Outcomes Following Operative Treatment of Adolescent Mallet Fractures

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Abstract *Background:* Many surgeons advocate for surgical intervention of adult mallet fractures that involve either subluxation of the distal interphalangeal (DIP) joint or those that involve more than one-third of the articular surface. However, the efficacy of operative treatment and complication rates are unclear regarding the adolescent population. *Questions/Purposes:* The goal of this study is to evaluate the clinical outcomes following operative fixation of bony mallet fractures in the adolescent population. *Methods:* Seventeen patients with bony mallet fractures treated surgically were retrospectively reviewed. Twelve patients were treated by closed reduction with extension block pinning. The other patients underwent an open reduction and pin fixation. The average age was 15.2 years (13–18). Most injuries were sport related. The average time from injury to presentation was 17 days and from injury to surgery was 24.5 days. Nine patients had subluxation at the DIP joint and all involved at least one-third of the articular surface. *Results:* The average time from surgery to pin removal was 28 days (19–46). All distal phalanx physis were closed or nearly closed. One patient reported pain at the final follow-up. Two patients (11.8%) had major complications. One had an extension contracture postoperatively, did not attend therapy, and re-fractured 5 months later requiring reoperation. The second was treated delayed (32 days) and lost fixation, requiring

revision surgery and antibiotics for a superficial infection. Two patients with delayed treatment (32 and 44 days) had an extensor lag (11.8%). *Conclusions:* Operative treatment of mallet fractures with subluxation or involving more than one-third of the articular surface appears effective. Pin removal 4 weeks postoperatively appears adequate. Complications occurred with delayed presentation and non-compliance.

Keywords mallet fracture · extension block pinning · adolescent fractures

Introduction

A bony mallet injury occurs after an axial load that leads to a disruption of the extensor mechanism via a distal phalanx base fracture at the distal interphalangeal (DIP) joint. In adults, non-surgical management with splint immobilization is generally considered the standard of care for mallet fractures involving less than one-third of the articular surface [1, 2, 9]. Management of mallet fractures involving more than one-third of the articular surface or with associated DIP joint subluxation remains controversial, as earlier literature suggested that all mallet fractures could be treated non-operatively [16]. However, a growing body of literature supports operative treatment for larger fractures to help prevent osteoarthritis, swan-neck deformity, and persistent stiffness [11].

Mallet fractures in the pediatric population represent a unique group and should be considered separately for a number of reasons. First, the distal phalanx growth plate is either still open or gradually closing approximately around 13–16 years of age [4, 6]. Additionally, patient compliance with splinting in this population is much more unpredictable and difficult, which may favor more aggressive treatment. A recent meta-analysis demonstrated the importance of strict adherence to a splint protocol [5]. Although a few children

Level of Evidence: Level IV: Case series.

Work performed at Rainbow Babies and Children's Hospital.

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Table 1 Summary of patient demographics and injury details

Patient demographics and injury details	
Male	13 (76%)
Age	15 (13–18)
Right hand	12 (71%)
Injured finger	
Index	1 (6%)
Middle	7 (41%)
Ring	6 (35%)
Small	3 (18%)
Injury mechanism	
Football	10 (59%)
Basketball	3 (18%)
Volleyball	1 (6%)
Baseball	1 (6%)
Trampoline	1 (6%)
Fall from scooter	1 (6%)

and adolescents have been included in existing studies, it is difficult to draw specific recommendations without a pediatric-specific study.

Our center has been treating the majority of acute larger and unstable mallet fractures with the extension block technique first described by Ishiguro [8]. This has been shown in adult studies to be effective as well as minimally invasive [7, 12]. The goal of this study is to (1) evaluate the efficacy and (2) assess the complication rates following operative fixation of bony mallet fractures in the pediatric population.

Patients and Methods

After approval by the institutional review board, we performed a retrospective review of pediatric patients who underwent operative fixation of a bony mallet fracture from March 2009 to April 2015 at a single academic institution. All patients with a Current Procedural Terminology (CPT) code of 26756 for percutaneous skeletal fixation of distal phalangeal fracture or 26765 for open treatment were identified. Inclusion criteria consisted of a closed injury as well as a bony mallet fracture defined as an intra-articular fracture at the dorsal base of the distal phalanx. Injuries of the thumb and open fractures were excluded from this study.

We identified 17 bony mallet fractures in 4 females and 13 males with an average age of 15.2 years (13–18). Eleven of the injuries (65%) involved the right hand, with the majority (13 patients, 76%) occurring in the middle and ring fingers. All injuries occurred during sports except for one

patient who fell off of a scooter, with over half occurring with football (10 patients, 59%). A summary of this data is displayed in Table 1.

The mean time from injury to presentation to orthopedic clinic was 17 days (1–52). Eight patients (47.1%) presented in delayed fashion to clinic, which was considered greater than 10 days from the initial injury. An initial attempt at conservative treatment was attempted in four patients using a stax finger splint. The average time from injury to surgical fixation was 24.5 days (6–56).

