The Hook Plate Technique for Fixation of Phalangeal Avulsion Fractures

Gavin Chun-Wui Kang, MBBS, MRCSEd, MMed(Surg), MEng, Andrew Yam, MBBS, MRCSEd, MMed(Surg), Ee San Phoon, MBBS, MRCSEd, MMed(Ortho), Jonathan Yi-Liang Lee, MBBCh, MRCSEd, MMed(Surg), and Lam-Chuan Teoh, MBBS, MMed(Surg), FRCS(Glas)

Investigation performed at Singapore General Hospital, Singapore

Background: Avulsion fractures of the phalanges involve small osseous fragments that are usually attached to structures that are necessary for stability or movement of the joint. Satisfactory healing of the fracture to preserve joint function may require open reduction and internal fixation, which can be difficult because of the small size of the fragments.

Methods: We used a hook plate fashioned from a 1.3-mm Synthes titanium plate in thirteen patients with a phalangeal avulsion fracture. Four patients had an avulsion fracture of the volar plate with dorsal proximal interphalangeal joint dislocation, four had a dorsal avulsion fracture of the extensor central slip from the middle phalanx, three had a flexor digitorum profundus avulsion fracture from the distal phalanx, and two had an avulsion fracture of the phalangeal insertion of the collateral ligament.

Results: Union without complications was achieved in all cases. After an average duration of follow-up of seventeen months, all patients had a good to excellent result and the average total interphalangeal motion was 149°.

Conclusions: This indirect fixation technique produces stable fixation allowing early active finger motion.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

Avulsion fractures of the phalangeal base are periarticular fractures containing the insertion of a volar plate, tendon, or ligamentous structure. Flexor or extensor tendon avulsion results in loss of motion at the interphalangeal joint. Avulsion of the volar plate or collateral ligament insertion disrupts joint stability, particularly if the fragment is large. Accurate reduction and stabilization of these fractures restores joint function and integrity, with early postoperative motion necessary to prevent stiffness. Unfortunately, stable fixation of small bone fragments is not easily obtained with use of conventional techniques and implants[1,2]. The smaller the fragment, the more difficult it is to secure stable fixation.

A variety of fixation methods are currently used for the treatment of avulsion fractures of the phalanges[3-5]. The most stable fixation is the interfragmentary screw technique, but the diameter of the fragment should be at least three times that of the screw to avoid fragmenting the small bone piece under the compressive force. Accurate placement of the implant is necessary for optimum stability, and other methods include wire suture, tension band wire, Kirschner wire, and plates[3-5]. Kirschner-wire and extension-block-pin fixation alone are not compressive and are not stable enough to allow immediate postoperative joint motion, with a risk of infection if the pins are left external to the skin. Stability and compression are increased by adding a tension band wire or intraosseous wire suture. Tension band wiring as reported by Jupiter and Sheppard and other authors is applicable to collateral ligament and extensor avulsion fractures[6-9]. For this technique to work, the fixation has to be placed on the tension side[6]. This fixation works well if placed dorsally or laterally on the tension side of the joint but is difficult to use for volar avulsion fractures. A pull-out intraosseous wire with an external button may predispose to infection along the wire, and the button may cause pressure damage to the underlying skin or nailbed. These techniques also require drilling tunnels

Disclosure: None of the authors received payments or services, either directly or indirectly (i.e., via his or her institution), from a third party in support of any aspect of this work. None of the authors, or their institution(s), have had any financial relationship, in the thirty-six months prior to submission of this work, with any entity in the biomedical arena that could be perceived to influence or have the potential to influence what is written in this work. Also, no author has had any other relationships, or has engaged in any other activities, that could be perceived to influence or have the potential to influence what is written in this work. The complete **Disclosures of Potential Conflicts of Interest** submitted by authors are always provided with the online version of the article.

