Acta Orthop. Belg., 2010, **76**, 425-431

REVIEW ARTICLE

Operative management of intra-articular distal interphalangeal joint fractures of the hand

Kanthan THEIVENDRAN, Talvinder SINGH, Vaikunthan RAJARATNAM

From the Birmingham Hand Centre, University Hospital Birmingham, UK

The management of intra-articular fractures of the hand represents a challenge. Large articular fragments require reduction and operative fixation. A number of surgical techniques have been described in literature, with variable results. Distal interphalangeal joint fractures have been fixed by various methods including screw, plate and suture techniques. Generally operative fixation is indicated when more than 30% of the articular surface is involved with or without subluxation of the joint. The aim of surgery is to reduce the fracture fragments anatomically whilst providing osseous stability, and to commence early active movement of the joint to prevent stiffness. In this review we aim to summarise the main management options for intra-articular distal interphalangeal fractures, placing particular emphasis on surgical treatment.

Keywords : distal interphalangeal joint ; fracture ; hook plate ; internal fixation.

INTRODUCTION

Fractures involving the phalanges of the hand are the most common fractures of the skeletal system ; they account for 10% of all bony injuries (5). Most of them are treated with a brief period of immobilisation, followed by early range of motion exercises.

In contrast to unstable extra-articular metaphyseal and diaphyseal fractures which can be treated with percutaneous pinning, intra-articular fractures often require open reduction and internal fixation (ORIF) to restore the articular congruity and to allow early active movement.

Fractures involving the articular surface of the distal interphalangeal joint (DIPJ) are generally treated non-operatively. However, if the articular fragment involves a significant portion of the articular surface, internal fixation has been advocated to restore stability and pain free range of motion.

According to the articular segment involved, fractures of the DIPJ can be distinguished as mallet fractures, flexor avulsion fractures and condylar fractures of the middle phalanx.

MALLET FRACTURES

Mallet fractures involve avulsion of the dorsal base of the distal phalanx with the attached extensor tendon. Disruption of the extensor mechanism results in a characteristic flexion deformity of the DIPJ (mallet deformity). The mechanism of injury usually involves an axial load which forcibly flexes

■ Kanthan Theivendran, MRCS, Specialist Registrar.
■ Talvinder Singh, MRCS, Registrar.
■ Vaikunthan Rajaratnam, FRCS, Consultant Hand Surgeon.
Birmingham Hand Centre, University Hospital Birmingham, UK.
Correspondence : Mr Kanthan Theivendran, 81 Pennine Way, Ashby-de-la-Zouch, Leicestershire LE65 1EZ, U.K. E-mail : kanthan@hotmail.co.uk

No benefits or funds were received in support of this study

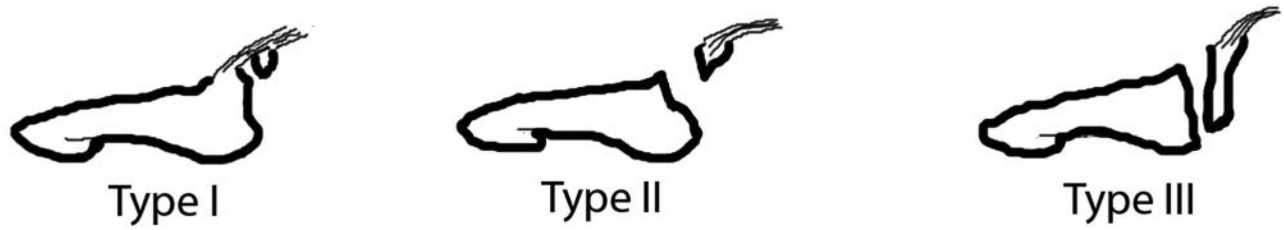

Fig. 1. — Wehbe and Schneider Classification of mallet fractures (*30*)

an extended finger and commonly results from ball related sporting activities (*19*). Larger mallet fractures can be a result of hyperextension and impaction forces (*16*).