Initial radiographs were examined and confirmed the mallet fracture. The Wehbe and Schneider classification was used initially to classify the fractures [16]. Types I–III specify subluxation or physis involvement, while types A–C specify the percentage of the articular surface involved. Type I fractures do not have evidence of any subluxation at the distal interphalangeal (DIP) joint. Type II fractures are associated with subluxation at the DIP joint. Type III fractures involve the physis of the distal phalanx. Each type is then divided into three subtypes. Subtype A involves less than one-third of the distal phalanx articular surface. Subtype B involves one-third to two-thirds of the joint surface. Subtype C involves greater than two-thirds of the articular surface. Nine (53%) of the patients were noted to have subluxation at their DIP joint. The classification of the studied injuries is displayed in Table 2.

Twelve of the patients (71%) were treated with closed reduction and extension block pinning (Fig. 1a–c). Two patients required open reduction followed by extension block pinning. These two patients presented in delayed fashion and did not have surgical fixation until 25 and 32 days after their injuries. Three additional patients underwent open reduction with intrafocal pinning. Overall, the average time from surgery to pin removal was 28 days (range, 19–46). The average follow-up time was 106 days (range, 22–461). Major complications including skin necrosis, nail deformity, infections, loss of fixation, and re-fracture were identified post-operatively. Extensor lag was considered a minor complication.

Extension block pinning was performed using the technique first described by Ishiguro et al. (Fig. 2a–d) [8]. Briefly, the distal and proximal interphalangeal joints are held in maximum flexion. Using fluoroscopy, a k-wire is placed through the terminal extensor tendon into the middle phalanx just proximal to the fracture. This blocks the movement of the mallet fragment and allows the distal phalanx to reduce to the fragment when the finger is extended. A second wire is then used to immobilize the DIP joint palmar

Table 2 Wehbe and Schneider classification of injuries

Wehbe and Schneider classification				
	A	B	C	Total
I	0 (0%)	6 (35.3%)	0 (0%)	6 (35.3%)
II	0 (0%)	8 (47.1%)	0 (0%)	8 (47.1%)
III	0 (0%)	2 (11.8%)	1 (5.9%)	3 (17.6%)
Total	0 (0%)	16 (94.1%)	1 (5.9%)

Fig. 1. **a** Injury film of a 13-year-old patient following volleyball injury. **b** Operative films with extension block pinning 9 days after injury. Note that in cases where there is concern of compliance or concern of the purchase of the pin crossing the DIP joint, then this pin can be advanced across the PIP joint. **c** Follow-up radiographs at 2-month post-operative visit.

to the fracture site. An intrafocal pinning technique involved one or two k-wires for fixation directly perpendicular to the fracture site and was used if inadequate stability was suspected, generally only in revision cases. Immobilization was performed with a splint and pins were removed in clinic once there was radiological evidence of healing on post-operative radiographs. Passive and active exercises were then initiated.

Results

Only one patient reported pain at their follow-up. Twelve patients were noted to have full extension on physical exam. Three additional patients did not have specific mention of their clinical extension, but were noted to have full extension without assistance on post-operative radiographs. The remaining two patients were noted to have a minor complication of an extensor lag of 10 and 20° at their last follow-up. One underwent conservative treatment initially with a stax splint and due to lack of healing, subsequently underwent open reduction and intrafocal pinning 44 days after injury. The patient was pain-free,

but did have a 20-degree extensor lag at his last follow-up visit. The second patient with extensor lag presented delayed to clinic and underwent open reduction with extension block pinning 1 month following the injury. One week later, it was noted that the fracture lost fixation and revision surgery was performed. Pins were in place for a total of 34 days, with a superficial infection treated with pin removal and oral antibiotics. Ultimately, the patient went to occupational therapy for stiffness and at 3-month follow-up, although he was pain-free, he was noted to have only limited range of motion with a 10-degree extensor lag and flexion only to 40°. This was considered a major complication due to revision surgery as well as a superficial infection requiring antibiotics.

One additional patient had a major complication. After an initial extension block pinning procedure, he was noted to have limited flexion to 50° and was referred to occupational therapy, but never attended. The patient then presented 5 months following his initial surgery with a repeat mallet fracture at the same site after a second injury. He ultimately required two additional surgeries: an open reduction and pinning of the re-fracture and a subsequent revision due to loss of fixation. At his last follow-up, the patient had 5° of

Fig. 2. **a** Ishiguro extension block pinning technique. First, the distal and proximal interphalangeal joints are held in maximum flexion for reduction. **b** Using fluoroscopy, a k-wire is placed through the terminal extensor tendon into the middle phalanx just proximal to the fracture. **c** This blocks movement of the mallet fragment and allows the distal phalanx to reduce to the fragment when the finger is extended. **d** A second wire is used to immobilize the distal interphalangeal joint palmar to the fracture site. **e** An AP radiograph is obtained to confirm placement of wires.

extensor lag and 20° of flexion and was still experiencing pain. This was the only patient that was noted to have pain at their last follow-up visit.

