

ORIGINAL RESEARCH

Non-Surgical Management of Boney Mallet Fractures: A Single-Centre Study of Outcomes in 141 Patients

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Mallet fractures are traditionally treated surgically when greater than one third of the articular surface is involved. We aimed to investigate outcomes in a cohort of 141 patients with Doyle Type IV closed mallet injuries, treated with conservative splint therapy. Pearson chi-squared test was used to investigate the significance of subluxation and articular surface greater than one third. Articular surface was also investigated as a continuous variable using Spearman-rank correlation. Sixty-five patients had involvement of less than one third of the articular surface, and 75 had involvement of one third to two thirds. Subluxation was present in 53. Crawford outcomes were excellent in 54% of patients, good in 37%, and fair in 9%. Percentage of articular surface involvement and presence of subluxation were both independent of outcomes. Our findings support non-surgical treatment of closed mallet injuries in the presence of up to two thirds of articular surface involvement.

Keywords: Mallet fractures; subluxation; articular surface; conservative; non-surgical; outcome

Introduction

The aim of treating mallet injuries is to establish a stable, congruent joint and minimize extension lag. In cases of Doyle Type I, conservative management with extension splinting is well accepted amongst hand surgeons [5, 11]. (Table 1) Similarly management of Type II and III injuries with exploration and suture repair is also agreed. However the management of Doyle type IV mallet injuries, specifically those with large boney fragments, remains debated. Such type IV injuries can be sub-classified according to Wehbe and Schneider based on the degree of articular surface involvement, and the presence or absence of distal phalanx subluxation [33] (Table 2).

Fracture involvement of greater than one third of the articular surface has been considered an indication for surgical repair. Authors cite the risk of permanent

Table 2: Wehbe and Schneider classification of Mallet Fracture Injuries.

	Definition
Type	
I	No DIP joint subluxation
II	DIP joint subluxation
III	Epiphyseal and physeal injuries
Subtype	
A	<1/3 Articular surface
B	1/3–2/3 Articular surface
C	>2/3 Articular surface

Table 1: Doyle classification of Mallet Fracture Injuries.

	Definition
Type	
I	Closed injury +/- small dorsal avulsion fracture
II	Open laceration
III	Open abrasion involving skin loss and tendon substance
IV	Mallet Fracture – A: Distal phalanx physeal injury (paediatrics) B: Fragment involving 20–50% of articular surface C: Fragment involving >50% articular surface.

deformity, stiffness, and secondary arthritis when these injuries are treated conservatively [7, 8, 21, 29]. However the evidence to support this theory is limited. The assumption is rather based on the historic anecdote that involvement of greater than one third of the articular surface results in distal phalanx subluxation, and that these fractures would be unsuitable for conservative management. More recent cadaveric biomechanical, and clinical studies, have revealed subluxation to only occur consistently when greater than 52%, and 48%, respectively, of the articular surface is involved [15, 18]. Whilst excellent outcomes following operative management of boney mallet injuries have been reported by authors, the reported complications cannot be overlooked. Previous literature has referenced rates ranging from 0–52% [4, 20, 31]. Post-operative complications not only have implications for patients in terms of inconvenience and delays in return to work, but also have cost implications for service providers.

Conservative management of boney mallet injuries was first publicized by Wehbe and Schneider in a study of 21

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patients in 1984 [33]. They concluded that all mallet injuries could be treated conservatively, regardless of the size of fracture fragment, or presence of subluxation. Despite this early evidence, only a handful of authors adopted such practice, likely related to Wehbé and Schneider's small sample size [28, 32]. In more recent years however, further studies demonstrating acceptable conservative outcomes have appeared [17, 22, 24, 25].

