extension lag (P=0.87), type of injury (P=0.48), dominant injured hand (P=0.76), and injured finger (P=0.21). There was a significant difference in the DASH scores between the two groups at the baseline, and the mean of the DASH score was higher in the chronic group (acute: 14.2 (±4.9), chronic: 25.3 (±8.7); t=5.32, P<0.05).

Table 1. Demographic and clinical characteristics of participants at the baseline

		Acute (n=25)	Chronic (n=18)
Age		38.8 (±15.8)	38.3 (±9.7)
Gender (female)		7 (28%)	7 (38.9%)
Injured dominant hand		14 (56%)	11 (61.1%)
Type of injury	**Bony**	5 (20%)	6 (33.3%)
	Tendinous	20 (80%)	12 (66.7%)
Finger	**Index**	1 (4%)	4 (22.2%)
	Middle	4 (16%)	3 (16.7%)
	Ring	13 (52%)	5 (27.8%)
	Little	7 (28%)	6 (33.3%)
Extension lag		23.6 (±12.2)	23.06 (±8.4)
Time passed from injury (days)		10.5 (±7.4)	70.5 (±29.4)

Extension lag

A repeated-measures ANOVA indicated that the mean of extension lag decreased significantly across three follow-up time points (F (1, 43)=518.56, P=0.00) with a medium effect size (0.04). A post hoc pairwise comparison using the Bonferroni correction showed a significant (P=0.00) decrease in extension lag between baseline and 12-week follow-up evaluation in both groups (23 vs. 18.9, respectively). No significant difference was detected between the two groups regarding extension lag improvement at either of the follow-up time points (P=0.21) [Figure 2].

The results of ANCOVA indicated that there was a statistically significant difference in post-intervention extension lag (P<0.05) between the acute and chronic group once their mean was adjusted for baseline extension lag. The

adjusted mean between-group difference in extension lag was 3.40 (95% confidence interval, 3.01 to 3.49). Although extension lag was reduced in both groups, the between-group difference favored the acute group by 3.40 degrees greater reduction than the chronic group. Both groups demonstrated clinically significant reduction in extension lag, and we could not detect the superiority of each group over another. Partial eta square, which is the measure of variance, indicated that baseline extension lag could explain 20% of the variance of extension lag at 6 weeks.

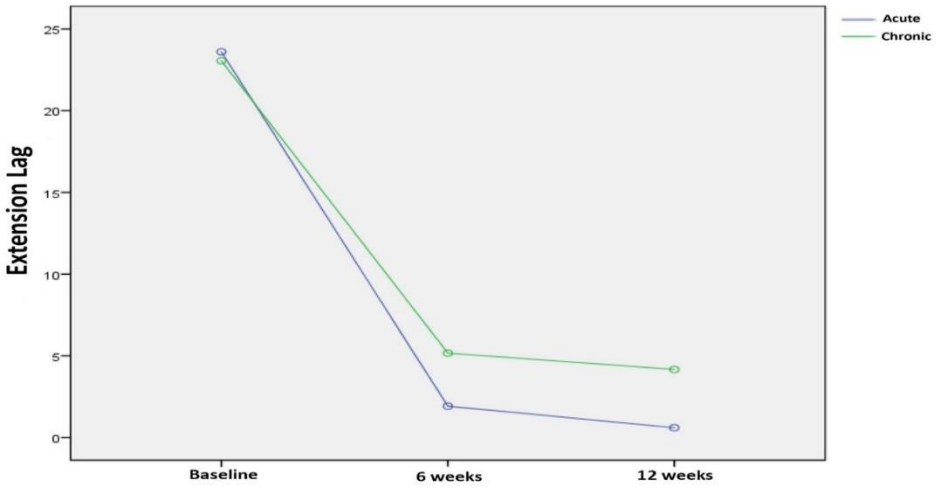

Figure 2. Extension lag at three evaluation time points. This figure illustrates extension lag measured by a goniometer on the vertical axis, and three evaluation time points on the horizontal axis. The purple line represents the acute group, and the green line represents the chronic group

Disability (DASH) and Satisfaction

There was a significant improvement in the mean of DASH score in both acute and chronic groups between the baseline and 12-week evaluation; accordingly, this score decreased 11.4 (from 14.2 to 2.8) and 19.9 (from 25.3 to 5.4), respectively (P<0.05). Between-group comparison indicated a statistically significant difference in the DASH scores (acute group: 2.8 (±2.2), chronic group: 5.4 (±2.9)) at the follow-up (P<0.05). However, this difference was not clinically significant.

