INTRODUCTION

The extensor mechanism of the digit is intricate and complex in anatomy and function. It is a linkage system created by the extrinsic system and the intrinsic system.\(^1,2\) The extrinsic system is innervated by the radial nerve. It respectively extends the metacarpophalangeal joint and the interphalangeal joints primarily and secondarily. The intrinsic system is innervated by the ulnar nerve and the median nerve. It is composed of four dorsal interossei, three palmar interossei and four lumbrical muscles. They extend the proximal and distal interphalangeal joints but flex the metacarpophalangeal joint.

Mallet finger is a common clinical problem caused by injury to the extensor mechanism at or near the distal interphalangeal joint.\(^3\) A mallet fracture refers to a similar injury, but it is due to a fracture at the dorsal base of the distal phalanx.

According to a retrospective review of mallet fractures in 42 patients, 74% of fractures involved the dominant hands while only 26% involved the non-dominant hands.\(^4\) More than 90% of injuries were found to be occurred in the ulnar three digits. Most of the injuries were found in young men with a mean age of 30 years old. They were mostly related to athletic activities including football, baseball, basketball and volleyball etc. Simpson et al did an epidemiologic study on mallet deformity in sport and discovered that it accounted for 2% of all the sporting injuries.\(^3\) The majority of injuries happened in young men with a mean age of 29 years old over the ulnar 2 digits during high impact sports such as rugby, football, basketball, etc. Jones et al did an epidemiologic study of 24 members of a three-generation family and proposed a familial predisposition to develop the mallet finger deformity.\(^6\)

Classification of Mallet Fingers

There are a few classification systems published in the literatures for mallet finger injury.\(^2,4\) In 1985, Niechajev classified the pathomechanism for the mallet finger into five types with increase in severity from Type A through Type E.\(^7\) Type A is due to a tendon rupture. Type B is due to a chip fracture at the dorsal aspect of the base of the distal phalanx. Type C is due to an avulsion fracture without dislocation of the fracture fragment. Type D is due to an avulsion fracture with dislocation of the fragment. Type E refers to a dislocated avulsion fracture with subluxation of the distal phalanx.
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The author recommended conservative treatment for Type A to Type C and surgical repair for Type D & Type E.
**Treatment Options**

Should both interphalangeal joints or just the distal interphalangeal joint be immobilized for treatment of mallet finger? Katzman et al performed experiments on 32 cadaveric fingers and confirmed that only the distal interphalangeal joint needs to be immobilized for treatment of mallet finger. Most mallet finger injuries are recommended by modern textbooks of orthopaedic surgery to be treated with immobilization of the distal interphalangeal joint in extension by splints. Full-time splinting is recommended for 6 weeks, followed by 2 to 6 weeks of splinting at night and during strenuous activities. This kind of treatment is generally accepted and usually gives satisfactory results.

Mallet thumb injuries are treated in the same manner as mallet finger injuries. Many different kinds of splints have been described and used for immobilization of the distal interphalangeal joint.

The indications for operative treatment remain controversial. There were some reviews comparing nonoperative and operative treatments. Wehbe et al concluded in his review that most mallet fractures can be treated conservatively, ignoring joint subluxation and the size and amount of displacement of the bone fragment since surgical treatment was considered to be difficult and unreliable. Kalainov et al analyzed the results of nonsurgical treatment for closed and displaced mallet finger fractures with greater than one-third articular surface damage using extension splinting. He found that the patient satisfaction with finger function and treatment outcome was relatively high at 2-year follow-up evaluation. However, he noticed that some patients developed a dorsal distal interphalangeal joint prominence, distal interphalangeal joint extension lag, swan-neck deformity and degenerative joint changes particularly in cases with palmar subluxation of the distal phalanx. Lubahn compared open and closed techniques for treatment of mallet finger fractures and concluded that anatomic restoration of the joint by open treatment provided a cosmetically and functionally better result.

