

# Causes of Procedural Failures of Closed Reductions using an Extension-Block Pin for Bony Mallet Finger

Taku Suzuki<sup>1</sup> Takuji Iwamoto<sup>1</sup> Noboru Matsumura<sup>1</sup> Hiroo Kimura<sup>1</sup> Masaya Nakamura<sup>1</sup>  
Morio Matsumoto<sup>1</sup> Kazuki Sato<sup>2</sup>

<sup>1</sup>Department of Orthopaedic Surgery, Keio University School of Medicine, Tokyo, Japan

<sup>2</sup>Institute for Integrated Sports Medicine, Keio University School of Medicine, Tokyo, Japan

**Address for correspondence** Taku Suzuki, MD, PhD, Department of Orthopaedic Surgery, Keio University School of Medicine 35 Shinanomachi, Shinjuku-ku, Tokyo 160-8582, Japan (e-mail: sutaku49@gmail.com).

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## Abstract

This retrospective study evaluated procedural failures of closed reductions using an extension-block Kirschner wire (K-wire) for bony mallet finger. A total of 132 patients who underwent a closed reduction for bony mallet finger in a procedure using an extension-block K-wire were radiographically assessed. Radiographs were used to evaluate (1) postoperative displacement of the reduction before or after K-wire removal and (2) inaccurate reduction of the fragment immediately after surgery. The causes of procedural failure and bone union were evaluated using radiographs and medical records of the intraoperative findings. Out of 132 patients, 17 with procedural failure were enrolled. Displacement of the reduction before and after K-wire removal occurred in seven and six cases, respectively. Inaccurate reduction immediately after surgery occurred in four cases. The most common cause of procedural failure was inaccurate insertion of the K-wire to fix the distal interphalangeal joint (eight cases) followed by inaccurate insertion of the extension-block pin (five cases). All patients had bone union regardless of the displacement of the reduction or inaccurate reduction of the fragment. Caution should be exercised during the reduction and fixation when an extension-block K-wire is used in a closed reduction procedure.

## Keywords

- ▶ bony mallet finger
- ▶ displacement of the reduction
- ▶ mallet finger
- ▶ postoperative displacement
- ▶ procedural failure

## Introduction

Bony mallet finger is a common injury of the finger at the distal interphalangeal (DIP) joint. Surgical treatment is generally recommended for a fracture involving more than one-third of the articular surface or a subluxation of the DIP joint.<sup>1</sup> To date, various surgical techniques have been used, including closed reduction using an extension-block pin (Ishiguro et al's method),<sup>2</sup> open reduction and internal fixation with a screw,<sup>3</sup> tension band wiring,<sup>4</sup> pullout suturing,<sup>5</sup> and a hook plate fixation.<sup>6</sup> Of these, the closed reduction using an extension-block Kirschner wire (K-wire) is the most frequently performed procedure for bony mallet finger fractures because an open reduction and internal fixation is technically damaging and can sometimes lead to fragment comminution, skin breakdown, or nail deformity.<sup>7</sup>

Numerous studies report favorable surgical outcomes, an excellent union rate (almost 100%), and a postoperative

average DIP joint extensor lag ranging from 1 to 6 degrees.<sup>1,8,9</sup> However, a systematic review of mallet fingers demonstrated that nail deformity and pin-tract infection are the most common surgical complications.<sup>1</sup> Other complications identified using radiographs include secondary displacement of the reduction, resorption of the bone fragment, and nonunion of the fragment.<sup>1,9</sup> Secondary displacement is likely to cause functional impairment.

Although complications of bony mallet fingers identified radiographically have been reported, few studies have performed a detailed analysis to investigate the cause and the clinical course of these patients, of which little is known. When investigating the cause of displacement of the reduction, it is important to plan a strategy and aim to improve the surgical technique in such a way that patients will benefit. In this study, we retrospectively enrolled patients who underwent surgical treatment for acute bony mallet fingers and for whom there

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was radiographic confirmation of an unsatisfactory outcome. The purpose of this study was to use radiographs to evaluate the cause of displacements of reductions and the clinical course of these patients.