Despite this emerging evidence, the limitations of such studies support discord amongst surgeons. Indeed a meta-analysis concluded insufficient evidence to determine when conservative treatment is indicated [13]. Limitations have included sample size, and heterogeneous cohort definitions. For example, several studies have grouped boney mallet injuries alongside those mallet injuries without fractures [21, 22]. The biomechanical sequela of type IV mallet injuries differs greatly from non-boney mallet injuries and as such the outcomes are not directly comparable. Other authors have reported solely on fractures involving greater than one third of the articular surface [17, 34]. Lastly many studies are retrospective reviews, whereby patients received either conservative or surgical treatment based on surgeon preference [20, 30, 34]. To truly assess the impact of articular surface involvement, or subluxation, a consecutive cohort free from selection bias is required.

In this study we report on the outcomes of a consecutive single-center cohort of patients with Doyle Type IV boney mallet injuries treated with conservative splint therapy. We also investigated whether outcomes are affected by percentage of articular surface involvement, or presence of DIPJ subluxation.

Methods

Cohort

Between 2010 and 2014, a total of 164 consecutive adult patients presented with single digit closed Doyle Type IV mallet fractures. Out of these 164 patients, 23 were excluded from our study due to either an irreducible fracture at time of manipulation ($n = 9$) or as the patient was lost to short-term follow-up ($n = 14$). Patient history was documented and clinical examination performed. In all patients the percentage of pre-treatment extensor lag was recorded through goniometer measurements.

Injury classification

Pre-treatment posteroanterior and lateral radiographs were uploaded to the digital Picture Archiving and Communication System (PACS) and reviewed by 2 authors (M.M, G.O). Fracture fragment size was calculated as a percentage of the total length of the articular base in the lateral view using curved line measurements. Subluxation was defined when palmar displacement of greater than 7% of the articular surface diameter was present according to Hussain et al (Hussain et al., 2008). Injuries were then categorized according to the Wehbé and Schneider Classification Scheme [33].

Treatment protocol

All patients were treated conservatively as per departmental protocol. The protocol involved reduction

of the fracture fragment with axial pull, hyperextension and dorsal pressure over the fracture fragment, and the fabrication and application of a custom-made waterproof palmar thermoplastic extension splint (Aquaplast, Patterson Medical Ltd, Nottinghamshire, UK.). Patients were offered local anesthetic during this process. The splint was fabricated to maintain neutral to 10° of DIP joint hyperextension, and secured to the digit by 2 self-fastening nylon straps. Radiographs (PA and lateral) were repeated after splint application to ensure a good position of the fracture. Continuous splinting was mandated for 6 weeks followed by a 3 week course of night-time only splinting. If persistent extensor lag existed after 6 weeks of continuous splinting, continuous splinting was maintained for a further 2 weeks prior to the night-time only regime. Patients were followed up by specialist hand therapists weekly for the first two weeks of splinting, and fortnightly thereafter. Hand therapists assessed skin condition, ROM of the unaffected joints, ability to self-manage, and potential complications. At each appointment splint fit was also checked. If splints were worn or loose, a new splint was fabricated. Patients were instructed to not remove their waterproof splints at home: splints were only removed at appointments by the hand therapists. Compliance checks were undertaken at the beginning and end of each appointment, and patients educated on the potential adverse outcomes of non-compliance. Radiographs were repeated at 1, 2 and 6 week follow-up appointments.

Outcome assessment

All patients returned specifically for the purpose of this study at a mean of 4 months after injury. Assessment included; DIP joint extension, active finger motion, presence of pain, and radiographic assessment of bone. Case notes were also reviewed for any record of complications. DIP joint extension and active finger motion measurements were calculated with a goniometer, and documented on proformas. After then incorporating pain outcomes, each patient was assigned an outcome from excellent to poor using the criteria published by Crawford [9]. (Table 3) Post-treatment PA and lateral radiographs were reviewed by the same 2 authors (M.M, G.O), and assessed for fracture union. Eighteen months after the study completion date, patients were invited again for clinical review and repeat assessment.

Statistical analysis

The Mann Whitney test was used to test the independence of continuous variables that did not follow a normal distribution. A nonparametric Chi squared test was used to test

Table 3: Crawford Outcome Criteria (Crawford, 1984).