THE JOURNAL OF BONE & JOINT SURGERY · JBJS.ORG
VOLUME 94-A · NUMBER 11 · JUNE 6, 2012

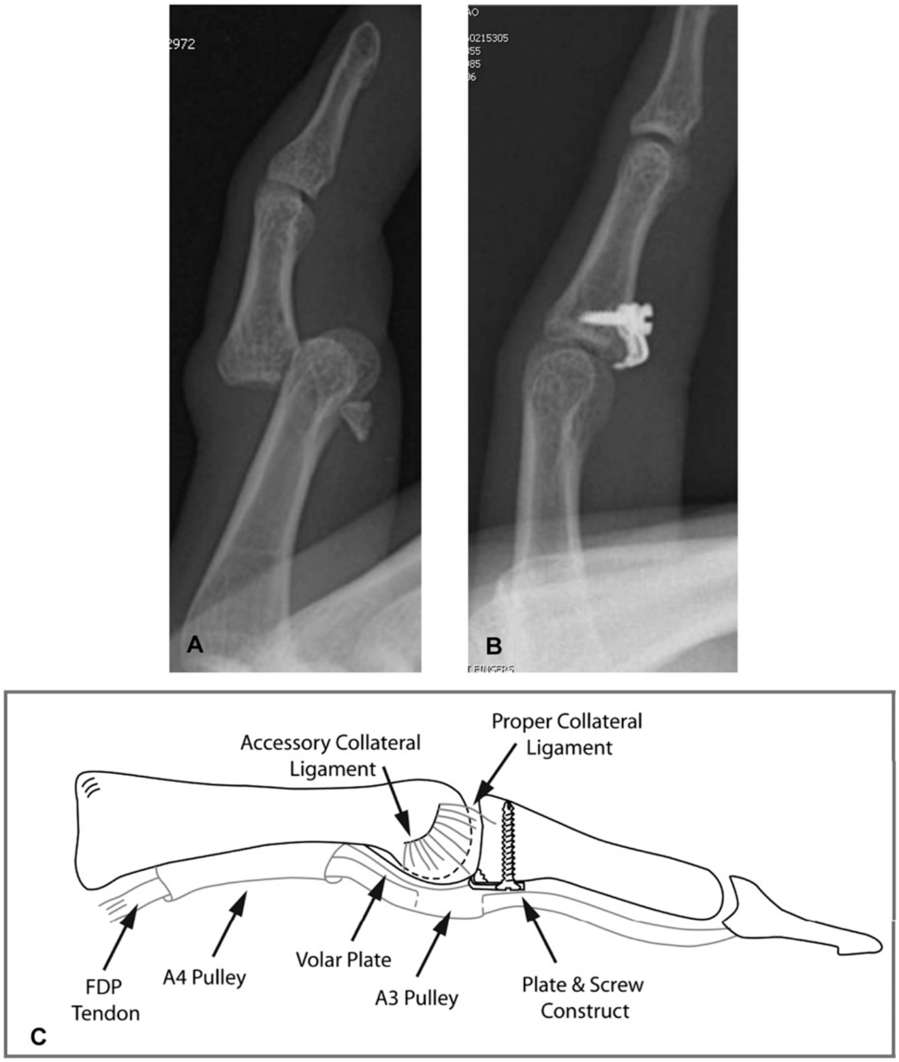

Fig. 1

Figs. 1-A, 1-B, and 1-C A twenty-one-year-old man sustained a dorsal fracture dislocation of the proximal interphalangeal joint of the left little finger. **Fig. 1-A** Lateral radiograph showing that the palmar fragment with the attached volar plate has rotated and migrated proximally. **Fig. 1-B** Lateral radiograph showing osseous union at three months. The fracture had been exposed with a palmar Bruner incision, and the reduced fracture had been fixed with hook plates. Two adjacent hook plates, located side by side, had been used to provide optimal fixation of the relatively broad fragment. **Fig. 1-C** Illustration showing hook plate fixation of a volar plate avulsion fracture. FDP = flexor digitorum profundus.

in the bone fragments for the wires, which requires more dissection to expose the bone.