## Materials and Methods

### Patients

From July 2000 to December 2015, 132 patients with acute mallet finger fractures were surgically treated at two institutions. Among them, patients with radiographs that confirmed displacements of reductions were enrolled retrospectively for this study. Radiographs were used to determine if patients met any of the following criteria: (1) postoperative displacement of the reduction before or after K-wire removal and (2) inaccurate reduction of the fragment immediately after the operation. As controls, patients with successful reductions were also enrolled.

Patients were eligible for inclusion in this study if they had sustained acute subcutaneous fractures and underwent surgery within 4 weeks after the injury. The indication for surgery was a bone fragment larger than 30% of the articular surface or a subluxation of the distal phalanx. Patients who underwent surgical procedures other than closed reductions using an extension-block K-wire, such as open reductions with a K-wire or screw, were not included in the study. Patients with less than 1 year of follow-up were also excluded. All patients provided informed consent, and an Institutional Review Board approved the study.

### Operative Procedure

Operative procedures were performed by six hand specialists with at least 10 years of orthopaedic surgical experience. All the procedures were performed percutaneously under digital block anesthesia, with image intensifier control.

During maximum flexion of the distal and proximal interphalangeal joint, 1.0 mm of K-wire was dorsally inserted into the head of the middle phalanx behind the fragment, and the wire was then inserted into the volar cortex of the middle phalanx. One or two extension-block K-wires were used according to each surgeon's preference. For a case that presented within 3 or 4 weeks after an injury, the fracture site was refreshed percutaneously using a 23-gauge needle.

Manual reduction was performed to extend a distal phalanx. When sufficient reduction was not able to be achieved, an additional 0.8- to 1.0-mm K-wire or a 23-gauge needle was used to correct the rotation of a dorsal fragment. If necessary, the K-wire was then inserted into the fragment for direct fixation. Avoiding the dorsal fragment, a 1.0-mm K-wire was obliquely introduced from the lateral side of the distal phalanx to fix the DIP joint. When this technique proved difficult, the K-wire was inserted from the top of the digit into the distal phalanx. After cutting the K-wire, extension-block K-wires were not bent close to the joint in order to not diminish the effectiveness of the extension block.

### Postoperative Rehabilitation

Inserted K-wires were removed in the outpatient clinic 4 to 6 weeks postoperatively. Passive extension of the DIP joint, which exerts a compressive force on the fracture surface and active range of motion of the DIP joint, was initiated after K-wire removal.<sup>2</sup>

In the event that a reduction was displaced postoperatively, a second operation could be indicated according to each surgeon's judgment. In the absence of additional surgery, displacement notwithstanding, a splint was applied intermittently during the day and nocturnally to the DIP joint for 4 to 8 weeks after K-wire removal. Low-intensity, pulsed ultrasound was not used to promote bone union.

### Evaluations

The primary end point of this study was to analyze the cause of a secondary displacement of the reduction before or after K-wire removal or an inaccurate reduction of the fragment immediately after the operation using radiographs. These evaluations were performed by one hand specialist using plain anteroposterior and lateral radiographs, as well as medical records of the intraoperative findings.

Secondary end points were to investigate the presence or absence of bone union and the time to union according to radiographic assessments. Union was determined by the identification of trabecular bridging on lateral radiographs.

A tertiary end point was to evaluate the clinical results and complications in patients. At the final follow-up, the six treating surgeons measured the active range of motion of the DIP joint using a goniometer. Clinical outcomes at final examination were assessed using Crawford's criteria, which evaluates extensor tendon function with total extension lag and total flexion loss.<sup>10</sup> Complications included tenderness at DIP joint, nail deformity, infection, skin breakdown, and prominence of the DIP joint.

### Statistical Analysis

To compare clinical results, statistical analyses were performed using Welch's *t*-tests for continuous variables and Mann-Whitney's *U*-tests for ordinal variables. A *p*-value of less than 0.05 was considered statistically significant.

## Results

### Patients

Of the 132 patients screened, a total of 17 patients with displaced reductions and 88 patients with successful reductions were eligible for study inclusion on the basis of the availability of appropriate radiographic evidence, whereas 27 patients were excluded because of a short follow-up period (23 cases) or open reduction with a K-wire or screw (4 cases). There were no open fractures. The characteristics of the patients are shown in ► **Table 1**. Of the 17 patients, 2 underwent a second operation and an open reduction with a K-wire or tension band wiring, respectively, and the dorsal fragment remained displaced in the other 15 patients.

