

# A Modified Pull-out Wire Technique for Acute Mallet Fracture of the Finger

## Abstract

**Background:** A variety of surgical techniques for treating mallet fracture finger has been reported with different outcomes and complications. However, the optimal procedure remains controversial. This study describes surgical outcomes of mallet fractures of the finger with distal phalanx treated by modified pull-out wire fixation with Kirschner wire (K-wire) stabilization of the DIP joint in hyperextension. **Materials and Methods:** 30 patients who had mallet fracture finger injuries (Doyle's classification type IVC) with DIP joint subluxation between January 2009 and January 2015 were included in this study. The mean age was 28 years (range 18–50 years), and the mean duration of followup was 8 months (range 6–12 months). Outcome assessments included the skin necrosis, wire tract infection, bony union, and extension lag. We measured the pinch strength test at 8 weeks and 12 weeks postoperatively and graded the clinical results using Crawford's criteria. **Results:** All fractures united after surgery. There was no iatrogenic fracture fragmentation, marginal skin necrosis, wire tract infection, and nail deformity. The mean extension lag was 1.8° (range 0°–17°) through goniometer, 24 of 30 patients had 0° of extension lag. The pinch strength measured at 8 weeks and 12 weeks was 79% and improved to 91%, respectively, compared with uninjured opposite finger. According to Crawford's criteria, 24 patients were classified as excellent, 3 were good, and 3 were fair. No poor result in this study. **Conclusion:** Our modified pull-out wire fixation over a button and K-wire stabilization of DIP joint in hyperextension is a reliable surgical method for treating acute mallet fracture finger and DIP joint volar subluxation.

**Keywords:** Kirschner wire, mallet fracture finger, pull-out wire, distal phalanx

**MeSH terms:** Phalanges of fingers, tendon injuries, joint instability

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## Introduction

Mallet finger injuries occur in association with any activity leading to forced flexion of the distal interphalangeal (DIP) joint. The term mallet fracture finger represents an avulsion fracture with a bony fragment from the dorsal base of the distal phalanx.<sup>1</sup> Mallet finger injuries can be treated nonoperatively with splinting in full extension for 6–8 weeks with no flexion of the DIP joint.<sup>2</sup> Good outcomes have been reported for patients with fracture avulsion of less than one-third of the articular surface.<sup>3,4</sup>

This injury results in disruption of the extensor mechanism of the DIP joint. Kinematic studies of the terminal extensor tendon showed that a 1 mm lengthening leads to 25° extension lag and a 1 mm shortening causes restricted DIP joint flexion.<sup>5</sup> Indications for surgery include open injuries, fractures that involve more than one-third of the joint surface and DIP joint subluxation (theoretically, greater joint

involvement leads to joint subluxation). Numerous surgical methods have been described, but the ideal treatment continues to be debated. A review of the literature shows that the overall complication rate of open treatment is 53%. Major complications include infection (20%), permanent nail deformities (18%), joint incongruity (18%), fixation failure (13%), and bony prominence (11%).<sup>6</sup> The technique of pull-out stainless steel wire fixation alone with the wire tied over a pad or button was once reported, but loss of reduction occurred in 50% of cases.<sup>7</sup> A study by Zhang *et al.* showed that Kirschner wire (K-wire) stabilization of the DIP joint and pull-out wire fixation with the wire twisted in the K-wire did not result in redisplacement of the fragment.<sup>8</sup> The mean extension lag was 7° in their study.

This study describes a surgical technique with modified pull-out wire fixation tied over a button and K-wire stabilization of the DIP joint in hyperextension position to improve clinical outcomes and avoid complications.

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## Access this article online

Website: [www.ijoonline.com](http://www.ijoonline.com)

DOI:  
10.4103/ortho.IJOrtho\_325\_16

## Quick Response Code:



**How to cite this article:** Lu YH, Wu CC, Hsieh CP. A modified pull-out wire technique for acute mallet fracture of the finger. *Indian J Orthop* 2018;52:611-5.