Teoh and Lee reported on the use of a "hook plate" fashioned from a 1.3-mm titanium Synthes plate for the fixation of mallet fractures of the distal phalangeal base[10]. The hook plate acts as both a buttress and tension band, without the placement of an implant across the small bone fragment. Minimal bone exposure beyond the fracture site is needed to place the screw that holds the plate in place. The fixation is usually stable enough for early mobilization, and no implants are external. Since then, the senior author (L.-C.T.) has widened the indications for this technique to include stabilization of all periarticular small-fragment fractures of the phalangeal bases. In the present report, we describe the successful use of this technique in thirteen patients with various phalangeal avulsion fractures.

Materials and Methods

Over a period of seven years, from January 2003 to April 2010, thirteen phalangeal avulsion fractures in thirteen patients were identified and treated with open reduction and internal fixation with use of the hook plate technique. Four patients had an avulsion fracture of the volar plate with dorsal proximal interphalangeal joint dislocation, four had a dorsal avulsion fracture of the extensor central slip from the middle phalanx with boutonnière deformity, three had a flexor digitorum profundus avulsion from the distal phalanx, and two had a phalangeal collateral ligament avulsion fracture. The patients included eleven men and two women with a mean age of 44.3 years (range, twenty-one to sixty-three years). The affected digits included six little fingers, three long fingers, two index fingers, and two ring fingers. The injuries were sustained in a wide variety of settings, including sports activity, assault, and