**Table 1** The characteristics of the patients

|                                       | Displaced reduction (N = 17)            | Successful reduction (N = 88)              |
|---------------------------------------|---|--|
| Age, years                            | 48 (17–71)                              | 45 (18–64)                                 |
| Sex                                   | Male: 12; female: 5                     | Male: 58; female: 30                       |
| Affected finger                       | Index: 2; middle: 8; ring: 3; little: 4 | Index: 6; middle: 32; ring: 27; little: 23 |
| Affected side                         | Right: 14; left: 3                      | Right: 58; left: 30                        |
| Time to surgery, day                  | 13.8 (8–28)                             | 11.9 (3–26)                                |
| Fragment size, % of articular surface | 45.8 (30–80)                            | 43.0 (30–70)                               |
| Number of extension-block pin         | One: 10; two: 7                         | One: 38; two: 50                           |
| Time to K-wire removal, week          | 5.1 (4–6)                               | 4.8 (4–6)                                  |
| Follow-up period after the surgery    | 14 (12–30)                              | 13 (12–24)                                 |

Abbreviation: K-wire, Kirschner wire.

Note: Data are presented as number or mean (range).

### Cause of Displacements of Reductions

Radiographs were used to confirm postoperative displacements of reductions before and after K-wire removal in seven and six cases, respectively, and inaccurate reductions immediately after the surgery in four cases.

The most common cause of unsatisfactory outcomes was the inaccurate insertion of the K-wire to fix the DIP joint in eight cases. The K-wire was not inserted from the lateral cortex of the distal phalanx but rather from the fracture site or within close proximity to the fracture site, which can destabilize DIP joint fixation (►Fig. 1A, B). The K-wire was obliquely inserted into the DIP joint in those eight cases. The next most common cause of unsatisfactory outcomes was inaccurate insertion of the extension-block pin in five cases. The position of the K-wire deviated from the center of the head of the proximal phalanx, which resulted in insufficient compression of the bone fragment (►Fig. 2A, B). A single extension-block pin was used in those cases. Less frequent causes of reduction displacement were residual rotation of the large fragment due to difficulties associated with performing the reduction in three cases and an unknown cause in one case.



**Fig. 1** (A) The Kirschner wire was inserted in close proximity to the fracture site. (B) Displacement of the volar fragment.



**Fig. 2** (A) Extension-block pin shown deviating from the center of the head of the proximal phalanx. (B) Sufficient compression was not applied to the fragment.

### Union of the Fragment

In the displaced reduction group, bone union was confirmed radiographically in all 15 patients who did not undergo a second operation, regardless of displacement of the reduction or inaccurate reduction of the fragment (→Fig. 3A–D). Although bone remodeling gradually occurs, some residual deformity of the articulation remains in most of the cases. The mean time to union was 12 weeks postoperatively (range: 7–24 weeks). The two patients who underwent a second operation also had radiological evidence of bone union. In the successful reduction group, bone union was also confirmed in all 88 patients, and the mean time to union was 8 weeks postoperatively (range: 7–12 weeks).

### Clinical Results and Complications

The mean of the DIP joint was 10.4 degrees (range: 0–25 degrees) in the displaced reduction group and 8.3 degrees (range: 0–20 degrees) in the successful reduction group. The mean flexion of the DIP joint was 56.6 degrees (range: 35–80 degrees) in the displaced

reduction group and 65.8 degrees (range: 50–80 degrees) in the successful reduction group. There was no significant differences between the two groups (extension lag:  $p = 0.16$ ; flexion:  $p = 0.07$ ). According to Crawford's criteria, in the displaced reduction group, the outcomes were excellent in 1 case, good in 6 cases, fair in 8 cases, and poor in 2 cases, whereas in the successful reduction group, they were excellent in 45 cases, good in 35 cases, and fair in 8 cases. There was a significant difference between the two groups ( $p < 0.001$ ). Postoperative complications included tenderness in 4 cases, nail deformity in 3 cases, and prominence of the DIP joint in 3 cases in the displaced reduction group, and nail deformity in 16 cases in the successful reduction group. There was no infection or skin breakdown in any of the patients.