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## Materials and Methods

30 patients (28 closed and 20 open) of mallet fracture fingers with DIP joint volar subluxation treated by pull out wire fixation tied over a button with hyper extension of DIP joint fixation between January 2009 and January 2015 were included in this study. There were 25 males and 5 females with a mean age of 28 years (range 18–50 years). The injury occurred in the dominant hand in 26 patients and in the nondominant hand in 4 patients. The injured finger in each subject was the thumb ( $n = 1$ ), index ( $n = 5$ ), middle ( $n = 15$ ), ring ( $n = 5$ ), and little fingers ( $n = 4$ ), respectively. According to Doyle's classification,<sup>9</sup> all injuries in the present study were classified as Doyle classification type IV C (a hyperextension injury with fracture of the articular surface >50%) with DIP joint volar subluxation. 30 patients received surgical intervention within 2 weeks of injury. The mean duration of followup was 8 months (range 6–12 months).

Surgical indications included: fractures involving more than one-third of the articular surface, fractures associated with volar subluxation of DIP joint, and fractures with fragment displacement of 2 mm or more of the joint surface. Exclusion criteria were comminuted fractures, the size of fragment involved less than one-third of the joint surface, the displacement was <2 mm, and the fracture could be reduced nonsurgically, and fractures without subluxation of DIP joint.

We obtained anteroposterior and lateral view radiographs before and after surgery in all cases. A lateral radiograph of the injured digit was valuable for determining the size and displacement of the fracture fragment as well as the presence or absence of volar subluxation of the distal phalanx [Figure 1a].<sup>10</sup> In each case, the size of the fragment



Figure 1: A 31-year-old basketball player injured at right ring finger, dominant hand during the game. The image intensifier identified mallet bony injury. (a) Fracture involving 44% of the articular surface with distal interphalangeal joint volar subluxation, shown as the mismatch between the midaxial lines of the middle and distal phalanges. (b) Pull-out wire twisted and knotted at the polypropylene button over the finger pulp with distal interphalangeal joint stabilization by a Kirschner wire in hyperextension. (c) Bony solid union at 6 weeks after surgery

involved more than one-third of the joint surface and fracture displacement was measured >2 mm. All injuries were associated with volar subluxation of DIP joints. The same experienced hand surgeon initially treated all patients nonsurgically in the emergency department and arranged surgical intervention within 2 weeks after injury.

## Operative procedure

The patient was positioned supine with the hand placed palm down on a hand table, accessible for fluoroscopy. A tourniquet was applied on the affected finger, and upper arm was draped. We performed these procedures under digital nerve block, with 3 ml injection of 2% lidocaine.

The DIP joint was exposed through a dorsal longitudinal zigzag incision over the DIP joint and with care to avoid extension above the germinal matrix. The fragment connected with extensor tendon was released and retracted proximally after that fracture surface site was exposed. Hematoma was removed as well as the interposed soft tissue to better inspect the articular surface.

Two drill holes were made in the center of the fragment using the 0.028-inch K-wire. A 4-0 monofilament stainless steel wire was passed from the fragment and through attached extensor tendon with modified Kessler suture technique by the straight needle. The wire passed through the wire loop before the wire passed outside edges of the tendon [Figure 2a and b].

Two drill holes were made in the center of the bone defect base of the distal phalanx by drilling from dorsal to volar using the 0.028-inch K-wire. Two needles were passed from the base of the distal phalanx out the tip of the finger. Traction on the wire suture would advance the fragment into bone defect. The DIP joint was manually reduced,

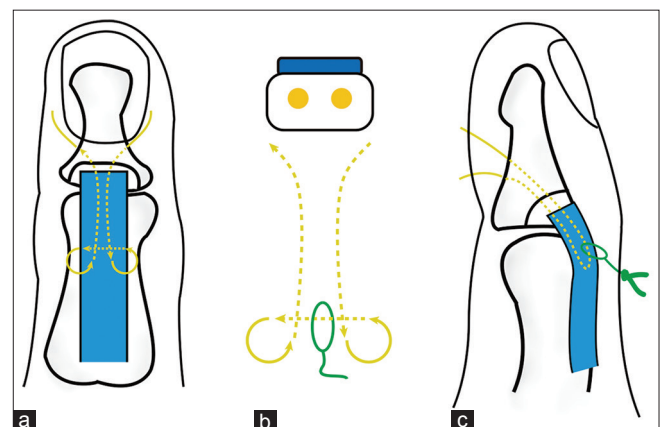


Figure 2: (a) The 4-0 monofilament stainless steel wire (yellow line) passed through the extensor tendon (blue band) with modified Kessler technique on anteroposterior view. (b) The wire passed through the dorsal fragment in two parallel tunnels (two yellow dots). Note that the 4-0 monofilament stainless steel loop (green line) should be crossed to the wire. (c) The lateral view showed that two free ends of the wire were passed through the volar cortex from the other two drill holes in the center of the bone defect and finger pulp by two straight needles. The pull-out wire sutures were tied over a button