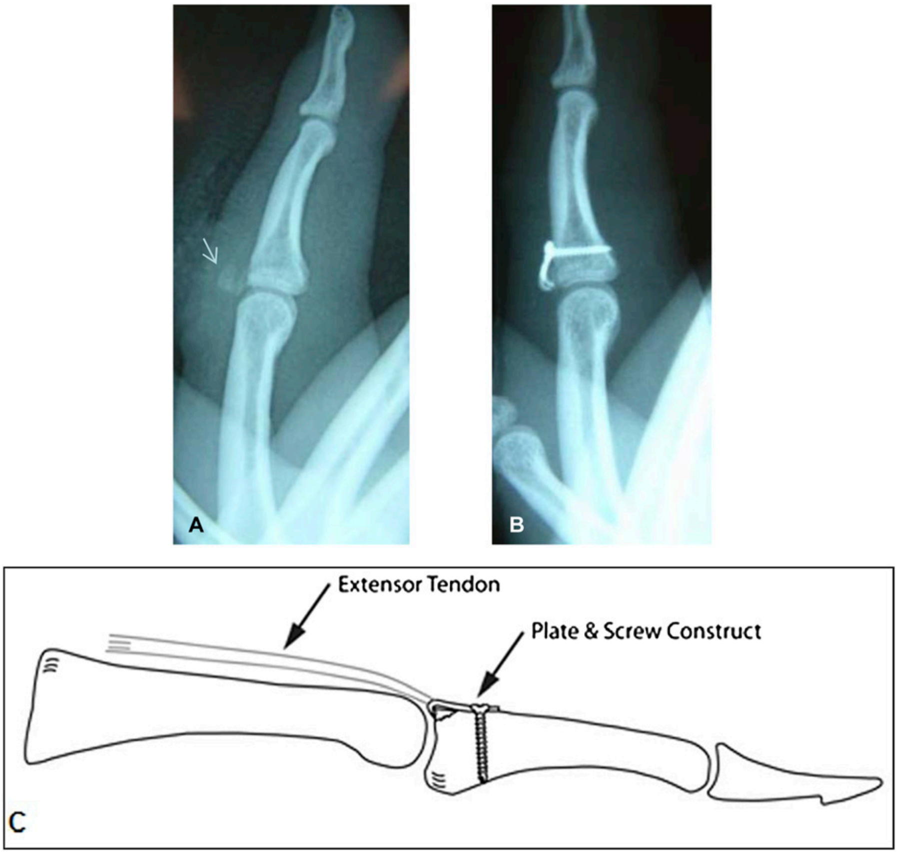

Fig. 2

Figs. 2-A, 2-B, and 2-C A thirty-seven-year-old man sustained an open injury of the left ring finger. **Fig. 2-A** Radiograph showing that the extensor central slip was avulsed with a small bone fragment (arrow) from the dorsal lip of the base of the middle phalanx. **Fig. 2-B** Radiograph made three months after hook plate fixation. The osseous fragment was well united. **Fig. 2-C** Illustration showing the hook part of the plate biting into the extensor central slip and the fracture fragment secured to the middle phalanx with a single screw.

industrial accident. The average time from the injury to the operation was 8.2 days (range, one to twenty days).

Preoperative anteroposterior and lateral radiographs were used to determine the presence of subluxation of the involved phalanx, fracture fragment displacement, fragment size, and the degree of comminution. Operative fixation was indicated if the avulsion fracture fragment was unstable and displaced, causing joint instability and loss of function from the avulsed structures. As the smallest screws available are 1.3 mm in diameter, interfragmentary screw fixation was avoided if the avulsed fragments were <5 mm in diameter and the hook plate technique was used instead.

All procedures were performed with the patient under general or regional anesthesia. An arm tourniquet was inflated after upper limb exsanguination. An arm tourniquet was used at the surgeon's preference, but the technique can be performed with use of digital block with a digital tourniquet replacing the arm tourniquet if pain occurs after inflation of the arm tourniquet. The hook plate is fabricated from a 1.3-mm AO modular hand system titanium plate (Synthes, Zuchwil, Switzerland). Detailed instructions on how to fabricate the hook plate are included in the original report by Teoh and Lee[10]. The hooks of the plate bite into soft tissue at its insertion into the bone, allowing the small fragment to be reduced and braced onto the main fracture fragment. The plate crosses the fracture line and is fixed with a single screw distal to the fracture (Figs. 1 through 4). A single-hole plate is usually sufficient. If there is fracture comminution or if the fragment is larger, a two-hole plate may be necessary to allow screw placement beyond the fracture line.

For avulsion fractures of the volar plate with dorsal proximal interphalangeal joint dislocations (four cases), we used a palmar Bruner incision to open the A3, C2, and C3 pulleys and then retracted the profundus and superficial flexor tendons to expose the fragment directly. The proximal interphalangeal joint was first reduced by means of traction and manipulation. The avulsion fragment was reduced, and a 1.3-mm hook plate was placed over the fracture fragment, with the proximal hook end biting into the soft volar plate. The plate crossed the fracture line, and the distal hole was fixed with a 1.3-mm screw into the main fragment of the phalanx. In one case of volar plate avulsion, the fragment was a thin rim of bone measuring <5 mm wide but extended across the base of the proximal phalanx (Fig. 1). Two hook plates, placed side by side, were used to ensure stable fixation (Fig. 1). There was one pilon fracture with associated metaphyseal comminution that required bone-grafting. A two-hole hook plate was necessary to place the screw securely in strong bone beyond the zone of injury. Stability of the fixation was confirmed by passively moving the joint through a full range of passive motion under mini c-arm fluoroscopy.

Four patients had a digital injury with boutonnière deformity resulting from an avulsion fracture of the extensor central slip. The fractures were approached dorsally with a curved incision over the proximal interphalangeal joint. Reduction was accomplished by placing the proximal interphalangeal joint in neutral and dorsally translating the middle phalanx into concentric reduction of the proximal interphalangeal joint and then reducing the fragment into position. Care should be taken to translate the middle phalanx dorsally as attempting to extend it at the proximal interphalangeal joint will result in hinging at the fracture site and a nonconcentric reduction of the joint. In cases of chronic volar subluxation, the collateral ligaments may need to be released partially to achieve dorsal translation of the middle phalanx and concentric reduction of the proximal interphalangeal joint.

