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Original Research

Comparison of Orthosis Management Failure Rates for Mallet Injuries

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Purpose: A closed mallet injury is a common finger injury involving terminal extensor tendon avulsion from its insertion on the distal phalanx. Nonsurgical treatment with continuous extension orthosis fabrication is the preferred treatment. Our purpose was to report the failure rates of orthotic management by digit and investigate other factors that contribute to failure.

Methods: This was a retrospective chart review of all patients with an isolated mallet finger injury managed at our institution from 2011 to 2019. Patient demographics, details of management, and treatment outcomes were collected. Failure rates were compared for all digits, specifically comparing the little finger versus all other digits. A categorical variable analysis was performed to identify risk factors for failure of orthosis management.

Results: Out of 1,331 identified patients, 328 met the inclusion criteria. There was no statistically significant difference of failure rate between digits. There was a trend toward the little finger failing at a higher rate (n = 131, 40%) than the other digits individually ($P = .08$) and combined (n = 95, 29%; $P = .06$). An older age at injury was associated with failure. The median patient age with failure was 54 years, versus the median patient age with nonfailure of 48 years ($P < .01$). The failure rate was higher in tendinous versus bony mallet injuries (n = 131, 40% vs n = 66, 20%, respectively; $P < .01$). The orthotic type was associated with the failure rate, and failure was highest in patients treated with Stack orthoses (n = 183, 56%; $P = .01$).

Conclusions: There was no significant difference in the orthotic management failure rate by digit for a mallet injury. Statistically significant risk factors for failure are increasing age, a tendinous injury, and the orthotic type. Further evaluation with a larger cohort is warranted to increase the statistical power of the findings.

Type of study/level of evidence: Therapeutic III.

Mallet finger is a common injury involving the terminal extensor tendon or its bony insertion on the distal phalanx, in which the extensor tendon is avulsed or ruptured. In some injuries, the distal phalanx bone itself can also be fractured. The injury mechanism typically involves forced passive distal interphalangeal (DIP) joint flexion during attempted active extension. This may affect any finger but is more common in the middle finger (MF), ring finger (RF), and little finger (LF).[1]

The goal of management is to reapproximate the ruptured tendon or bone, allowing for healing and restoration of the extensor function.[2–5] Nonsurgical management with extension orthosis fabrication is thought to be an effective treatment for most injuries.[6] Relative operative indications include open injuries, large bony fragments, intolerance of orthosis fabrication, or for failure of orthotic management. However, guidelines for operative management remain controversial.[2,6,7] During the healing period, inadvertent flexion of the injured DIP joint may rerupture the tendon and hinder the healing process. Failure to adequately reduce and heal the extensor mechanism can lead to a persistent DIP extensor lag or a fixed flexion deformity, which can have functional and cosmetic effects.[3,8–13] The risk factors for failure are not fully understood.

A variety of literature exists evaluating operative as well as nonsurgical management techniques, including different orthotic

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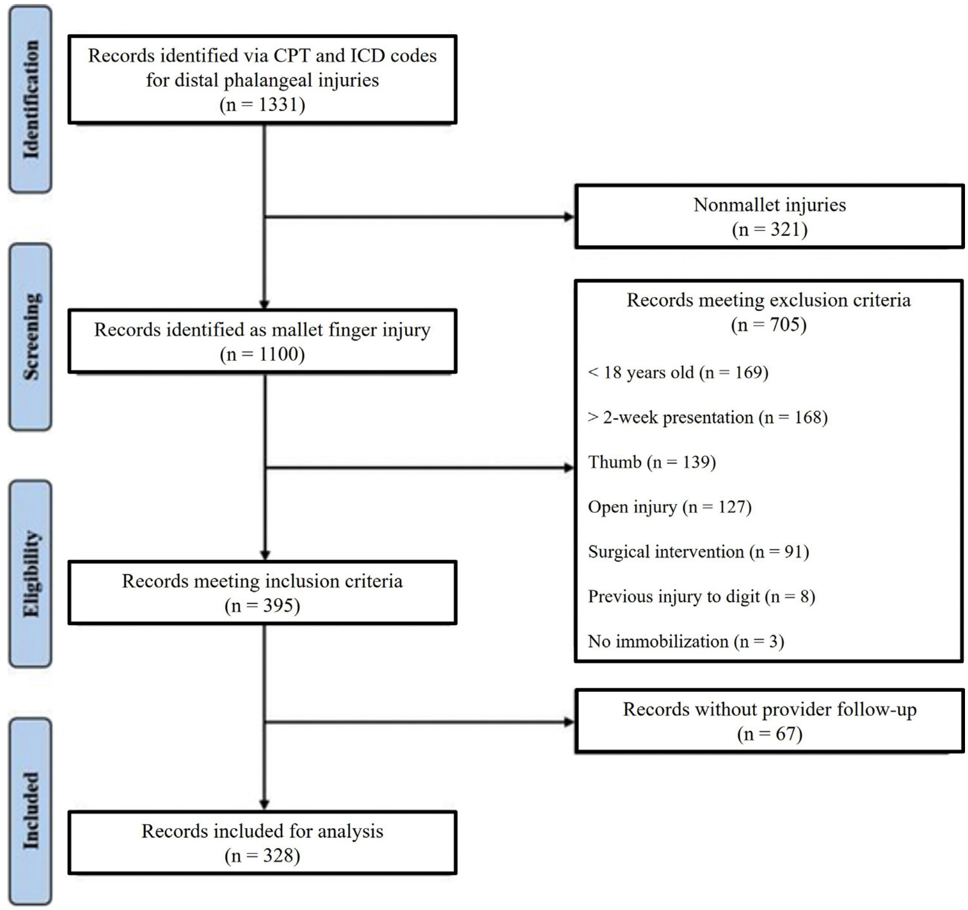


