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Non-surgical management of displaced bony mallet injuries using dorsal hyperextension splint: An early-term outcome analysis

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ABSTRACT

Purpose: There is still controversy over the ideal treatment of acute bony mallet injuries. The purpose of this study was to evaluate outcomes of a dorsal hyperextension splint treatment for displaced bony mallet injuries.

Methods: A retrospective review of a single institution database identified all acute displaced bony mallet injuries that were conservatively treated using dorsal hyperextension aluminum splint in a one-year period. In this method, each splint is custom-made and applied by a one surgeon at the clinic. The demographics, treatment process, complications, and outcomes were reviewed.

Results: Seventeen patients (11 men, 6 women) with a mean age of 25.1 years (range 15–45) were enrolled. The mean treatment delay was 7 days (range 1–21). Radiographic healing was achieved in all patients at a mean duration of 5½ weeks (range 4–6 weeks). Early complications included the maceration, prolonged erythema in two patients and a partial thickness wound in one patient. The mean follow-up period was 22 months (range 17–26) for fifteen patients. Late complications included two slight swan neck deformities and one complex regional pain syndrome. Four patients had noticeable (>5°) extension lag between 6° and 11°. Two patients had intractable pain with Visual Analog Scale of 3 and 4 points. Overall, 12 out of 15 fingers were subjectively rated as good or excellent.

Conclusion: Using a dorsal hyperextension splint, conservative treatment of displaced bony mallet injury provides overall good results in terms of union rates, patient outcomes, function, and few complications in a short term.

Key words: *Mallet finger, bony mallet, hyperextension, splint*

Introduction

Bony mallet injury is a common lesion seen usually in sports, daily activities, or work-related settings. The mechanism of injury is usually caused by a forced flexion of an extended DIP joint producing an avulsion fracture at the base of the distal phalanx [1]. The disruption of the terminal extensor mechanism results in a characteristic flexion deformity of the DIP joint. An adequate treatment is mandatory to avoid chronic sequelae.

The management of mallet finger injuries varies based on fracture pattern and surgeon preference. Although the surgical treatment of the bony mallet injury has increased among surgeons in the last decades to achieve the anatomical reduction of intra-articular

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fracture [2-4], recent systematic reviews showed that the conservative treatment is still a preferable option [5,6]. The most significant late complications include extension lag, joint stiffness, swan neck deformity, loss of reduction, and long-term osteoarthritis, common to both conservative and surgical treatment [1,6-10].

Several studies have shown that conservative treatment provides good results in cases with fragment base percentage involving larger than one-third of the distal phalanx [1,10-13]. Various plaster/cast and splint options are available, the most common being the Stack, aluminum-foam, and thermoplastic. Regardless of the splint type, immobilization of only the DIP joint, positioning in slight hyperextension, uninterrupted immobilization for six weeks, frequent outpatient reviews, and patient compliance are necessary to achieve an acceptable outcome.

Several studies recommended the dorsal aluminum splint for treating bony mallet injuries [1,11,14-16]. Among these, we identified only two studies that have applied the dorsal aluminum splint in hyperextension [1,16]. Although the hyperextension position is theoretically advantageous, it is less preferred among surgeons due to some potential complications. The purpose of this study was to assess short-term outcomes of our patients treated conservatively with the dorsal hyperextension splint for displaced bony mallet injuries.

Patients and Methods

The institutional review board approved the study. (Reg. No: 940/17.06.2020) We retrospectively reviewed the medical records and radiographs of patients with the diagnosis of bony mallet injury who underwent conservative treatment with dorsal hyperextension aluminum splint in a single institution from March 2019 to March 2020. The selection criteria included acute (up to 3-weeks) displaced and closed bony mallet injuries, and no persistent volar subluxation of the distal interphalangeal (DIP) joint after splint application. The exclusion criteria included accompanying laceration, comminuted fracture at the phalanx base, persistent volar subluxation after splint application, and non-compliance with the treatment protocol.