Three conditions are frequently cited as indications for surgery. These include open injuries, closed injury in someone who is unable to work with a splint and injury with a large dorsal bony fragment associated with palmar subluxation of the distal phalanx.

Husain et al performed a biomechanical study to determine the relationship between the percentage of the dorsal articular surface damage and the distal interphalangeal joint subluxation in a cadaveric mallet fracture model. He found that palmar subluxation of the distal phalanx was not seen when the dorsal fracture fragment measured less than 43% of the articular surface. However, palmar subluxation of the distal phalanx was consistently seen when the dorsal fracture fragment measured more than 52% of the articular surface. He concluded that palmar subluxation of a distal phalangeal joint is expected when more than one half of the dorsal articular surface is injured.
Surgical Treatment

Many different surgical techniques have been described and proposed for treatment of mallet fractures involving more than one third of the articular surface or where the distal interphalangeal joint is subluxed. The techniques for fixation of the fracture fragment include the use of a tension band wire, figure-of-eight wire, pull-out wire, pull-in suture, intramedullary wire fixation, "umbrella handle" Kirschner wire fixation, external fixation with Kirschner wires, screw fixation, mini external fixators, compression fixation pins and hook plate fixation etc.2,14,21-38 Most of the fixation methods require an axial Kirschner wire across the distal interphalangeal joint for protection of the fixation whereas a few of them require only splinting at rest.25,37,38

Both nonoperatively and operatively treated mallet fingers were reported to have complications related to the treatment methods. Stern et al reviewed the complications of treatment in 123 mallet fingers.39 He found that the complication rate was 45% in 84 splinted digits and was mostly related to skin problems which were almost always transient. He also noticed that the complication rate was 53% in 45 surgically treated digits which included deep infection, joint incongruity and nail deformity with 76% of the complications still present after a long period of follow-up. Another retrospective review by Kang et al revealed 41% postoperative complication rate among 59 surgically treated mallet fractures.40 He found that marginal skin necrosis on the dorsal aspect of the distal phalanx was the most common complication. Other complications including recurrent extension lag, permanent nail deformities, transient infections along the Kirschner wires and pull-out wires and osteomyelitis were also noticed.

There are many clinical studies on different surgical techniques. However, only one biomechanical analysis of mallet finger fracture fixation techniques is found on literature review. Damron et al conducted a biomechanical study in 1993 to determine the best fixation technique for mallet finger fractures among four fixation methods.41 The techniques tested included fixation using Kirschner wire, figure-of-eight wire, tension band wire and tension band suture. He noticed that the energy absorbed to failure was significantly greater for the tension band suture technique and the figure-of-eight wire technique than for the Kirschner wire technique.

One of the post-operative problems related to the fixation of fracture or protection of fixation by axial Kirschner wire across the distal interphalangeal joint is stiffness of the joint. The early results of the "umbrella handle" technique and the hook plate technique were published recently and seemed to be encouraging.35,37,38 These two techniques do not require the protection of fixation by trans-articular axial Kirschner wire. The "umbrella handle" device allows free and full active motion of the distal interphalangeal joint immediately after operation while the hook plate device allows protected early active motion in the post-operative period to prevent joint stiffness.

The "umbrella handle" technique. It was described by Rocchi L. et al.35 The dorsal fragment was transfixed with a Kirschner wire of 1.2mm diameter directed obliquely from proximal to distal into the main fragment of the distal phalanx under fluoroscopic control. The dorsal end of the Kirschner wire was bent into the shape of an "umbrella handle" and then a small dorsal skin incision was made. The Kirschner wire was pulled down by a pair of pliers from the palmar aspect to reduce the dorsal fragment. The Kirschner wire was passed through a thermoplastic splint and a cannula to distribute the pressure of the fixation over the pulp of the digit and to prevent dorsal displacement of the Kirschner wire.
The figure-of-eight (F8W) wire technique. It was reported by Jupiter J. B. et al using 28-gauge stainless steel wire. The wire was passed palmar to the extensor tendon and just proximal to its insertion, cross over the dorsal fragment surface, and then through a transverse hole created by a 1.2mm diameter Kirschner wire in the dorsal aspect of the main fragment of the distal phalanx just distal to the osteotomy site. The figure-of-eight wire loop was tightened by a pair of pliers over the dorsal surface with a single twist knot. The fixation was confirmed by fluoroscopic images.