Standard antero-posterior and lateral radiographs of the injured digit are obtained to determine comminution, subluxation of the joint and to determine the articular fragment size. Mallet fractures are classified by the Wehbe and Schneider method (table I) based on the lateral radiographs (*30*) (fig 1).

Table I. — Wehbe and Schneider (*30*) classification of mallet fractures

Type	Description
I ABC	No DIP joint subluxation
II ABC	DIP joint subluxation
III ABC	Epiphyseal & Physeal injuries
Subtype	Articular involvement
A	1/3
B	1/3 - 2/3
C	> 2/3

DIP : distal interphalangeal

An accompanying hyperextension of the proximal interphalangeal joint or swan-neck deformity is possible in each type.

The management of mallet fractures, whether conservative or operative, has remained controversial as no single treatment modality has shown to resolve issues with arthritis, deformity, stiffness and complications (*3*). Suboptimal treatment can lead to extensor lag, swan neck deformity and post-traumatic osteoarthritis (*7,30*).

Nonoperative Treatment

Mallet avulsion fractures are most often treated in a closed manner When there is less than one third of the articular surface involved with no volar subluxation, then DIPJ extension splinting for 6 to 8 weeks can be used, followed by gradual introduction of active flexion. Kalainov *et al* retrospectively reviewed 22 closed mallet fractures involving more than one third of the joint treated conservatively in a splint. Patients reported negligible pain, minimal difficulties with activities of daily living and work, relatively high satisfaction with finger function and treatment outcome, but only marginal satisfaction with finger appearance (*13*). However, these authors noted that more severe type IIB mallet fractures were associated with large joint prominences, swan-neck deformities and moderate arthritis. However, the difference between type IB and type IIB cases was not significant. This study is in agreement with Wehbe and Schneider's observations that most mallet fractures can be treated conservatively regardless of subluxation, size and amount of displacement of the bony fragment (*30*).

Operative Management

Operative fixation has been advocated when the mallet avulsion fracture involves a fragment greater than one third of the articular surface, or in case of persistent volar subluxation and displacement of the fracture fragment despite splintage of the DIPJ in full extension (*3*). Some authors have advocated that the operative goal is to maintain a stable arc of motion of the DIPJ without subluxation (*21*) whilst others have advocated anatomical reduction and internal fixation to prevent residual deformity, post traumatic arthritis and stiffness (*8*). Husain *et al* in their biomechanical cadaveric study of surgically created mallet fractures aimed to identify the size of the fracture fragment that may lead to subluxation. They concluded that subluxation consistently occurred with a defect greater than 52% of the articular surface whereas less than 43% involvement resulted in no observed subluxations (*11*). The authors did not mention the mechanism of injury which would be relevant to this study. As explained earlier, forced flexion when the joint is in extension is the usual mechanism but hyperextension forces may also play a role and may account for larger fracture fragments and subluxed joints (*16*).

Surgical Anatomy

The terminal extensor tendon is a thin, flat structure approximately 1 mm thick and 4-5 mm wide. This tendon occupies the sparse space between the bone and dorsal skin and inserts onto the dorsal base of the distal phalanx, well proximal to the germinal nail matrix. At the DIPJ, the tendon's excursion is only a few millimeters from full joint extension to 80° of flexion. The tendon is the terminal extension of the dorsal mechanism, which is a complex crossing of fibers at the PIPJ and at the metacarpophalangeal joint (MCPJ). The volar plate inserts onto the epiphysis and proximal metaphysis of the distal phalanx and the FDP tendon inserts and flares out at the metaphyseal region.

Surgical Techniques

A variety of techniques have been described in the literature and can be grouped into K-wire fixation methods including open K-wiring (*8,26*), percutaneous pin fixation (*6,31*), extension block pinning (*10*) and compression pin fixation (*31*). Open reduction and internal fixation using screws (*15*) and tension band techniques using tension band wires (*1,12*), pull-out steel wires (*2*) and hook plate (*27,29*) fixation techniques have also been described.