The aluminum finger splints padded with closed-cell foam were used. Splints that are easily malleable, open-cell foam coated, and broader than the involved finger were discarded. The splint was cut to length from the proximal interphalangeal (PIP) joint dorsal crease to the tip of the nail and bent to 10-15° of hyperextension at the level of the DIP joint. To avoid direct contact between the finger and the foam pad, a two-folded woven gauze in the same size was placed on the interface [11]. While the finger was kept in approximately 10-15 degrees of hyperextension, the splint was placed over it dorsally, and strapped from both distal phalanx and middle phalanx using two-layer of 1-1.5 cm wide, rigid, and porous medical tape, avoiding excess pressure (Figure 1). The patients were asked to keep the splint away from water, not to change it at home by themselves, and to strap with the same type of tape over the existing if the splint loosened. The patients were encouraged to move their PIP joints and reviewed 2 or 3-weekly intervals up to 6-week, for finger cleaning, splint reapplication, radiographic confirmation of DIP joint stability, fragment position, and union. After achieving union, the splint was used for an additional 2-week period at

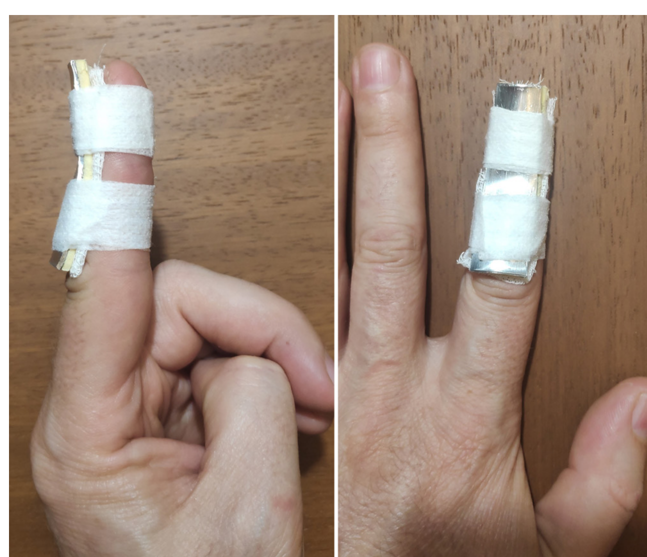

Figure 1. Application of the dorsal aluminum hyperextension splint.