Discussion

Although the vast majority of pediatric hand fractures can be treated non-operatively given their remodeling potential, large and unstable mallet fractures may represent a subset of fractures that can benefit from early recognition and operative intervention. This study sought to clarify the efficacy of operative fixation in the pediatric population.

As is the case with all retrospective reviews, there are several inherent limitations to this study. Notably, there is a lack of a comparison group and more specifically, a non-operative treatment group. However, we did have four patients where conservative treatment was attempted with splinting that then required surgical fixation. This is a small population and therefore it is difficult to draw many conclusions regarding the rates of complications, although it appears to be an acceptable risk.

Compliance is a major issue in the non-operative treatment of mallet fractures in the pediatric population due to failure to maintain the splint, either because of behavioral issues or an improper fit [17]. The fracture must remain immobilized for a period of 6–8 weeks, with deviation from constant splinting possibly leading to adverse outcomes. Compliance rates have been reported to be 59 to 70% in adults [3]. It is suspected that the compliance rate in pediatric patients is worse.

All mallet fractures in this study involved at least one-third of the articular surface with subluxation in over half of

the patients. The majority of these fractures (70%) were treated with closed reduction and extension block pinning, which has been shown previously to be effective and minimally invasive in adults [7, 8, 12, 15]. Given the healing potential of children, pins can likely be removed earlier than adults. The average pin time was 28 days in this study, with the only re-fracture related to a persistent extension contracture rather than lack of bony healing. K-wires in previous adult studies have remained in for at least 35 days [7, 12, 15].

Physeal fractures of the phalanges are common and account for over one-third of all physeal injuries in children [13]. Possible complications following a physeal injury include premature physeal arrest, angular deformity, and limb length discrepancy [13]. In this study, we reviewed the extensor lag, pain, and presence of other major complications. One of the two patients with an extensor lag had a major complication due to loss of fixation as well as a superficial infection. The other major complication was in a patient that was non-compliant with therapy that re-fractured at the initial site requiring additional surgery. Persistent lack of flexion was noted in a few patients, and aggressive occupational therapy should be considered in children who do not regain flexion appropriately. Kang et al. reported a 41% complication rate following operative treatment for mallet fractures with open reduction and fixation and a Kirschner wire fixation. The majority of these were secondary to marginal skin necrosis [10]. The decreased rate of complications noted here is likely multifactorial including decreased co-morbidities and shorter duration of pin insertion. Furthermore, the majority of these fractures were close reduced and fixed with percutaneous technique.

The Wehbe and Schneider classification has typically been used to describe mallet fractures and is based on articular involvement and evidence of subluxation [16]. Type III fractures involve the physis of the distal phalanx. The patients in our study ranged from 13 to 18 years. It was often difficult to assess the status of the distal phalanx physis on the injury plain radiographs, but upon careful review, we only found three open physis, with the growth plate nearly closed in those cases. The distal phalanx physis has been described to close around 13–16 years of age [4, 6]. The mallet fracture may be a type of transitional fracture that occurs as the physis is closing, but this requires further study. If the physis is completely open, it may be more common to see Salter-Harris type I or II fractures, or juxtaepiphyseal injuries as described by Ganayem et al. [4]. For pediatric and adolescent patients, it may be more practical to classify patients simply based on the involvement of the articular surface as well as presence of subluxation.

A recently published study also noted successful clinical and radiographic results with percutaneous fixation in both acute and chronic pediatric mallet fractures [14]. Reddy et al. utilized percutaneous towel clip reduction through the flexor tendon and intrafocal k-wire fixation for 38 acute and 13 chronic fractures. No patients were noted to have an extensor lag $>10^\circ$, infection, or unplanned revision surgeries. Our cohort demonstrated similar excellent results and presents an option for fixation in the pediatric population that avoids theoretical injury to the flexor tendon, although Reddy et al. did not find any complications with such a maneuver. Our study suggests that 4 weeks for pin fixation is adequate in contrast to the 6-week protocol from Reddy et al. Our study was not powered to compare acute and chronic injuries, but it is interesting to consider a percutaneous technique to osteoclast the fibrous tissue in chronic injuries, which may decrease complications thought to be associated with an open reduction [10].

In conclusion, large mallet fractures at the base of the distal phalanx in the pediatric population appear to be amenable to surgical fixation. Closed reduction and extension block pinning appears to be an effective and minimally invasive option. However, as patients often present in delayed fashion, one must be prepared for an open reduction if necessary. In patients with delayed presentation, early referral to occupational therapy should be considered. Four weeks of pin fixation appears to be adequate. Future prospective randomized controlled trials comparing operative and non-operative management are needed to confirm these results.

Compliance with Ethical Standards

Conflict of Interest: Andrew T. Chen, MD, MPH; Keegan T. Conry, BS; Allison Gilmore, MD; and Jochen P. Son-Hing, MD, FRCSC have declared that they have no conflict of interest. Raymond W. Liu, MD reports payment from Orthopediatrics Corp, outside the work.

Human/Animal Rights: All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Informed Consent: Informed consent was waived from all patients for being included in the study.

Required Author Forms Disclosure forms provided by the authors are available with the online version of this article.

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