and the reduction was accurately verified on lateral images using intraoperative imaging [Figure 2c]. A 0.028-inch K-wire was placed across the reduced DIP joint with the joint in 15°–20° of hyperextension, to ensure that the joint was congruently reduced after the K-wire has been placed. Once a congruent reduction was made, the pull-out wire sutures were tied over a button. Then, the proximal wire loop was passed outside the dorsal skin far ahead the proximal incision wound and tied over it on the skin surface. This proximal wire loop was placed for the removal of suture wire after bone healing [Figures 1b and 3a-c].

5-0 prolene augmented sutures were used to attach the dorsal margins of the proximal extensor tendon to the distal remnants of extensor tendon and closed the wound. Light external splinting was still required to prevent premature loosening of the pin.

### Postoperative management

We encouraged our patients to perform proximal interphalangeal and metacarpophalangeal joint exercise 1 or 2 days postsurgery to avoid stiffness. The K-wire used to fix the DIP joint was removed 4 weeks after surgery. Pull-out wire was removed when bridging trabeculae were present, and the fracture site was nontender. The wire knot was loosened from the polypropylene button and pulled out from the dorsal skin through the former stainless steel loop 6 weeks after surgery. Removal of all implants could be performed on out door basis. Full active DIP joint exercise was started 6 weeks after surgery.

### Evaluation of outcomes

During the first 2 weeks followup at the outpatient department, we evaluated the condition of the injured digits, including wire tract infection, marginal skin necrosis, and skin breakdown. During followup, we also assessed for nail deformity and bony prominence. Postoperative radiographs were taken to check for fracture reduction, status of union, and correction of subluxation [Figure 1b]. Extension lag

and flexion angle were also measured through goniometer for each patient. At the final followup, all the patients rated their DIP joint pain using a visual analog scale. The clinical results were graded by Crawford's criteria, which ranked patients from excellent to poor based on degrees of flexion extension loss of the DIP joint and postoperative residual pain. According to literature review, there was lack of pinch adjustment in recent studies. Therefore, we measured the pinch force for the injured digit compared with the opposing uninjured finger at 8 and 12 weeks postoperatively.

### Results

No patient was lost to followup. The mean extension lag of the DIP joints was 1.8° (range 0°–17°). The mean flexion angle was 77° (range 65°–86°). Full flexion and extension of the joint without residual pain were noted in 24 digits (80%), extension loss of the joint was less than 10° in 3 digits (10%), and 10°–25° in 3 digits (10%), respectively. One case of thumb open injury had an initial extension loss of 70° preoperatively, after surgical intervention, the extension loss decreased to 17°. Finally, the postoperative clinical results based on Crawford's criteria showed that 24 digits were excellent [Figure 4a-d], 3 were good, and 3 were fair. There was no patient with poor result in the present study.

We measured the pinch strength at 8 and 12 weeks, respectively. The pinch strength measured at 8 weeks was 79% compared with the uninjured opposite finger. Further, pinch strength measured at 12 weeks improved to 91% compared with uninjured opposite finger. No iatrogenic fracture fragmentation due to manipulation during surgery occurred. Radiographic union and anatomic reduction were obtained in all 30 patients (100%). If the longitudinal line of the distal phalanx passed palmarly to the center of the