Crawford Outcome	DIPJ Extension Loss (degrees)	DIPJ Flexion	Pain
Excellent	0	Full	None
Good	1–10	Full	None
Fair	11–25	Any loss	None
Poor	>25	Any loss	Residual Pain

the independence of categorical variables (e.g. subluxation, articular surface less than one third versus greater than one third.). Spearman's rank correlation was used to evaluate the correlation of ordinal categorical variables (e.g. articular surface, age). A p-value of less than 0.05 was considered significant.

Results

Of the 141 patients included in our study, 89 were male (63%) and 52 female. Average age at time of injury was 35 years (range, 18–81 years). Mean time from injury to presentation was 8.7 days (range 0–90). The ring finger was the most frequent involved digit (45%), whereas the thumb was not involved in any case of injury. The dominant hand was affected in 53% of patients. The commonest (77%) mechanism of injury was a direct forceful axial blow to the tip of the finger. The majority of the injuries (81%) were sustained outside work, with sporting activities attributing for 52%.

Following radiographic assessment, average fracture fragment size measured 36.5% (range 20–80%, S.D. 16.48). Sixty-five (46%) patients had involvement of less than one third of the joint surface, 75 (53%) had involvement of one third to two thirds of the joint surface (**Figure 1**), and 1 patient sustained an injury that involved greater than two thirds of the articular surface. Subluxation of the DIP joint was present in 53 cases (38%) (**Figure 2**), with the palmar displacement averaging 30% (range 8%–52%). In our cohort, the majority of cases were type IA (46%) according to Wehbe and Schneider's classification. The second most common injury was type IIB (37%) (**Table 4**).

Early Complications

At 6 week follow-up 3 patients were noted to have lost satisfactory boney fragment contact. All three patients had a fracture fragment involving one third to two thirds of the articular surface and subluxation. These patients were converted to surgery with a standard Ischiguro technique and removed from our 4-month and long-term clinical outcome analysis. Mild swan-neck posturing with active finger motion was detected in 11 patients at 6 weeks follow-up, which was treated with 4 weeks of further full time splinting.



Figure 1: Pre-treatment XRAY of Patient A with mallet injury involving one third to two thirds of articular surface without subluxation (Wehbe and Schneider Type IB).

Clinical Outcome at 4 months

The mean post-treatment extension lag across all patients was 3.5 degrees (range 0–30). Twelve patients (9.2%) reported greater than 10 degrees of residual extension lag following their treatment completion, with one patient's residual extension lag greater than 25 degrees. Active distal interphalangeal joint flexion averaged 70 degrees (range 42–90). Two patients had greater than 10 degrees of flexion loss at the DIP joint comparative to their contralateral finger DIPJ range. No patient had persistent pain. According to Crawford's criteria, the outcome of 74 patients (54%) was excellent; of 51 patients (37%) good; of 12 patients (9%) fair, and in 1 patient poor.

Complications at 4 months

At 4 month follow-up there were no cases of skin abnormality or nail-plate deformity. The early swan neck posturing detected in those 11 patients at 6-week follow-up had resolved. Radiographic union was achieved in 137 of the remaining 138 patients (**Figures 3 and 4**), with only one case of nonunion. There were two cases of hypertrophic ossification and boney prominence. The patient with non-union had a mallet fracture involving 52% of the AS, without subluxation, and scored the poor Crawford outcome. This patient was subsequently managed with operative fusion of the DIPJ and excluded from our cohort for long-term assessment.

At 4-month follow-up our total cumulative complication rate was 12% (17 cases). Of these, a total of 4 patients required operative intervention (3%).

Statistical Analysis at 4 months

We found no significant difference between Crawford outcomes in those patients with injuries involving less

Table 4: Distribution of Mallet Fracture Injuries in our cohort according to the Wehbe and Schneider classification.

	Subtype A (<1/3 AS)	Subtype B (1/3–2/3 AS)	Subtype C (>2/3 AS)	Total
Type I	65	23	0	88
Type II	0	52	1	53
Total	65	75	1	141

AS: Articular surface.