Fig. 3

Figs. 3-A and 3-B A thirty-seven-year-old man fell and sustained a closed injury of the left little finger. **Fig. 3-A** Radiograph showing that the flexor digitorum profundus was avulsed with a small bone fragment (arrow) from the distal phalanx that retracted to the level of the proximal phalanx. **Fig. 3-B** Radiograph made three months after hook plate fixation. The osseous fragment was well united.

A single 1.3-mm hook plate was used for the fixation. The hook end of the plate bit into the central slip tendon, the plate braced the small fracture fragment, and the distal hole was fixed with a 1.3-mm screw onto the main fragment of the phalanx (Fig. 2). The stability of the fixation was tested by moving the proximal interphalangeal joint passively into full flexion under mini c-arm fluoroscopy.

Three patients had a Leddy and Packer Type-III flexor digitorum profundus avulsion[11]. The profundus carried an avulsed bone fragment from the distal phalanx and was tethered over the distal end of the A4 flexor pulley. A palmar Bruner incision that extended partially into the pulp was used to reduce the fracture fragment and attached profundus tendon back onto the distal phalanx. The hook end of the 1.3-mm hook plate bit into the flexor tendon, and the plate braced the fracture fragment and was fixed to the distal phalanx with a 1.3-mm screw (Fig. 3). In these cases, the fragment was large enough to place another 1.3-mm screw through the slot between the hooks for additional stability. Here, the plate also acted as a holder for the fragment, as a guide for accurate interfragmentary screw placement, and as a shield against fragmentation, simplifying the process of interfragmentary screw fixation.

Two patients had a collateral ligament avulsion fracture involving the metacarpophalangeal joint (one patient) or the proximal interphalangeal joint (one patient). The fragments were widely displaced, and the joints were grossly unstable. Fixation was indicated as we thought that the risk of fibrous nonunion with persistent symptomatic instability was high. The fracture was exposed through a dorsolateral incision, and the hook end of the plate was hooked onto the collateral ligament insertion; the plate braced the fracture fragment and was fixed to the phalanx with a 1.3-mm screw (Fig. 4).

On the second postoperative day, the surgical dressing was lightened and the patient was started on hand therapy tailored to the fracture type. For avulsion fractures at the proximal interphalangeal joint involving the volar plate, extensor central slip, or collateral ligaments, the joint was immobilized in full extension in a thermoplastic splint at rest to prevent the development of flexion contracture. The splint was removed and active flexion and extension exercises with passive assist were performed for ten minutes every hour. Following stable repair of the flexor profundus avulsion with use of the hook plate, the patient followed the flexor tendon protocol for six weeks: full extension and flexion were allowed in a dorsal splint with the wrist flexed 30° and metacarpophalangeal joint flexed 60°.

Serial radiographs were made at three weeks, six weeks, three months, and six months to determine the time to osseous union of the fracture. Clinical data on motion at the interphalangeal joints were collected. Functional outcomes were determined on the basis of the total active range of motion as