### Discussion

In this study, radiographs were used to evaluate the cause of procedural failures and the clinical course of patients with bony mallet fingers. The most common cause of



**Fig. 3** (A) Displacement of the reduction after Kirschner wire (K-wire) removal. (B) Two months after K-wire removal. (C) Bone union at 6 months after K-wire removal. (D) Twelve months after K-wire removal.

unsatisfactory outcomes was inaccurate insertion of the K-wire for DIP joint fixation. Although displacement of the reduction or inaccurate reduction of the fragment remained, bone union was achieved in all cases. Nevertheless, unsatisfactory clinical outcomes were observed in these patients.

The extensor tendon attaches to the proximal dorsal fragment and the flexor tendon attaches to the dorsal volar fragment, and displacement force is applied to the fracture site. Therefore, the K-wire for DIP joint fixation and an extension-block pin should be inserted accurately. In the original procedure (Ishiguro et al's method), the K-wire is obliquely inserted from the lateral side of the distal phalanx to the middle phalanx to fix the DIP joint.<sup>2</sup> Secure fixation of the DIP joint cannot be achieved if the K-wire penetrates through the fracture site because it results in displacement of the volar fragment.<sup>2</sup> When the K-wire is in contact with the dorsal fragment, the fragment can potentially be rotated and may displace the reduction. Insertion of the K-wire while avoiding the dorsal fragment is rather difficult when the fragment is large. Furthermore, the length of K-wire penetrating the distal phalanx is short when using the oblique insertion technique because it decreases the stability of the DIP joint fixation. Choosing to insert the K-wire from the tip of the distal phalanx might be a more practical option when oblique insertion is difficult.<sup>11</sup>

To block the dorsal fragment, an extension-block pin should be inserted behind the center of the dorsal fragment. Deviation from the center resulted in insufficient compression of the fragment and difficulties with its reduction. In this study, insertion of a single extension-block pin at times deviated from the center of the head of the proximal phalanx. Based on our experience, drawing a longitudinal line along the axis of the middle phalanx helps the surgeon to insert the K-wire into the center of the middle phalanx (→Fig. 4). To control the dorsal fragment, Lee et al recommended a double extension block K-wires when the fragment is large, markedly displaced, or rotated.<sup>8</sup> Furthermore, when a single K-wire is inserted inaccurately, the inadequacy could be compensated for by another K-wire. We also consider



**Fig. 4** A longitudinal line drawn along the axis of the middle phalanx helps the surgeon to insert accurately the Kirschner wire into the center of the middle phalanx.

that better control of the dorsal fragment could be achieved using a double extension-block technique.

In this study, radiographic assessments confirmed that all the patients had evidence of bone union regardless of postoperative displacement of the reduction or inaccurate reduction of the fragment. One of the reasons for this could be because the continuity of the periosteum is preserved with a closed reduction technique, even if the fragment is displaced. Continuous periosteum typically results in the satisfactory union of a fracture. We consider that this result might help the surgeon to decide whether reoperation is performed or not. However, the duration of DIP joint fixation with a splint after K-wire removal is longer compared with the successful reduction group, which can result in contracture of the DIP joint in some cases. Moreover, some residual deformity of the articulation remains in the displaced reduction group.

There are some limitations of our study. First, this study was retrospective, and the cause of displacement of the reduction was determined by postoperative radiographs and medical records. Unknown potential causes might lead to displacement of the reduction as assessed using radiographs. Second, the operations were performed by six surgeons at two institutions. Although all the hand specialists had more than 10 years of postgraduate orthopaedic surgical experience, the skill of the practitioner may have affected the results. A second operation was performed in two cases in accordance with the surgeons' decision in this study. The natural clinical course of the patients after displacement of a reduction in these cases is unclear.

We investigated procedural failures and pitfalls of the technique employed for closed reductions using an extension-block K-wire. Caution should be exercised in the reduction and fixation of bony mallet finger fractures, and we anticipate that this study will assist in the improvement of surgical techniques used to treat them.

### Conflict of Interest

None declared.

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