Figure 2: Pre-treatment XRAY of Patient B with mallet injury involving one third to two thirds of articular surface with subluxation (Wehbe and Schneider Type IIB).

than one third of the articular surface, and those with injuries involving greater than one third of the articular surface, Pearson's Chi Square test $p = 0.30$. Correlating articular surface involvement as a continuous variable against Crawford outcomes, we also found no significant association, Spearman correlation $p = 0.36$. Further, presence of subluxation was independent of Crawford outcomes, Pearson's Chi Square test $p = 0.17$. Specifically in those patients with greater than one third of articular surface involvement, or subluxed injuries, excellent or good outcomes were achieved in 86%, and 84%, respectively. (Tables 5 and 6) Residual extension lag however was influenced by age at time of injury, Spearman's $\rho = 0.259$, $p = 0.002$.

Clinical Outcome at long-term follow-up

A total of 89 out of 137 patients (65%) responded to long-term assessment recall. Thirty-one patients were uncontactable, and 17 did not wish to or were unable to attend for assessment. Median long-term follow-up was

36 months (range 18–63 months) Fifty patients had initial injuries involving greater than one third of the articular surface, and 36 had subluxation. The proportional differences of patients with greater than one third joint surface involvement or subluxation who responded to long-term follow-up comparative to the original cohort were non-significant, $p = 0.628$, and $p = 0.522$, respectively. The mean post post-treatment extension lag across all patients was 2.0 degrees (range 0–13). Thirty patients had minor (1–10 degrees) of extension loss (range 2–4 degrees), and eight patients were assessed to have greater than 10 degrees of residual extension lag (range 11–13 degrees). Among those assessed; active distal interphalangeal joint flexion averaged 72 degrees (range 53–90), with two patients having <10 degrees of flexion loss. Two patients had persistent pain, described further in both as cold intolerance. According to Crawford's criteria, the long-term outcome of 48 patients (54%) was excellent; of 29 patients (33%) good; of 10 patients (11%) fair, and in 2 patients (2%) poor.

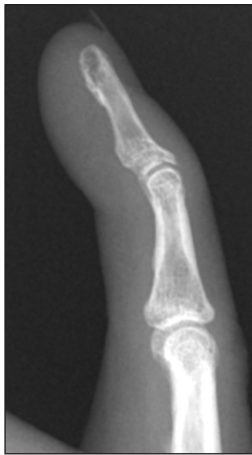


Figure 3: Radiographic union in Patient A following conservative treatment.



Figure 4: Radiographic union in Patient B following conservative treatment.

Table 5: Proportion of Crawford outcomes in patients with less than, and greater than, one third of articular surface fracture involvement.

Crawford Outcome	All patients, n = 138 % (n)	Less than 1/3 articular surface involvement, n = 65	Greater than 1/3 articular surface involvement, n = 73
Excellent	54% (74)	58%	49%
Good	37% (51)	37%	37%
Fair	9% (12)	5%	12%
Poor	0.7% (1)	0%	1.4%

Table 6: Proportion of Crawford outcomes in patients without subluxation, and patients with subluxation at time of injury.

Crawford Outcome	All patients % (n138)	No subluxation (n = 88)	Subluxation (n = 50)
Excellent	54% (74)	58%	46%
Good	37% (51)	36%	38%
Fair	9% (12)	5%	16%
Poor	0.7% (1)	1.1%	0%

Discussion

We evaluated outcomes in the largest study to date of 141 closed boney mallet injuries treated with conservative splint therapy, and demonstrated that percentage of articular surface involvement and presence of subluxation, are not predictive of outcome. According to Crawford criteria, 54% of patients in our cohort had an excellent outcome, 37% had a good outcome, and 9% had a fair outcome. At long term follow-up of 89 patients, excellent or good outcomes were achieved in 87%. Among the potential risk factors, age at time of injury was significantly associated with the degree of residual extensor lag. We found no association between outcomes and initial fracture fragment size or presence of subluxation.