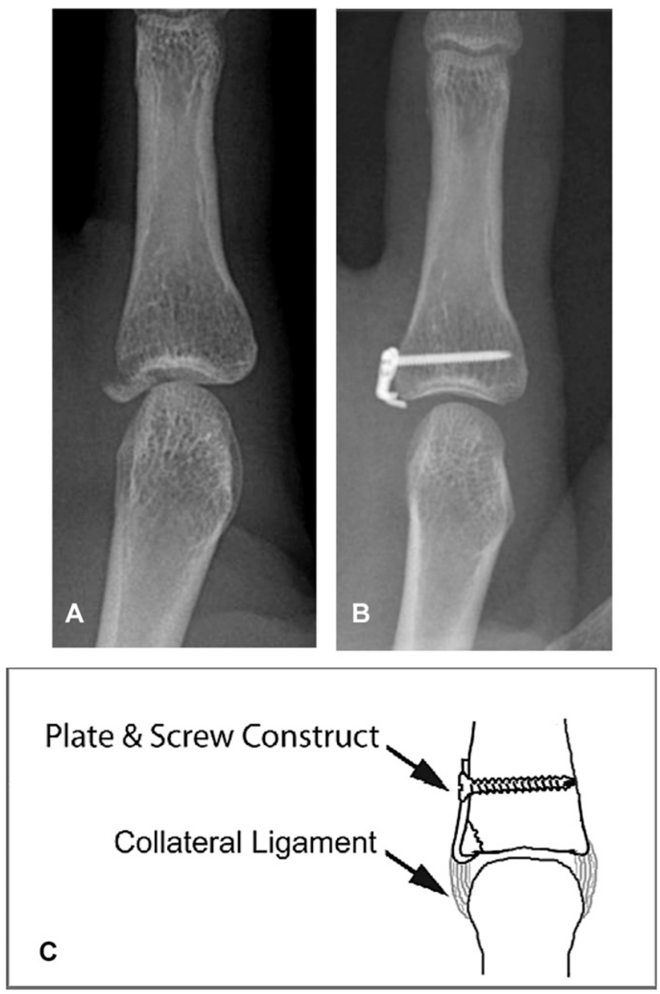

Fig. 4

Figs. 4-A, 4-B, and 4-C A thirty-four-year-old man pulled on a door handle and sustained a closed injury of the left index finger. **Fig. 4-A** Radiograph showing that the metacarpophalangeal joint ulnar collateral ligament was avulsed with a small bone fragment from the proximal phalanx. **Fig. 4-B** Radiograph made three months after hook plate fixation. The osseous fragment was well united. **Fig. 4-C** Illustration showing the hook part of the plate inserted into the collateral ligament and the fracture fragment secured to the proximal phalanx with a single screw.

described by Strickland[12]. A normal total active range of interphalangeal motion (calculated as the sum of proximal interphalangeal joint and distal interphalangeal joint active motion) of 175° was used to determine the percentage return of function.

Source of Funding
There was no external funding source.

Results

There were no complications. The average duration of follow-up was seventeen months (range, twelve to fifty-two months). Bridging trabeculae or callus was seen in all cases by six weeks after surgery. Osseous union was achieved in all cases by three months after surgery. All joints had good stability, and the articular surfaces were congruent, with no joint subluxation. All patients had returned to work by the time of the three-month follow-up.

According to the Strickland method of assessment, eleven digits had an excellent outcome (75% to 100% return of normal total range of motion of the interphalangeal joints) and two digits had a good outcome (50% to 74% return of normal total range of motion of the interphalangeal joints). The average total range of motion of the interphalangeal joints was 149°, or 85% of the normal total range of motion of the interphalangeal joints. None of the four patients who had a proximal interphalangeal joint volar plate avulsion injury developed flexion contracture, but three had an extension lag ranging from 10° to 20°. There were no cases of boutonnière deformity among the patients with proximal interphalangeal joint central slip avulsions.

We do not remove the implant unless there are adhesions or other complications related to the implant or unless the patient wants it to be removed. Eight implants in this series were removed, all at the request of the patient. Finger motion was preserved after removal of the implant in all cases.

Discussion

The majority of collateral ligament avulsion fractures of the phalanges can be treated conservatively by immobilizing the joint in a splint for three weeks followed by protected mobilization. However, some of these fractures are too widely displaced to immobilize in adequate apposition and may lead to the development of a fibrous nonunion with persistent joint instability. Volar plate avulsion fractures without dorsal subluxation can be treated with an extension block splint with the proximal interphalangeal joint in flexion to appose the fragment until the fracture unites, but serial extension splinting is later required to restore extension, and permanent flexion contracture may occur. Avulsed fragments attached to the flexor digitorum profundus must always be reduced surgically to restore flexion at the distal interphalangeal joint. Proximal interphalangeal joint subluxation can be dorsal (arising from avulsion or impaction fracture of the volar plate) or volar (arising from avulsion or impaction fracture of the extensor central slip), and the subluxation must be concentrically reduced for proper joint function. Stability is maintained in these cases by reconstituting the avulsed volar or dorsal lip of the middle phalangeal base. We believe that these fractures are all better treated with stable fixation and early mobilization. However, surgical fixation of these small fragments with use of currently published techniques either is technically demanding or does not allow sufficient early mobilization, and therefore we adapted the hook plate technique that was previously described for the treatment of mallet fractures.