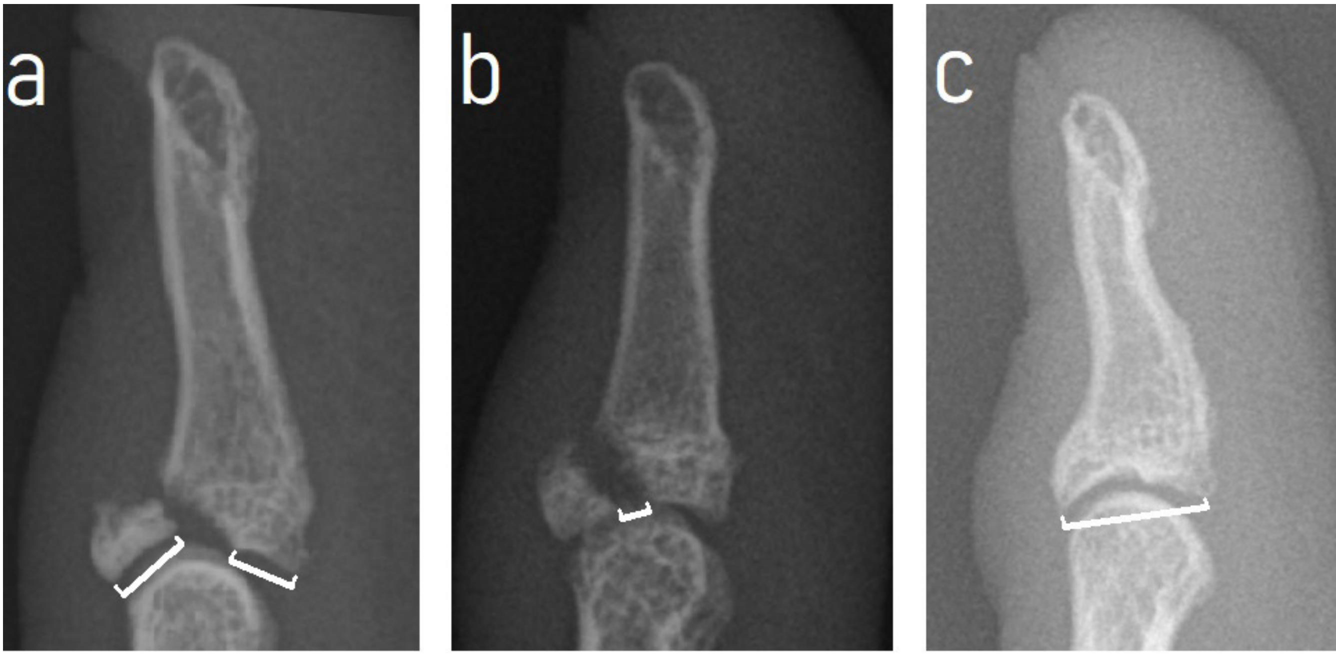

Figure 2. Radiographic measurements **(a)** Fracture base percentage = a / a + b; **(b)** Fracture gap; **(c)** Phalanx base length.

nighttime. Gentle active motion exercises and cleaning were allowed during the first two weeks of recovery, followed by harder exercises for later weeks. The final review was performed at 10-week for return to work.

Demographics, clinical progress, early complications, and radiographic analysis were collected from the hospital records. Demographics and injury data included age, sex, affected limb, affected finger, mechanism of injury, time elapsed from injury to treatment, and duration of uninterrupted splint usage. Clinical records were also reviewed in terms of early complications such as swelling, skin problems (maceration and pressure wounds), and conversion to surgery. Radiographic data included the fragment base percentage and union status. Osseous union was defined as radiographic evidence of bridging trabeculation obscuring the fracture line on lateral radiographs. Radiographic analysis included the fracture displacement (gap size) on the articular surface and phalanx base length on lateral x-rays (Figure 2). The fracture gap size was measured on the x-ray at 6-week. The phalanx base length was defined as the transverse distance between the volar and dorsal rims, measured on x-ray at final examination, and compared with that of the initial lateral x-ray of the contralateral uninjured finger. The paired-samples t-test was used to compare the involved and normal radiographic data. A p-value of less than 0.05 was considered statistically significant.

Patients were invited by telephone to attend a clinic appointment and were reviewed by an author who was not involved in treatment. Patients were assessed in terms of any late complications including swan neck deformity, chronic pain, complex regional pain syndrome, the bone protuberance at the DIP joint, and nail deformity. Outcome measures included the pain intensity, extension lag of the DIP joint, and satisfaction. Pain was assessed with the visual analog scale (VAS) for all patients based on a 10-point scale by the reviewer, based on the patient's subjective description. The extension lag was measured from the dorsal diaphyseal surfaces of the middle and distal phalanges of the involved finger using lateral x-ray taken in passive extension. Satisfaction was assessed with the scale according to Crawford [12]. The follow-up result is excellent if there is full range-of-motion and no pain; good if there is extension lag between 0° and 10° with full flex-

Figure 3. Lateral x-rays of a patient with a bony mallet injury of the ring finger. **(a)** Lateral view before treatment (fracture base percentage 44%); **(b)** Lateral x-ray taken with splint **(c)** Postoperative volar view at the time fracture union (fracture gap 2.2 mm) and **(d)** Follow-up at 18-months.

ion and no pain; fair if there is an extension lag between 10° and 25°, any flexion loss and no pain; poor if there is more than 25° extension deficit or any persistent pain.

Results

Seventeen patients (11 men, 6 women) with a mean age of 25.6 years (range 15–45) were identified. The middle finger was injured in six patients, ring in five, index finger in three, and little in three patients. The right/left ratio was 9:8. The mean time elapsed from injury to treatment was 7 days (range 1–21). The mechanism of injury was simple strike in eight, entrapment in two, and crush-type in seven. The mean duration of uninterrupted splint usage was 4.9 weeks (range 3-6). In terms of early complications, we did not encounter any conversion to surgery or excessive swelling to necessitate termination of splinting. An uncomplicated maceration developed in two patients followed by prolonged erythema; one patient exhibited a partial-thickness small wound at the level of DIP joint probably related to maceration and/or pressure by the splint. Her wound healed rapidly without scarring after serial dressing throughout two weeks.