The pull-in suture technique. It was described by Ulusoy M. G. et al using 4-O Prolene suture. The suture was passed palmar to the extensor tendon and just proximal to its insertion in a Kessler type suture. A small palmar incision was made in the finger pulp. Then, a 1.2mm diameter Kirschner wire was driven through the medial aspect of the dorsal fragment and the main fragment of the distal phalanx to exit from the medial side of the palmar incision to create a hole for passing the suture. A similar hole was created over the lateral aspect. Both ends of the suture were passed to the palmar aspect of the distal phalanx through the drill holes. The dorsal fragment was reduced and a knot was tied tightly at the palmar aspect of the distal phalanx. A 0.9mm diameter Kirschner wire across the distal interphalangeal joint was inserted to protect the fixation. The reduction of the dorsal fragment was confirmed by fluoroscopic images.
The hook plate technique. It was described by Theivendran K. et al. and Teoh L. C. et al. A 1.3mm 2-hole or 3-hole AO Modular Hand System Titanium Straight Plate was used to fashion the hook plate after one of the holes was cut to remove one third of its circumference. The remaining cut ends were bent through about 100 degrees palmarly to create two pointed hooks. The nail bed was elevated subperiostally for placement of the hook plate. The dorsal fragment was reduced and held in place by the two hooks of the plate over the dorsal lip of the fracture fragment. The hook plate was fixed with one or two 1.3mm diameter self-tapping titanium screw advanced obliquely into the main portion of the distal phalanx. The fixation was confirmed by fluoroscopic images.

It is generally agreed that most mallet finger injuries should be treated with immobilization of the distal interphalangeal joint in extension by splints. Surgical treatments were found to have higher complication rate than non-surgical treatments. Some surgical complications were technique related. However, surgical procedures are still considered necessary for treatment of mallet fractures involving more than one third of the articular surface or where the distal interphalangeal joint is subluxed. Various different surgical options had been described and proposed for treatment of mallet fractures. Many of them require open reduction, internal fixation and protection of fixation by trans-articular axial Kirschner wire in the clinical setting since they may not have the adequate strength to withstand the forces generated during early mobilization. This is believed to be the cause of the joint stiffness after operation due to the
articulare damage during the procedure and also the postoperative immobilization of the joint.

Some closed procedures using percutaneous Kirschner wires had been described e.g. the Ishiguro technique. Many complications of open surgery can be avoided by closed procedures. Clinically, the "umbrella handle" technique can reduce and immobilize a grossly displaced dorsal fragment easily using an ordinary Kirschner wire and allows immediate mobilization of the joint after operation. It has many advantages e.g. low cost, low technical demand, low risk of joint stiffness, low complication rate etc. It is a closed, percutaneous technique and only requires a small dorsal skin incision for the handle to pass through. The other three techniques require open reduction before internal fixation can be performed. The "umbrella handle" technique does not require trans-articular Kirschner wire fixation or protection while the figure-of-eight wire technique and the pull-in suture technique require it for protection.

The hook plate technique does not require a trans-articular Kirschner wire for protection but a thermoplastic Stack splint has to be fabricated and applied post-operatively for 6 weeks. It can be removed for ten minutes every one hour for protected active mobilization exercises. The "umbrella handle" technique requires a minor procedure at the out-patient clinic at 6 weeks post-operatively to remove the Kirschner wire through a small dorsal skin incision under local anaesthesia. For patients received the figure-of-eight wire technique and the hook plate technique, they need another formal open surgery to remove the implants from the digit.

CONCLUSION

It is necessary to design a biomechanical study to identify the strongest fixation technique among common mallet finger fracture fixation methods in the future.

REFERENCES