The satisfaction score was 9.2 in the acute group and 9.1 in the chronic group. This difference was not statistically significant (t=0.173, P=0.51) [Table 2].

Range of motion (TAM)

All patients in the acute group and 83% of the patients in the chronic group demonstrated good to excellent TAM. However, 17% of the patients in the chronic group demonstrated fair results.

Crawford criteria

Ninety-six percent of the patients in the acute group and 88% of the patients in the chronic group demonstrated good to excellent results considering Crawford criteria. More details of the measurements are provided in [Table 2].

Discussion

This study aimed to resolve the contentious issue among clinicians and researchers regarding the crux of the effectiveness of orthotic intervention for patients with chronic mallet fingers. The findings of this study demonstrated that orthotic intervention with custom-made thermoplastic material could effectively improve extension lag and reduce disability in patients with both acute and chronic Doyle type-1 mallet fingers. Patients in both groups reported satisfaction with the treatment outcomes and displayed an acceptable range of motion in the affected finger. These results support the use of custom-made orthosis as a safe and non-invasive treatment option for mallet finger injury.

To the best of our knowledge, this study was the first to prospectively compare the effectiveness of orthotic intervention in patients with acute and chronic mallet fingers, providing valuable insights into the efficacy of this intervention and comparing the clinical outcomes between the two groups. In addition, we fabricated a custom-made orthosis with thermoplastic material, which has recently gained popularity over traditional orthoses, such as stack or aluminum padded splints. [15]

The importance of this study stems from the conflicting evidence in the literature regarding the impact of orthotic intervention on clinical outcomes in patients with chronic mallet fingers. [7,8]

The current evidence suggests no significant difference in the residual extension lag after using custom-made thermoplastic material compared to the other types of orthoses. [16]

Nonetheless, the distinctive advantage of using a custom-made orthosis with thermoplastic material is primarily in reducing the likelihood of complications and skin irritations as opposed to enhancing extension lag. [8,17,18]

Table 2. Comparison of outcomes between the two groups

			Acute	Chronic
Baseline	**Extension lag**		23.6 (±12.2)	23.1 (±8.4)
	DASH		14.2 (±4.9)	25.3 (±8.7)
6 weeks	**Extension lag**		1.9 (±3.1)	5.2 (±3.5)
	Modified Miller Criteria	**Excellent**	19 (76%)	5 (28%)
		Good	6 (24%)	12 (67%)
		Fair	0	1 (5%)
		Poor	0	0
12 weeks	**Extension lag**		0.6 (±1.6)	4.2(±3.9)
	Modified Miller Criteria	**Excellent**	22 (88%)	6 (33%)
		Good	3 (12%)	11 (61%)
		Fair	0	1 (6%)
		Poor	0	0
	DASH		2.8 (±2.2)	5.4 (±2.9)
	Satisfaction		9.2 (±0.9)	9.1 (±0.8)
	TAM	**Excellent**	23 (92%)	7 (39%)
		Good	2 (8%)	8 (44%)
		Fair	0	3 (17%)
		Poor	0	0
	Crawford criteria	**Excellent**	20 (80%)	8 (44%)
		Good	4 (16%)	8 (44%)
		Fair	1 (4%)	1 (12%)
		Poor	0	0

DASH: Disability of the Arm, Shoulder, and Hand questionnaire; TAM: Total active motion

As previously noted, we provided instructions to our study participants on the proper removal of the orthosis for routine hygiene practices. During the intervention period, there were no reported complications, such as skin irritation, among the participants.

Our study aimed to investigate the impact of the time elapsed since the initial mallet finger injury on the clinical outcomes of patients. The results of our study indicated that patients who presented within 4 weeks of the injury (acute group) had similar clinical outcomes to those who presented after one month (chronic group). Therefore, the duration of injury did not appear to have a significant impact on the effectiveness of the orthotic intervention.

There is increasing evidence supporting the advantages of using conservative treatment for both acute and chronic mallet fingers. Kinninmonth et al. [19] conducted a study on 54 patients with 57 mallet fingers and reported that orthotic intervention resulted in satisfying results in patients with chronic mallet fingers (ranging from a 6-week to 15-month delay from injury to presentation) after 6 weeks of wearing the orthosis. [19] Furthermore, the researchers reported that orthotic intervention was effective in improving extension lag and reducing disability in patients with chronic mallet fingers. The results of the study demonstrated that 79% of

patients with the standard splint and 84% of patients with the perforated splint were able to change the splint satisfactorily. However, six patients in the standard splint group had to switch to a perforated splint due to difficulty in changing the splint and experiencing skin irritation. Overall, the study found that orthotic intervention was a successful treatment option for chronic mallet fingers, even when the injury had been present for an extended period.