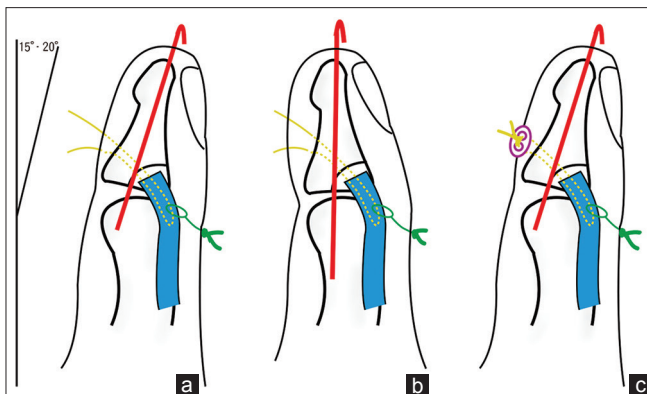


Figure 3: (a) The distal interphalangeal joint was fixed with a 0.028-inch-diameter Kirschner wire (red arrow) in slight hyperextension about 15°–20°. (b) Stabilization of the distal interphalangeal joint full extension was not recommended. (c) Twisted the two free ends of the wire on the button under appropriate tension. Too much tension was not recommended

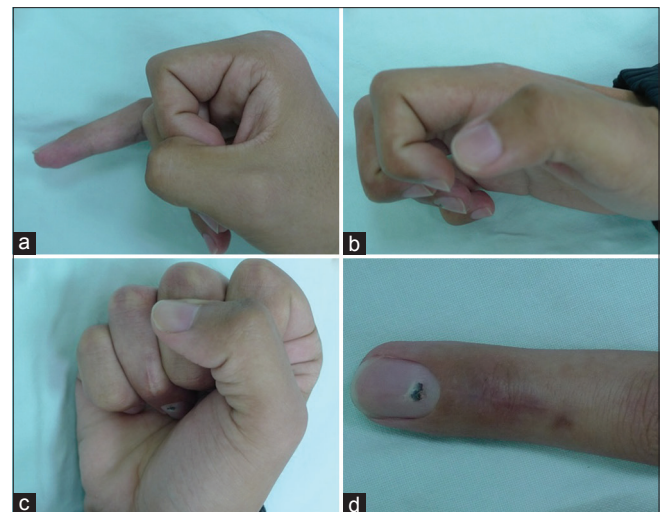


Figure 4: The same patient mentioned in figure at final followup. (a) Full extension in the injured finger. (b) Normal flexion. (c) Normal grasp position. (d) No skin complications

middle phalangeal head, we described this mismatch as a residual volar subluxation. There was no residual volar subluxation, shown as matching midaxial lines of the middle and distal phalanges, in our series [Figure 1c]. In addition, we considered a swan-neck posture as a significant volar subluxation. There was no swan-neck deformity during the followup period in the present study.

At the final followup, we observed no marginal skin necrosis, pin tract infection, and nail deformity. There was no DIP joint pain based on visual analog scale in any of the patient. One patient sustained pull-out wire breakage at 2-month followup and received open surgery to remove the implant.

## Discussion

Most of the mallet finger injuries can be treated nonsurgical.<sup>11</sup> However, inadequate treatment can result in extensor lag, significant swan neck deformity, early osteoarthritic changes, and poor functional outcomes. A variety of surgical techniques has been described in the literature with acceptable outcomes as shown below.

Hofmeister *et al.* treated displaced mallet fractures with an extension block pin and transarticular fixation of the DIP joint. In 24 mallet fractures, the average extension loss was 4° at 1-year or greater followup.<sup>12</sup> However, this technique may result in extension lag of up to 20°. Five minor complications were reported that including pin tract infection, nail deformity, skin necrosis, spur formation, and loss of the fracture reduction. Lee *et al.* presented nine cases of failed extension block pinning surgery and its revision surgery with open tension wire fixation technique.<sup>13</sup> Mean extension lag at final followup was 7° (range 0°–25°). Badia and Riano used a simple fixation method to treat unstable bony mallet finger. A 1.4-mm (0.045-inch) K-wire was driven from the fingertip and across the DIP joint to reduce subluxation and hold DIP joint in extension.<sup>14</sup> The second wire was then driven from the dorsal aspect of the distal phalanx to catch and reduce the avulsed dorsal fragment. Once reduction was acceptable, this second K-wire was bent and pulled from the volar aspect to hook the fragment. Although there was no damage of the dorsal fragment in their series of 16 patients, possible fragmentation and redisplacement during insertion of the second hooked-K-wire were still at risk. Zhang *et al.* described pull-out wire fixation of the reduced fracture fragment and K-wire stabilization of the DIP joint.<sup>8</sup> The K-wire was pulled volarly into position at an angle of 45°, and the pull-out wire was twisted around at the cross point of the K-wire loop out of the skin. Elastic force of the K-wire provided continuous traction on the fragment to maintain reduction. The stainless steel wire tied onto the K-wire could also avoid regional skin necrosis. The disadvantages of this technique included the complexity of the surgical procedure and relative higher mean extension loss of 7° compared with the previous