Fritz *et al* used open compression single double-ended K-wire fixation with the pin passing through the fracture site after reduction and stabilised by trans-articular passage of the wire in the middle phalanx. Twenty four of these cases were retrospectively reviewed. The average range of motion was from 2 to 72° of flexion. Nineteen patients were pain free, with 22 patients successfully treated according to the Warren and Norris classification. They reported no significant dorsal bump or residual mallet deformity. There were no pin tract infections or skin necrosis. Minimal ridging of the nail occurred in two patients (*6*). The extension block K-wire technique allows closed reduction of the fragment, but transfixation of the DIPJ can produce an extension lag of up to 20° and the complications rate ranges between 5% to 60% (*10,22,28*). These include pin-tract infections, skin necrosis, nail deformities, spur formation, joint narrowing and loss of reduction. Yamanaka and Sasaki used percutaneous 1.2 mm compression pin fixation of the dorsal fragment after reduction with an extension block K-wire. The K-wire was removed and patients were allowed active movements after a few days. They reported in their series of 15 patients a mean active range of movement of the DIPJ from 1° of hyperextension to 69°of flexion. One patient had an extensor lag of 20° at the DIPJ due to rupture of the terminal extensor tendon (*31*).

Kronlage and Faust used 0.8 mm screws to fix the dorsal fragment. Patients were allowed to start active movement after 4 weeks. In their series of 12 patients the mean range of motion was from 6° (extensor lag) to 70°of flexion. They noted volar prominence of the screw on radiographs of six patients who were asymptomatic. One patient had a dorsal bump related to a backed out screw and another with a loss of reduction due to poor compliance (*15*).

Tension band wiring of mallet fractures tend to produce poorer results compared to tension band wiring of other avulsion type fractures in the hand (*1*). Bischoff *et al* reviewed 24 patients treated with tension band wiring with an average follow-up of 14 months. They noted an average range of motion at the DIPJ of 50° (range : 15°-90°). Secondary operations for removal of the wire were needed in 20. Complications included infection, skin breakdown, loss of reduction, extensor tendon

Fig. 2. — Lateral (A) and anterior-posterior (B) radiographs of a mallet fracture with 50% involvement of the articular surface.

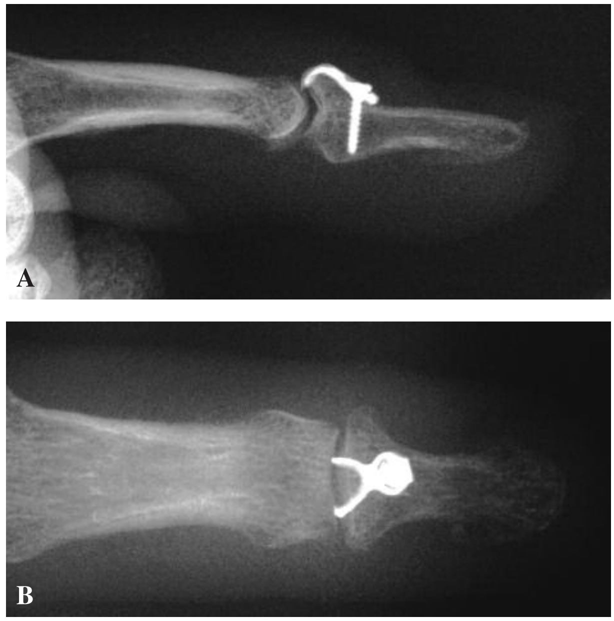

Fig. 3. — Lateral (A) and anterior-posterior (B) radiographs 7 weeks after surgery showing fracture union and hook plate *in situ.*

rupture, avascular necrosis of the fragment and nail growth disturbance (*1*). A biomechanical study by Damron *et al* compared common internal fixation techniques for bony mallet injuries and found figure-of-eight wiring and tension band suturing to be superior to K-wire fixation or tension band wiring (*3*).