This study on outcomes after conservative splint therapy in boney mallet injuries has several strengths. First, it used a large single-center consecutive cohort, which improved statistical reliability and reduced the risk of selection bias. Second, our cohort included Doyle Type IV boney mallet injuries of all fracture sizes, allowing the association of fracture size with outcome to be put in context. Third, we excluded non-boney mallet injuries from our study thus maintaining a homogeneous group of patients, aiding comparability of the investigated variables. Finally, all patients were treated with standardized conservative therapy, regardless of the percentage of articular surface involvement or presence of subluxation.

The study has limitations. Whilst all patients were followed up at a mean of 4 months, a third of patients were lost to longer-term follow-up. It may be that there was an element of participation bias. It should be noted however that similar proportions of excellent, good, and fair outcomes were reported at short and long term follow-up. Further similar proportions of patients with larger fracture fragments and subluxation as our initial cohort responded to long-term follow-up. Our minimum long-term follow-up was 18 months. Previous authors have advocated surgery in boney mallet injuries to avoid the development of premature osteoarthritis and any subsequent impact on clinical function [3, 16]. Extended follow-up with a minimum of 5 years would have allowed us to test this theory. However osteoarthritis has been shown to develop equally in boney mallet injuries treated conservatively, and in injuries treated with surgery. It has also been shown that presence of osteoarthritis holds no correlation with clinical outcomes, patient satisfaction, or activities of daily living at long term follow-up [22]. Another limitation was that our study did not include a comparative group of patients treated surgically. To provide a reliable comparison prospective randomization would have been required. Whilst we agree a blinded randomized control trial with sufficient power would provide more robust results, this was outside the scope and aims of our study. Such trials are challenging in the surgical setting owing to ethical implications, cost, and cohort sizes. Indeed, to date no large multicenter trial of boney mallet treatment has been undertaken [13]. Lastly, we only had one patient in our cohort with greater than two thirds of articular surface involvement. Whilst we have adequately shown no difference in outcomes between cases with less than one

third, and those with one third to two thirds of articular surface involvement, we would advise caution when applying our conclusions to patients with larger fractures. Further studies with subgroups of these larger fractures are required to truly assess their outcomes following conservative therapy.

Previous authors examining outcomes after conservative treatment of boney mallet injuries have reported similar results in smaller cohorts [22, 34]. Kalainov et al reported high patient satisfaction and finger function at 2 year follow-up in a study of 22 patients with injuries involving greater than one third of the articular surface. Further, they found no difference in outcomes between those patients with, and those patients without, subluxation [17]. Wehbe and Schneider concluded boney mallet injuries could be treated conservatively regardless of the size of fracture fragment or presence of subluxation. Their study included 21 patients with boney mallet injuries, of whom 15 were managed conservatively [33]. Further, a prospective randomised trial of 41 patients compared splint therapy to wire pinning, found comparable outcomes between the two groups [1].

Despite these previous studies supporting conservative management, many authors still advocate surgery when fractures are subluxed, or involve greater than one-third of the articular surface [2, 6, 7, 10]. However examining these surgical studies, similar clinical outcomes are seen. In our cohort mean residual extension lag was 3.5 degrees (range 0–30) at 4 months and 2.0 degrees (0–13) at long-term follow-up. Following surgical treatment, authors have reported DIPJ extension deficits to range from –1 to 30 degrees [19, 31]. Further, we found a 12% complication rate. Pegoli et al. treated 65 boney mallet injuries using Ischiguro pinning technique and reported excellent or good outcomes in 78% of patients and a 4.6% complication rate [23]. Hofmeister et al also treated boney mallet injuries with extension block pinning [14]. Whilst they found similar Crawford outcomes to our study, they had a 21% complication incidence. Impressively, Zhang et al. treated 64 boney mallet injuries using a pull-out wire technique and demonstrated excellent or good outcomes in 94%, and no complications [35]. It should however be considered that this technique is indeed more challenging. Complication rates after tension band wiring have been reported as high as 47%, after k-wire fixation 52%, and after pull-out wire techniques 38% [4, 20, 26].