studies. The authors further referred combined tendon/bone mallet fingers which were previously unclassified as Dolye's classification type V and treated such injuries with the same method in 9 patients. The mean extensor lag of the DIP joint was 8° (range 0°–19°).<sup>15</sup> Miura developed an external fixator (Tripod; Medical Engineering System, Tokyo, Japan) that was attached to the extension block pin to prevent dorsal rotation of the dorsal fragment.<sup>16</sup> Their modification of the external block pinning resulted in early union at an average of 5 weeks after surgery. They believed that control of dorsal rotation of the fragment was important for earlier union because it increased the contact area at the fracture site. The earlier active motion could also be achieved by this method. The average extension lag was 2° and active flexion was 74°. However, the bulk of the fixator may be a problem.

Our technique is an open surgery that can restore the extensor mechanism in the original anatomic site of the distal phalanx. Regardless of technical demand due to the small size of the fracture fragment, well reduction of dorsal intraarticular surface also can minimize the development of posttraumatic osteoarthritis and joint pain. Although some authors believe that anatomical reduction results in better functional outcomes,<sup>17</sup> the relationship between anatomical reduction and outcomes remain controversial. As reported, complication rate of open treatment is as high as 53%. The complications include skin necrosis, infection, nail deformity, joint incongruity, fixation failure, loss of reduction, and prominent dorsal bump. We observed only one case with pull-out wire breakage due to too much tension applied on the wire on removal. An experienced surgeon, well-selected patient without chronic presentation, and standard postoperative management can decrease the occurrence of complications.

During the procedure, the stainless steel wire and polypropylene button held the dorsal fragment in the reduced position. The wire passing through the extensor tendon and augmented tendon repair can both provide soft-tissue healing. According to our experience, more traction force to pull the wire button may cause volar skin necrosis and increase the risk of wire breakage. Damron *et al.* once found that the traction force could be absorbed by the button if pull-out wire was performed alone, leading to loss of reduction.<sup>7</sup> It is because pull-out wire fixation could not provide the enough tension till bone healing and easy loss of reduction. The fixation with stainless steel wire is less stable than block pinning, trans-fragmentary K-wire fixation, or small external fixator, as mentioned above. We modified the technique which added one K-wire stabilization of the DIP joint to keep the strengthening tension till bone healing and avoid loss of reduction. In addition, according to a review of the current literature,<sup>7,12,15,16</sup> the DIP joint was reduced and kept in full extension or slight flexion by longitudinal K-wire stabilization in almost all studies. In our experience, K-wire

stabilization of the DIP joint in hyperextension 15°–20° can provide the stable environment, and the appropriate tension of extensor tendon to avoid loss of reduction and pull-out wire breakage. In our study, union and anatomic reduction was achieved in all patients. Moreover, we believe that blocking the DIP joint in hyperextension also contributes to improve the extension lag. Extension lag is an important factor that affects outcomes. There was no extension lag in 24 of 30 patients (80%) in our case series. The mean extension lag is 1.8° and relatively better than previous reported data.<sup>8,10,12-15</sup>

Crawford's criteria are clinical assessment of DIP joint outcomes and commonly used to grade the result. It includes postoperative pain, active extension, and flexion but without function evaluation. Therefore, we measured pinch strength test in our study. The pinch strength measured at 8 weeks was 79% compared with uninjured opposite finger. The further pinch strength measured at 12 weeks improved to 91% compared with uninjured opposite finger.

This technique improved the extension lags, functional outcomes, low complication rates and is well tolerated with good patient compliance. The main limitation of this technique is that it is performed by an experienced hand surgeon due to the relative complexity of the procedure.

## Conclusion

Our modified pull-out wire fixation over a button and K-wire stabilization of DIP joint in hyperextension is a reliable surgical method for treating acute mallet fracture finger and DIP joint volar subluxation.

## Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

## Financial support and sponsorship

Nil.

## Conflicts of interest

There are no conflicts of interest.

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