In a study by Garberman et al., [20] the researchers compared the effectiveness of early and delayed treatment for mallet fingers. The findings of the study showed that there was no significant difference in the degree of extensor lag between the early (acute) and delayed (chronic) treatment groups, and that treatment with either stack or aluminum-foam splints had no impact on the final outcome. The results of the study also revealed that there was no significant difference in treatment outcomes between the two groups. [20]

In another study, [21] Altan et al. compared the impact of early (0-2 weeks) versus delayed (2-4 weeks) orthotic intervention after closed tendinous mallet finger while keeping the DIP joint in a pre-defined 10 degrees hyperextension in all patients. Patients were followed up for an average of 118 months, during which time they were satisfied with their treatment and reported no impairment in daily activities. The results of this study demonstrated comparable results for early versus delayed orthotic intervention, and no clinically significant difference was found between these two groups. In the most recent randomized clinical trial conducted in 2021, [17] Cavanaugh et al. compared the effectiveness of using two types of custom-made thermoplastic orthoses (Orfilight and Quickcast) in acute and chronic mallet fingers with less than a 12-week interval from the initial injury. The researchers found superior results in terms of pain and edema improvement and less skin complications in favor of the Quick cast group. However, no significant difference was detected in extension lag improvement.

One of the most important considerations in orthotic interventions for mallet fingers is the appropriate fitness of the orthosis. Improper fit of an orthosis is associated with less patient compliance. [22] Edema is one of the factors that affects how well an orthosis fits. [23]

During the initial week following an injury, patients typically experience edema in the injured finger, which would be particularly noticeable in acute bony injuries. Once the edema has reduced, patients may observe that their orthosis no longer fits snugly. Thermoplastic materials are more effective since they can be reshaped multiple times and tailored to get fit to the new desired finger condition. would have occurred naturally over time. One of the other limitations of this study was the short follow-up period, which limited us to assess the long-term effectiveness of the orthotic intervention. Future studies with longer follow-up periods are needed to determine the sustainability of the treatment outcomes.

Acknowledgement

Not applicable

Moreover, materials that can be molded around the finger circumference are beneficial in reducing edema. [24] The material we used in this study (Orficast) can be contoured to the injured finger and adjusted after the edema subsides, eliminating the need for a new orthosis.

Our study also had the advantage of incorporating patient-reported outcome measures in the evaluation of the participants. We evaluated disability and satisfaction with the treatment outcome in addition to the range of motion as an objective measure. Although the disability level was higher in patients with chronic mallet fingers at enrollment, the orthotic intervention was effective in improving disability regardless of the delay in referring for receiving treatment.

The most recent systematic reviews have demonstrated that both surgical and conservative methods can be effective in the treatment of mallet fingers. However, there is still controversy in the literature about the optimal approach for treating mallet fingers. Some argue that conservative methods should be favored due to the lower risk of complications associated with surgical intervention. Others suggest that surgery is necessary for more severe cases, particularly those with significant displacement or bone fractures. [8,23,25] Considering post-surgery complications, conservative treatment is currently favored as the primary course of action for uncomplicated cases of chronic and acute mallet finger injuries. [7,8,23,26]

Conclusion

In conclusion, the results of our study indicated that using custom-made orthosis with thermoplastic material as the first line of treatment for both acute and chronic mallet finger injury was effective in improving extension lag and reducing disability. The patients in both groups expressed satisfaction with their outcomes at the end of the follow-up period. According to the findings of our study, patients with chronic mallet fingers benefited from orthotic interventions in the same way that patients with acute mallet fingers did.

Limitations and weaknesses

This study had several limitations. Firstly, the assessing therapist was not blinded to the group assignment, which might have introduced bias. Secondly, we were unable to compare our findings to other interventions, such as surgery or other orthotic devices, as we did not include a comparison group. Additionally, the absence of a control group made it difficult to determine whether the improvements we observed were solely due to the orthotic intervention or

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Erfan Shafiee BSc/MSc OT, PT PhD[1]
Maryam Farzad BSc, MSc, PhD [2,3]
Hadi Beikpour MD [4]

1 University of Western Ontario, London, Ontario, Canada

2 Assistant Professor, University of Social Welfare and Rehabilitation Sciences, Tehran, Iran
3 University of Western Ontario, London, Ontario, Canada
4 Reconstructive and Microsurgery, Shahid Beheshti University of Medical Sciences, Tehran, Iran

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