Four patients had subluxation initially and reduced when the splint was applied. Radiographic union was achieved in all patients at a mean duration of 5½ weeks (range 4–6) from the beginning of treatment. Two adolescent patients healed in 4 weeks. The mean fragment base percentage was 50.1% (range 32-70). The radiographic analysis revealed acceptable reduction of the avulsed fragment but significant widening in the phalanx base length compared with normal phalanx. The mean fracture gap size was 1.8 mm (range 0.8–3.2) at the healing phase. The phalanx base length of the healed finger with a mean of 6.5 mm (range 5.4-7.7) was significantly greater ($p < 0.05$) than that of contralateral normal finger with a mean of 5.2 mm (range 4.3–6.1). The phalanx bases widened a mean of 1.3 mm (range 0.6–1.9). No patients evidenced any volar subluxations of the distal phalanx on final x-rays. Two cases are presented in Figure 3 and 4.

Two patients could not be contacted; the remaining 15 patients returned to us and attended all exam-

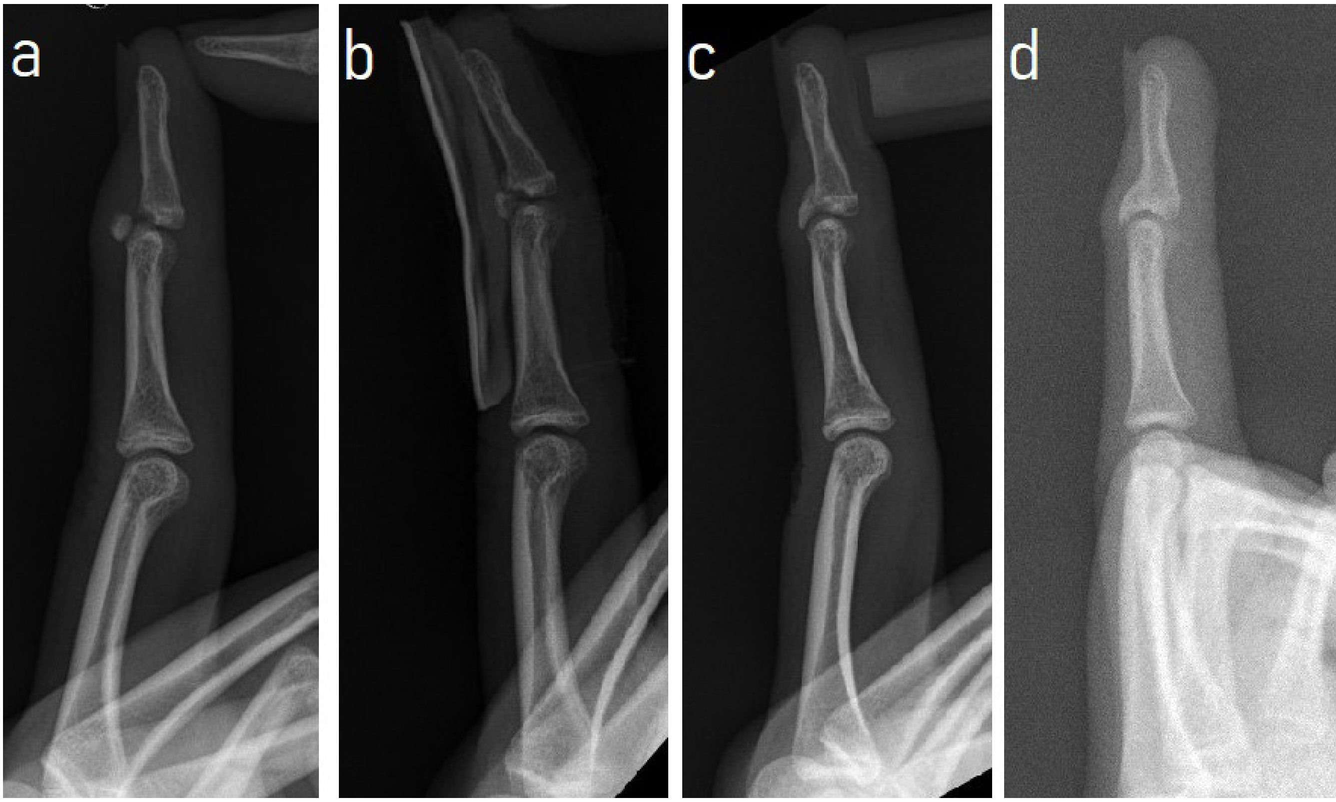

Figure 4. Lateral x-rays of a patient with a bony mallet injury of the ring finger. **(a)** Lateral view before treatment (fracture base percentage 4o%); **(b)** Lateral x-ray taken with splint **(c)** Postoperative volar view at the time fracture union (fracture gap 3.2 mm) and **(d)** Follow-up at 23-months.

inations. The mean follow-up period was 22 months (range 17-26). Late complications included slight swan neck deformity in 2 patients, complex regional pain syndrome in one, and nail deformity in one patient. Both patients with swan-neck deformity had pre-existing generalized finger laxities. Whereas seven patients reached to the hyperextension of their DIP joints nearly symmetrical to the contralateral fingers; four patients acquired neutral. The mean extension lag was 0.7° (-3° to +11°). A noticeable (>5°) extension lag was evident in four patients (with angles of 6°,7°,10°, and 11°), including two patients with swan-neck deformity. We encountered no flexion deficit. There were 8 digits with minimal dorsal prominence, 6 digits with moderate prominence and 1 digit with large prominence. Five patients had intermittent pain, (the VAS score ranged between 1 and 4 points) whereas two patients had persistent pain with the VAS score of 3 and 4 points. These two patients with persistent pain had another complication (complex regional pain syndrome or swan neck deformity). Satisfaction was rated as excellent in six patients, good in six, fair in one, and poor in two patients, according to Crawford [12]. In total, 12 of 15 patients were satisfied with their results.