Figure. Selection strategy for inclusion. CPT, Current Procedural Terminology; ICD, International Classification of Disease.

types and treatment protocols.[3,9–11,13–17] However, much of this literature focuses on the results of different techniques for treatment comparisons, without evaluating risk factors for worsened outcomes. Abouna and Brown,[17] in a case series of 148 patients, evaluated several factors related to mallet finger treatment outcomes, including sex, age, etiology, delay in time to treatment, extension loss, affected digit, bony involvement, and fracture union. However, the series reports only on patients treated with the author's custom rubber-coated wire orthosis (Abouna orthosis), and does not account for the various extension orthosis fabrication techniques currently employed in practice today.

The primary aim of this study was to retrospectively compare the failure rates of orthosis management of mallet finger for each digit. Secondary aims were to identify additional risk factors for failure of orthotic management. Based on previous literature, researchers hypothesize that Stack and dorsal padded alumafoam orthosis management techniques will result in the highest failure rates.[10]

Materials and Methods

Study design

Patients were identified through the electronic medical record of a large, multicenter health care system following Health Partners Institute Institutional Review Board approval. Patients were identified via Current Procedural Terminology and International Classification of Disease codes encompassing mallet injuries and related distal phalangeal injuries. A manual chart review was performed and included a review of clinician notes, hand therapy notes, radiographs, the presence of complete records, and an adequate follow-up length. Patients were included if they met all of the following: had a closed mallet finger injury (index finger [IF], MF, RF, or LF), initiated orthosis fabrication within 2 weeks of injury, were a minimum of 18 years of age, had a 4-week minimum course of orthosis fabrication, and had no prior or subsequent unrelated major injury to the involved digit. While the current standard of practice at our institution suggests a 6- to 8-week course of continuous orthosis fabrication, we included patients with a minimum of 4 weeks. Historically, some patients were treated with a 4-week course of orthosis fabrication, often for bony mallet injuries. We therefore included the small subset of patients that met this criterion (n = 11). Initial identification using Current Procedural Terminology and International Classification of Disease codes identified 1,331 potential patients. After further evaluation, 328 met the inclusion criteria (Fig.). These patients were seen by 55 different providers in a large health care system, including surgeons, musculoskeletal primary care physicians, physician assistants, and certified hand therapists. Patient demographics (age, body mass index, hand dominance), injury characteristics (bony vs tendinous, mechanism of injury), the treatment rendered (orthosis fabrication course length, type of orthosis), and details of the treatment course (unplanned surgical intervention, refabricating an orthosis after a completed period of initial orthosis fabrication, DIP extensor lag, unplanned return visits for ongoing dissatisfaction) were recorded. A DIP extensor lag was defined as a clinical

Table 1
Demographics

Variable	Percent or Median (Range)
Age, y	50 (18–96)
BMI, kg/m^2	25.5 (17.0–42.3)
Male	56
Dominant hand injured	46
Injury type	
Bony	40
Digit injured	
IF	7
MF	32
RF	33
LF	28
Etiology	
Crush	9
Fall	13
Jam	39
Sport	30
Other	9

BMI, body mass index.