More recently the tension band principle has been used in the form of a hook plate to fix large mallet fractures (*27,29*). Teoh and Lee and Theivendran *et al* described the use of a two-hole 1.3 mm AO modular titanium plate modified by cutting one end of the plate and bending the tips to form two hooks (fig 2 & 3). The plate is secured with a 1.3 mm screw with the hooks compressed onto the tendon substance and the dorsal lip of the bony fragment. Teoh and Lee in their series of 9 patients treated with this hook plate had excellent and good results according to the Crawford classification, with a mean flexion of the DIPJ of 64°. There were no hardware, infection or nail bed complications. However, they elected to routinely remove the metalwork, although this was not a mandatory part of the treatment. They concluded that, whilst being a demanding procedure to perform, it did allow early movement with acceptable functional outcomes. However, it is a short-term study with a small number of cases and further long-term studies will be required, with comparison with other well established procedures to find out the benefits of anatomical reduction with this plate.

FLEXOR DIGITORUM PROFUNDUS (FDP) AVULSION FRACTURES

Leddy and Packer described three types of avulsion injuries involving the FDP tendon (*17*). In type I, the tendon retracts to the palm with disruption of the entire vincula system. This may lead to stump ischaemic degeneration, and repair should be performed promptly (within 7-10 days). Type II avulsion is the most common type and is characterized by retraction of the tendon to the PIP level that spares the vinculum longum, therefore maintaining the blood supply. These can be reconstructed weeks to months later. In type III, the profundus tendon avulsion occurs along with a fracture of the distal phalanx base (fig 4). Retraction is prevented beyond

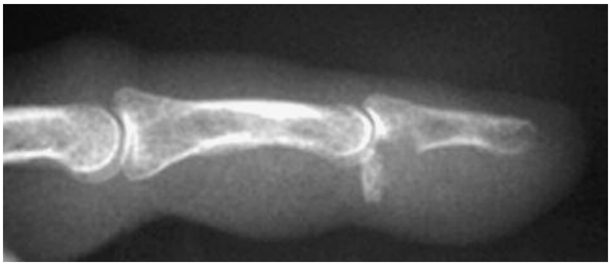

Fig. 4. — Lateral radiograph showing a Leddy and Packer Type III FDP avulsion fracture at the base of the distal phalanx (*17*).

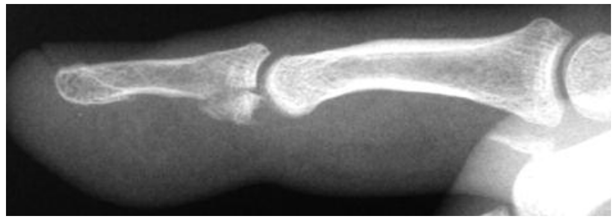

Fig. 5. — Lateral radiograph showing a Type IV FDP avulsion with fracture at the base of the distal phalanx with a further bony fragment attached to the tendon tethered at the proximal interphalangeal joint level.

the head of the middle phalanx as the bony fragment is caught on the distal tendon sheath.. Later Smith (*24*) added a fourth type in which, in addition to the original type III, there was also an avulsion of the tendon from the avulsed bony fragment with tendon retraction as in types I and II (fig 5). The focus will be on the management of types III and IV injuries involving the joint.

Non-operative treatment

Undisplaced type III injuries can be treated non-operatively in medically unfit patients and in patients with low functional demand and poor compliance. However, all displaced type III and IV injuries should be treated surgically.

Operative management

Surgical fixation of Type III and IV injuries is advocated in most patients. Patients with large bony fragments will have less tendon retraction but the fragment may involve a significant part of the articular surface and can cause joint instability and pain.