Further considering complication rates, important disparity is noted in those studies directly comparing surgically and non-surgically treated cohorts. Stern and Kastrup, reported a 53% complication rate following surgical procedures and a 45% rate in the splinting group [30]. Whilst the complication rate in their conservative group is significantly higher than the 12% we found, the majority of complications reported were self-limited superficial wounds, which could have been minimized with adequate splint selection. Auchincloss did demonstrate a higher rate of complications in patients treated conservatively comparative to those patients who had surgery, 14% versus 11%, respectively [1]. Yet the complications reported

in the conservative group were restricted to superficial skin irritation, whereas the complications in the surgical group were related to pin site infections, deep infections, joint incongruity and nail deformities. Overall, comparative to conservatively managed boney mallet injuries, complications after surgery are not only more severe, but rates are higher. We found in our study of 141 patients, that four patient required operative conversion (3%). Previous literature on conservative management has not reported on this important outcome at either short and long-term followup [27]. We believe that in future studies operative conversion should be a key criteria and disclosure of it would help further build on the current limited evidence base.

Many clinicians have accepted that fracture involvement of greater than one third of the articular surface requires surgical fixation owing to the risk of subluxation and potential adverse outcome, despite a lack of evidence to justify this arbitrary percentage. In recent years the risk of subluxation relative to articular surface involvement has been quantified in both biomechanical and clinical studies, as 52% and 48%, respectively [15, 18]. In our study we have further challenged this mantra of management by correlating clinical outcomes with articular surface involvement, and presence of subluxation in a large cohort of non-surgically managed boney mallet injuries. We have shown that percentage of articular surface involvement and presence of subluxation, are not associated with clinical outcomes. Specifically comparing outcomes in those patient with less than one third, and those patients with greater than one third, no significant difference was observed. Further as demonstrated in **Figure 4**, despite a small degree of residual subluxation, satisfactory outcomes were still achieved. Our clinical outcomes following conservative treatment are comparable to those reported in the literature following surgical fixation, and the complication rates lower. We would argue that articular surface involvement of one-third to two thirds, or presence of subluxation, should not be considered as indications for surgical treatment. Like Smit et al., we would recommend that surgical intervention be reserved for only those cases where a trial of splinting has failed, or in those cases with irreducible fracture fragments where boney contact cannot be achieved [27].

Conservative management relies on patients engaging with treatment and strict compliance. Poor compliance of patients treated non-surgically remains one of the treatment's most significant disadvantages. Compliance rates recorded in previous conservative studies have ranged from 59–70%, and as expected better compliance has been proven to equate to better outcomes [12, 24]. The fact excellent or good outcomes were achieved in 91% of patients at short-term, and 87% at long-term follow-up in our cohort is likely related to the 100% compliance rate with protocol and support our unit receives from hand therapy services. We hypothesis that our emphasis on patient education, and judicious attention to splint fit are the key elements attributed to the compliance rates we have achieved.

Conclusion

Our findings support non-surgical treatment of closed bony mallet injuries in the presence of up to two thirds of articular surface involvement regardless of subluxation. Strict adherence to protocol is necessary in conservative management, and support from hand therapy services crucial. Surgical treatment should be reserved for cases where non-surgical treatment has failed to achieve a satisfactory outcome, or when fractures are irreducible. Age could be considered a prognostic factor in terms of clinical outcome and resultant DIPJ extensor lag, and this should be acknowledged when opting for non-surgical treatment.

Ethics and Consent

Local Research and Ethics approval was granted before initiating the study. Registration number: 4437.

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Competing Interests

The authors have no competing interests to declare.

Author Contributions

MM, JM, GO, and JA were all responsible for the conception of the study, interpretation of data, drafting the manuscript, and final manuscript review. MM and JM were responsible for data collection and analysis.

Guarantor

Jamil Ahmed is the guarantor.

Peer Review

This is a non-commissioned paper that has undergone external peer review according to journal policy.

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