Table 2
Treatment and Outcomes

Variable	Percent or Median (Range)
Type of immobilization	
Alumafoam	4
Custom thermoplastic	22
Soft cast	61
Stack	11
Unspecified	2
Time to immobilization	
<1 wk	80
<2 wks	20
Immobilization time, wks, median	7 (4–16)
Failure by finger injured	
IF	17
MF	34
RF	25
LF	40
Other fingers (IF+MF+RF)	29
All fingers (IF+MF+RF+LF)	32
Reason for failure	
>20° extension lag	52
Second course of orthosis fabrication	33
Surgery	15

(nonradiographic) measurement taken by the provider. In line with previous research, failure was defined by any of 3 criteria: a DIP extensor lag >20° after a minimum 4-week course of continuous immobilization, unplanned conversion to a surgical intervention, or the initiation of a second, unplanned course of orthosis fabrication after completion of the first period of orthosis fabrication.[18] Soft casts and thermoplastic orthoses were applied by physical therapists, while Stack, alumafoam, and other orthoses were applied by a variety of trained and certified providers. All patients were advised not to remove the orthosis during the treatment period.

Data analysis

Statistical significance was set a priori at a P value of <.05. For the risk factor analysis, categorical variables were reported as frequencies and continuous variables were reported as medians with ranges. Categorical data, including the primary outcome (failure) and finger injured (LF vs other finger), were evaluated with demographic and clinical categorical variables using chi-square tests. Continuous data were analyzed using independent 2-sample t tests or Mann-Whitney U tests, where appropriate. Logistic regression was performed to examine the association between the digit injured (LF vs other digit) and treatment failure, adjusted for confounding variables, resulting in an odds ratio.

Table 3
Associations Between Demographic and Clinical Variables and Treatment Failure of Mallet Injuries

Variable	Percent or Median (Range)	P Value
Age, y, median	54 (20–87)	<.001
BMI, kg/m^2, median	25.1 (17.3–38.2)	*
Male	28	*
Female	37	
Dominant hand injured	34	*
Injury type		
Bony	20	<.001
Tendinous	40	
Initial immobilization time, weeks		
<6	18	*
6–7	25	
7	43	
8	36	
>8	44	
Orthotic type		
Alumafoam	42	.009
Custom thermoplastic	26	
Soft cast	28	
Stack	57	
Unspecified	3	
Etiology		
Crush	33	*
Fall	35	
Jammed	36	
Sport	25	
Other	31	

BMI, body mass index.
* $P > .05$

Results

A total of 328 patients sustained a mallet finger injury and met our inclusion criteria. Table 1 shows the demographic data for all patients, including injuries by digit. All 328 patients were initially treated with extension orthosis fabrication. The median length of initial immobilization was 7 weeks (range, 4–16). Various orthoses were used in treatment, including soft cast (n = 201, 61%), custom thermoplastic (n = 72, 22%), Stack (n = 36, 11%), alumafoam (n = 13, 4%), and unspecified (n = 6, 2%) orthoses (Table 2).

Influence of injured digit on nonsurgical failure rate

Table 2 shows the results of orthotic treatment. The overall failure rate for orthotic management of mallet finger injuries among all digits was (n = 105, 32%. The most common reason for failure was a >20° extensor lag (n = 171, 52% of failures), followed by an additional course of orthosis fabrication (n = 108, 33%), then an unplanned surgical intervention (n = 49, 15%). There was no statistically significant difference in failure rates amongst digits. A trend suggesting higher failure rates in the LF (40% failure) was observed when compared to digits individually (IF, 17%; MF, 34%; RF, 25%; P = .08) and all other digits combined (IF+MF+RF: 29%; P = .06).

Other risk factors for nonsurgical failure

Demographic and clinical variables were analyzed to determine associations with the finger injured and treatment failure (Tables 3, 4). A higher age at injury was associated with failure. The median patient age with failure was 54 years, versus the median patient age

Table 4
Associations Between Demographic or Clinical Variables and LF Versus Other Finger Mallet Injuries *

Variable	Other Finger Percent or Median (Range)	LF Percent or Median (Range)	P Value
Age, y, median	50 (20−96)	49 (18−81)	*
BMI, kg/m^2, median	25.7 (17.3−42.3)	25.1 (17.0−36.3)	*
Male	56	58	*
Female	44	42	
Dominant hand injured	47	52	*
Injury type			
Bony	39	42	*
Tendinous	61	58	
Initial immobilization time, weeks			
<6	3	5	*
6−7	45	48	
7	7	4	
8	31	34	
>8	10	8	
Orthotic type			
Alumafoam	5	1	.04
Custom thermoplastic	19	31	
Soft cast	63	57	
Stack	11	11	
Unspecified	3	0	
Etiology			
Crush	8	12	*
Fall	13	14	
Jammed	40	38	
Sport	32	27	
Other	8	9	

BMI, body mass index.
* $P > .05$.

with nonfailure of 48 years ($P < .01$). Age was not associated with the specific injured digit ($P = .18$). The failure rate was higher in tendinous mallet injuries versus bony mallet injuries (n = 131, 40% vs n = 66, 20%, respectively; $P < .01$). The incidence of tendinous versus bony injuries was greatest in the MF (68%) but similar between all digits (IF, 43%; RF, 57%; LF, 58%).