Discussion

Although bony mallet injuries present the features of an avulsion fracture due to the terminal extensor tendon pull, an excessive displacement is rare. Regarding this condition, some pathoanatomic studies were performed [17,18]. Garcia-Elias et al [17] measured only a maximum of 1.3 mm of excursion of the terminal tendon from the lateral band between full flexion and full extension. Katzman et al [18] found that gapping of the terminal tendon occurs because of the DIP joint flexion, rather than by retraction of the proximal tendon edge under the influence of other elements of the extensor apparatus and the connective tissue attachments between the terminal tendon and periosteum [18]. The other anatomical features of the terminal tendon (the preserved tendinous connection with the DIPJ capsule and intact peripheral tendinous attachments) may potentially contribute to limiting the displacement of the avulsed fragment. These pathoanatomic findings support the rationale of conservative treatment and immobilization of only the DIP joint in the treatment of mallet fingers.

For surgical indications, most studies recommended the use of two criteria: the fragment base percentage involving more than one-third of the articular surface and/or volar subluxation of the distal phalanx [5,8,12,19,20]. There is a consensus that conservative treatment provides ideal treatment for mallet fractures involving less than one-third of the distal phalanx base with no associated DIP joint subluxation [5,13,21]. Controversy exists over conservative treatment of larger fracture fragments involving more than one-third of the articular surface. Some authors recommended the conservative treatment for most mallet fractures, regardless of DIP joint subluxation or fragment base percentage [1,6-10,12]. Kalainov et al [10] showed good outcomes with thermoplastic splint treatment of mallet injuries involving greater than one-third of the articular surface at 2 years of follow-up, and no difference between those with subluxation and those without. Wehbe and Schneider [1] recommended nonoperative treatment for most mallet fractures and concluded that reduction is not mandatory because of bone remodeling. In contrast, some authors [14,19,20,22] stated that these fractures may lead to poor results if conservative treatment is used, and advocated anatomical reduction to prevent extension lag, post-traumatic osteoarthritis, and stiffness, and to gain better cosmetic appearance and range-of-motion.