Surgical techniques

Type III injuries can be treated in a variety of ways. Crossed K-wires have been described by Strickland (*25*) and intraosseous K-wires by Moeimen and Elliot (*20*). However, interosseous wiring can be difficult to achieve without injury to the nailbed or extensor mechanism. Avulsed fragments are often fragile such that the wires cut out when they are tightened. Additionally, the size of the avulsed fragments (relative to K-wires) may make it difficult to achieve rigid fixation with crossed K-wires. Kang *et al* used a mini plate and screws to fix these bony fragments (*14*). They exposed the fracture site through a midlateral incision with an oblique extension across the pulp. The avulsed fragment with the FDP tendon attached was retrieved and reduced. A two- or three-hole titanium miniplate was modified by clipping off an appropriate length from a miniplate (Leibinger). The plate was contoured to the bone and was then fixed with a single 1.5 mm bicortical screw placed in the proximal fracture fragment ; one or two bicortical screws were used to fix the plate to the distal phalanx. The five cases in this series achieved bony union by 6 months with one rupture of the FDP at 2 weeks. All five patients were satisfied with the operation. This is a small case series with short follow-up, and potential problems with the high profile plates which may become loose over a longer period were not investigated. A single 2.0 mm screw has been used to fix the avulsed bony fragment and a pull-out suture repair was used to fix the tendon to bone in type IV injuries (*4*). The screw and the pull-out suture were removed after 7 weeks and the patient achieved a near normal range of movement at the distal interphalangeal joint. Suture fixation of Type IV injuries has recently been described in two cases with and without mini screw and K-wires supplementation by Henry *et al* (*9*). They noted disappointing outcomes in their patients as one had joint incongruity and minimal active DIPJ range of motion despite early range of motion therapy. They recommend independent repairs of the bone and tendon, as rigid fixation of the fracture is essential to allow early active movement. If Type IV injuries are suspected, MRI or ultrasound is useful to identify the lesion preoperatively.

MIDDLE PHALANX CONDYLAR FRACTURES

These fractures have been classified by London (*18*). Grade I injury involves an undisplaced unicondylar fracture that tends to be stable. Treatment is generally non-operative with protective splinting for 2 to 3 weeks followed by active range of motion exercises without resistance. It is important to follow these injuries closely with serial radiographs as they may displace. Grade II injuries are displaced intercondylar fractures. ORIF should be performed via a dorsal incision with fracture reduction and fixation with either 1 or 2 small K wires or using a mini fragment lag screw. K wires may be preferable to prevent further comminution. Mobilisation may be started at 3 to 4 weeks post injury. Grade III injuries are bicondylar or comminuted fractures which may be associated with significant soft tissue injuries. Attempts should be made to perform closed reduction and splinting. Due to the multi-fragmented nature of the injury, anatomical reduction and internal fixation is often difficult to achieve (*23*). A single small 1.0 mm K-wire can be used to align the condyles and the joint is protected with a splint for 4 to 6 weeks.