The orthotic type was associated with failure rate (Table 3). Failure was highest in patients treated with Stack orthoses (57%; $P = .01$), followed by alumafoam (42%), soft cast (28%), custom thermoplastic (26%), and unspecified (3%) orthoses. Additionally, the orthotic type used varied between digits. Custom thermoplastic orthoses were used more often for the LF than for other digits (31% vs 19%, respectively), while soft cast material was used more for other digits than for LFs (63% vs 57%, respectively; $P = .04$). No other variables, including body mass index, gender, dominant hand injury, initial immobilization time, and etiology of injury, were associated with the failure rate or injury to a particular digit.

Multivariate analysis for failure

A multivariate analysis was performed using logistic regression to evaluate the independent risk of failure for the digit injured (LF), accounting for the age at injury and bony versus tendinous injury (Table 5). In this analysis, an LF injury was identified as an independent risk factor for failure when controlling for age ($P = .03$) and age plus bony injury ($P = .02$).

Discussion

Researchers have hypothesized that Stack and dorsal padded alumafoam orthotic management techniques will result in the highest failure rates.[10] The hypothesis was supported by data collected in this research. We identified the age at injury as an independent risk factor for failure. Age has previously been reported as a risk factor for both failure and residual extensor lag.[9,10,17,19] For example, Abouna and Brown[17] reported a 0% cure rate in patients over the age of 61, compared to a 59% cure rate in patients aged 41−60. They defined a cure as an extension deficit <5°, with no stiffness and normal flexion and extension. Currently, the age at injury is not typically accounted for in treatment outcomes (ie, extension lag). Given the lower potential for healing in older patients, it is possible that we must consider age-dependent measures that could account for differences in healing potential. Furthermore, clinicians may choose to treat patients differently based on the age at presentation or to better counsel patients on expected outcomes.

We report tendinous injuries as a risk factor for failure. Orthosis management is usually suggested for both bony and tendinous mallet injuries.[6] Abouna and Brown[17] and Crawford et al[16] both found bony injuries to have worse outcomes in their studies. In contrast, Warren et al[15] found tendinous injuries to have worse outcomes. Several other studies found no differences in outcome between bony and tendinous injuries.[9,10,19] Here, we report an increased risk of failure for tendinous mallet injuries. It is possible that bony healing is more reliable than tendinous healing, providing better outcomes. It is also possible that patients self-protect a bony injury more because of pain or because of the perception of fracture as a more severe injury. The relationship between tendinous versus bony injuries and failure remains unclear, given the highly variable literature.

We report higher failure rates when using Stack orthoses compared to other orthotic types. However, there was a significant difference in the orthotic type used by digit. Little finger injuries were more likely to be treated with custom thermoplastic orthoses when compared to other fingers. Given the discrepancy of use by digit, the orthotic type was not considered to be statistically significant as it related to our primary measure of failure rates in the different digits. The orthotic type for mallet finger treatment has been thoroughly studied.[3,9−13,15,16,20] Several randomized controlled trials have reported variable

Table 5
Analysis of Maximum Likelihood and Odds Ratio Estimates for LF Injury, Age, and Bony Injury

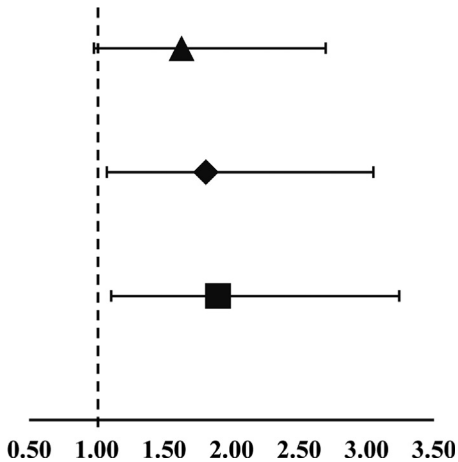
Parameter	Mean Confidence Interval	Odds Ratio (95% Confidence Interval)	*P* Value
LF only		1.62 (0.98–2.70)	.06
LF + Age		1.82 (1.08–3.05)	.03
LF + Age + Bony		1.90 (1.11–3.24)	.02