Several comparative studies were performed for splints versus surgery [1,11,14,19,22-24]. Older studies [1,11,14] compared the complications of various types of splinting with those of the surgery (simple pinning), found a high incidence of complications for both modalities, and recommended the conservative treatment because the surgical complications were often more serious, especially pin track infection/osteomyelitis, fixation failure, skin necrosis, or swan neck deformity. In contrast, recent comparative studies [19,23,24] have reported overall good results and a lower incidence of complications, with similar rates for surgery (extension block pinning) and splinting (volar aluminum or Stack splints). Although Thillemann et al [19] found that the flexion range is better for conservative treatment, they favored surgical treatment citing the thought that better articular alignment will reduce the extensor lag and the severity of future arthritis [8,12,14,22]. Okafor et al [7] analyzed the development of long-term osteoarthritis at a 5-year follow up after Stack splint treatment and found 48% incidence of radiographic evidence of osteoarthritis. Despite this finding, complaints and functional impairments were minimal and similar to the non-arthritic group. No reliable evidence to support the superiority of surgical treatment over nonsurgical treatment in such cases [5-7,25]. In current study, the fracture base percentage was greater than 30% for all patients. Our early-term results were overall good with few complications. Our complication rates are comparable with previously reported rates. Therefore, splinting is a reasonable treatment for bony mallet injuries.

Early complications during conservative treatment are infrequent and benign, and in most cases are related to the skin, which are transient and resolved with adjustment of the splint or after completion of treatment. Skin lesions, including maceration, slough, ulcers, superficial infections, and nail dystrophy, are especially common. Numerous splints and casts have been manufactured for managing mallet finger injuries. The splints previously reported for use in bony mallet injuries include the Stack splint [1,7,9,11-13,23,24], thermoplastic splint [11,16,22,25-27], and the aluminum-foam splint [1,8,11,14,15,19,24,26,28]. All mallet finger splints are designed to keep the DIP joint in full extension or slight hyperextension. Most splints can be applied dorsally, volarly, or in combination, depending on surgeon's preference. The disadvantages of the volar splints are inadequate DIP joint hyperextension, dorsal skin blistering attributable to adhesive tapes, and pulp blockage. The prefabricated Stack splint is not customizable and associated with the maceration, inadequate DIP joint extension, and non-compliance [29,30], although it is probably the most commonly used splint. The custom-made thermoplastic splints are also ideal for mallet finger treatment [11,16,22,25-27,30] but require special equipment and professionals. The aluminum splints are also customizable and used most frequently because of their availability, and ease of application. Nonetheless, no splint design has proven to be superior to another in achieving a better clinical outcome [26,30].

The extension lag is an inevitable complication after both conservative and surgical treatment [7,10,14,20, 23-26,28]. In a systematic review performed by Lin and Samora [5], the mean extension lag of the 480 bony mallet injuries was 5.5°, greater than reported in our study (0.7°). In our opinion, a slight hyperextension of the splint is necessary to maintain reduced position of the fragment and not to fail due to the splint loosening. We found only two studies that have applied the dorsal aluminum splint in hyperextension of the DIP joint for bony mallet injuries [1,26]. The dorsal aluminum foam-padded splints potentially increase the risk for dorsal skin problems due to direct pressure itself. However, in our opinion, this problem is more likely to be associated with maceration, rather than direct pressure. This problem can be minimized by putting a woven gauze beneath the foam-coating, in agreement with the recommendation of Stern and Kastrup [11].

The primary limitations of the current study were the retrospective design and small number of patients. Another limitation was the lack of data for development of osteoarthritis. Although the follow-up time was adequate for all parameters in this study, too early for detection of osteoarthritis and late restriction of range-of-motion.

In conclusion, almost all acute and displaced bony mallet injuries with the DIP joint stable or reducible, even if the fragment base percentage involved more than one-third of the articular surface, can be treated conservatively using dorsal hyperextension aluminum splints. Frequent outpatient assessment and solving their splint-related discomforts are essential for patient compliance and successful nonsurgical treatment.

Conflict of interest statement

The authors have no conflicts of interest to declare.

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