REFERENCES

1. **Bischoff R, Buechler U, De Roche R *et al.*** Clinical results of tension band fixation of avulsion fractures of the hand. *J Hand Surg* 1994 ; 19-A : 1019-1026.
2. **Damron TA,Engber WD.** Surgical treatment of mallet finger fractures by tension band technique. *Clin Orthop Relat Res* 1994 ; 300 : 133-140.
3. **Damron TA, Engber WD, Lange RH *et al.*** Biomechanical analysis of mallet finger fracture fixation techniques. *J Hand Surg* 1993 ; 18-A : 600-607 ; discussion 608.
4. **Eglseder WA and Russell JM.** Type IV flexor digitorum profundus avulsion. *J Hand Surg* 1990 ; 15-A : 735-739.
5. **Emmett JE,Breck LW.** A review and analysis of 11,000 fractures seen in a private practice of orthopaedic surgery, 1937-1956. *J Bone Joint Surg* 1958 ; 40-A : 1169-1175.
6. **Fritz D, Lutz M, Arora R *et al.*** Delayed single Kirschner wire compression technique for mallet fracture. *J Hand Surg* 2005 ; 30-B : 180-184.
7. **Garberman SF, Diao E,Peimer CA.** Mallet finger : results of early versus delayed closed treatment. *J Hand Surg* 1994 ; 19-A : 850-852.
8. **Hamas RS, Horrell ED,Pierret GP.** Treatment of mallet finger due to intra-articular fracture of the distal phalanx. *J Hand Surg* 1978 ; 3-A : 361-363.
9. **Henry SL, Katz MA,Green DP.** Type IV FDP avulsion : lessons learned clinically and through review of the literature. *Hand (NY)* 2009 : 4 : 357-361.
10. **Hofmeister EP, Mazurek MT, Shin AY *et al.*** Extension block pinning for large mallet fractures. *J Hand Surg* 2003 ; 28-A : 453-459.
11. **Husain SN, Dietz JF, Kalainov DM *et al.*** A biomechanical study of distal interphalangeal joint subluxation after mallet fracture injury. *J Hand Surg* 2008 ; 33-A : 26-30.
12. **Jupiter JB, Sheppard JE.** Tension wire fixation of avulsion fractures in the hand. *Clin Orthop Relat Res* 1987 ; 214 : 113-120.
13. **Kalainov DM, Hoepfner PE, Hartigan BJ *et al.*** Nonsurgical treatment of closed mallet finger fractures. *J Hand Surg* 2005 ; 30-A : 580-586.
14. **Kang N, Pratt A, Burr N.** Miniplate fixation for avulsion injuries of the flexor digitorum profundus insertion. *J Hand Surg* 2003 ; 28-B : 363-368.
15. **Kronlage SC, Faust D.** Open reduction and screw fixation of mallet fractures. *J Hand Surg* 2004 ; 29-B : 135-138.
16. **Lange RH, Engber WD.** Hyperextension mallet finger. *Orthopedics* 1983 ; 6 : 1462-1421.
17. **Leddy JP, Packer JW.** Avulsion of the profundus tendon insertion in athletes. *J Hand Surg* 1977 ; 2-A : 66-69.
18. **London PS.** Sprains and fractures involving the interphalangeal joints. *Hand* 1971 ; 3 : 155-158.
19. **McCue FC 3rd, Meister K.** Common sports hand injuries. An overview of aetiology, management and prevention. *Sports Med* 1993 ; 15 : 281-289.
20. **Moiemen NS, Elliot D.** Primary flexor tendon repair in zone 1. *J Hand Surg* 2000 ; 25-B : 78-84.
21. **Niechajev IA.** Conservative and operative treatment of mallet finger. *Plast Reconstr Surg* 1985 ; 76 : 580-585.
22. **Pegoli L, Toh S, Arai K *et al.*** The Ishiguro extension block technique for the treatment of mallet finger fracture : indications and clinical results. *J Hand Surg* 2003 ; 28-B : 15-17.
23. **Schneider LH.** Fractures of the distal phalanx. *Hand Clin* 1988 ; 4 : 537-547.
24. **Smith JH Jr.** Avulsion of a profundus tendon with simultaneous intraarticular fracture of the distal phalanx – case report. *J Hand Surg* 1981 ; 6-A : 600-601.
25. **Strickland JW.** Flexor tendons-acute injuries, in Green DP, Hotchkiss RN, Pederson WC (eds) : *Operative Hand Surgery*. Churchill-Livingstone, New York. 1999, pp 1877-1883.

26. Takami H, Takahashi S, Ando M. Operative treatment of mallet finger due to intra-articular fracture of the distal phalanx. *Arch Orthop Trauma Surg* 2000 ; 120 : 9-13.

27. Teoh LC, Lee JY. Mallet fractures : a novel approach to internal fixation using a hook plate. *J Hand Surg Eur Vol* 2007 ; 32 : 24-30.

28. Tetik C, Gudemez E. Modification of the extension block Kirschner wire technique for mallet fractures. *Clin Orthop Relat Res* 2002 ; 404 : 284-290

29. Theivendran K, Mahon A, Rajaratnam V. A novel hook plate fixation technique for the treatment of mallet fractures. *Ann Plast Surg* 2007 ; 58 : 112-115.

30. Wehbe MA, Schneider LH. Mallet fractures. *J Bone Joint Surg* 1984 ; 66-A : 658-669.

31. Yamanaka K, Sasaki T. Treatment of mallet fractures using compression fixation pins. *J Hand Surg* 1999 ; 24-B : 358-360.