Table 6
Crawford Evaluation and Abouna and Brown Criteria for Mallet Finger Failure

Crawford Evaluation		Abouna-Brown	
Grade	Characteristics at DIP Joint	Group	Characteristics
Excellent	Full extension Full flexion No pain	Cured	<5° extension defect No stiffness Normal flexion and extension
Good	0° to 10° extension deficit Full flexion No pain	Improved	5° to 15° extension defect No stiffness Normal flexion
Fair	10° to 25° extension deficient Any flexion loss No pain	Unchanged	>15° extension defect Stiffness or impairment of Flexion
Poor	>25° extension deficient Persistent pain		

findings. Pike et al[9] found no extension lag difference when comparing dorsal or volar padded aluminum versus custom thermoplastic orthoses. However, they did report a trend suggesting improved lag with custom thermoplastic orthoses. O'Brien et al[10] reported higher failure rates in both Stack and dorsal aluminum orthoses when compared to custom thermoplastic orthoses. In contrast, Tocco et al[11] demonstrated greater extension lag in patients treated with custom thermoplastic compared to quick cast orthoses. Most recently, a study on outcomes in the pediatric population reported no statistical differences in outcomes for patients treated with Stack, aluminum, and custom thermoplastic orthoses.[20] The significance of the orthotic type remains unclear, given the variable literature, even with prospective randomized trials.

We report an overall failure rate of 32% for conservative management of mallet finger injuries. This failure rate was consistent with prior literature, which reported rates ranging from 5% to 50%, depending on the definition of failure.[8,13–15,21,22] Our definition of failure was intentionally strict to more closely approximate actual clinical experience, which can be subjective. For instance, 33% of failures in our study were due to a second, unplanned course of orthosis fabrication, which is ultimately driven by the patient's and providers' perceptions of persistent extensor lag. Unfortunately, there is currently no standardization for assessing clinical outcomes of mallet finger injuries. The Crawford Evaluation Criteria and Abouna-Brown criteria (Table 6) are frequently cited, and variations of these criteria are common in the literature.[10,11,13,16,17,19,23,24] It is still possible, however, that subtle suboptimal outcomes were not captured by our study design. For example, patient dissatisfaction is often used as a criterion for failure. We identified 20 patients who returned to the clinic without an extension lag >20° and reported dissatisfaction but chose not to proceed with additional treatment. Therefore, we did not include these as failures by this criterion alone. It is also possible that dissatisfied patients sought treatment elsewhere, limiting our data.

Study limitations

We performed a power analysis prior to data collection. Using a failure rate that was consistent with the literature and observed in our own institution, we estimated our study population was large enough to provide statistical significance. However, our failure rate in non-LF digits was much higher, and our post hoc power calculation was only 48%. Due to the retrospective nature of this study, we were unable to include enough patients to show a statistically significant difference in failure rates. A subsequent sample size calculation based on our observed values indicated that 292 subjects per group would be required to demonstrate higher rates of failure in the LF. A follow-up or prospective study may be able to address this. Given the broad nature of our original database search, many patients originally identified did not meet our inclusion criteria, limiting the study numbers. Our inclusion criteria for the study were established in order to eliminate potential unaccountable variability in outcomes. We choose to exclude patients under the age of 18 due to skeletal immaturity. Recently, Lin et al[20] evaluated outcomes of mallet finger in the pediatric population. While they did note that many of their patients were adolescent (mean age, 13.7), they concluded there were similar outcomes with nonsurgical treatment in adolescents and the adult population. Additionally, in our study patients were excluded if they presented for an initial visit more than 2 weeks after their injury. However, some previous studies have suggested that delayed nonsurgical management may be similar to acute management.[8,25] Given that 337 patients in our study were excluded due to either a young age or delayed treatment, it is possible that we could strengthen our data by expanding our inclusion criteria to include a fraction of these patients. Additionally, recording the specific days from injury to presentation may have allowed for a more detailed statistical analysis to take place, thus examining the potential relationship between the 2 variables. This study only collected the time to presentation as a measure for inclusion criteria, in line with previous research involving mallet finger injuries and findings that delayed treatment likely improve outcomes, but future research into this variable and its influence on healing is recommended.[26,27] Finally, it is recommended that future research examine the influence of the length of immobilization time on failure rates, as well as the influences of patient satisfaction, initial DIP lag, and bony lesion types, with a larger sample to benefit the literature and future treatment recommendations. By examining additional variables, future studies may be able to better inform practitioners for patient success.

In summary, our data show no significant difference in failure rates between the digit injured, although a trend suggests higher failure rates in the LF. A larger study population is needed to increase the statistical significance of our findings.

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