Teoh and Lee described the hook plate technique for the fixation of digital mallet fractures[10]. The hook plate is fashioned from a 1.3 or 1.5-mm two-hole titanium plate that is cut to form a single-hole plate with two hooks at one end. The hook plate is a bracing indirect fixation that can act as a buttress, a tension band, or both. The hooked part hooks onto the soft tissue at its insertion into the avulsed fragment, and the fragment is braced onto the main bone by the plate, which is secured to the main fragment with a screw. We fashion our hook plates from the remnants of plates that had been cut to length for conventional phalangeal shaft fracture fixation.

The main indication for the hook plate technique is to restore joint stability in a patient with a phalangeal fracture-dislocation with a small osseous fragment. It may also be considered as an alternative to pull-out sutures as a way to restore profundus tendon continuity and to allow immediate controlled active mobilization in a patient with a small avulsion fracture of the flexor digitorum profundus insertion.

Additional study is needed to compare the hook plate with pull-out sutures for this indication, but we are encouraged by our results.

Variations to the technique described here are useful for different fracture configurations. To secure a more stable fixation of a broad and thin volar avulsion fragment, we used two hook plates that were placed side by side (Fig. 1). Although we have not used this technique, a T-plate could possibly be used and the transverse row of holes could be fashioned into a series of hooks. This T-plate version of the hook plate is advantageous in that only one screw is needed to fix a broad fragment; however, the T-plate is difficult to contour to the fragment and allows less flexibility in placement. A two-hole hook plate fashioned from a three-hole straight plate and anchored with two screws was utilized to treat pilon fracture associated with comminution. The additional length bridges the comminution completely for a more secure screw placement in good bone stock. Longer plates allowing additional screws would increase the stability of the fixation but may increase the risk of tendon adhesions and may be limited by exposure, particularly on the volar side. For larger fragments, the hook plate can be used as a holder to secure the fragment indirectly, making it easy to place an interfragmentary screw across the fracture site via the slot between the hooks. It then becomes a buttress as well as a neutralizing plate and washer to prevent fragmentation under compression. Holding a subluxated joint in reduction while applying the hook plate may be challenging, and the insertion of a temporary Kirschner wire to secure the joint reduction while fixing the avulsed fragment is useful.

Plates fixed on the volar digital surface may theoretically cause flexion adhesion and contracture as a consequence of volar soft-tissue dissection and the presence of a titanium plate. In their series of volar lip fractures of the middle phalanx that were reduced and fixed by means of a midlateral incision and volar dissection, Wilson and Rowland[13] reported eleven cases of proximal interphalangeal joint flexion contracture ranging from 5° to 20°. Their technique of Kirschner-wire fixation required pinning of the joint in slight flexion for three to four weeks before commencing mobilization. Chew and Cheah[14] reported on a patient with pilon fracture of the middle phalangeal base that was fixed with a volar titanium T-plate, resulting in a proximal interphalangeal joint range of motion of 10° to 90°. The hook plate technique is stable enough for early mobilization and introduces less foreign material than a T-plate does. We believe that our protocol of early mobilization with splinting in full extension between exercises and during sleep minimizes the risk of both adhesions and contractures.

In conclusion, the hook plate technique is a versatile and effective method of internal fixation for small avulsion fractures of phalanges. It appears to be a better alternative technique than other methods of internal fixation for these small fracture fragments and provides stable fixation to allow immediate joint motion, resulting in excellent outcomes. ■

Gavin Chun-Wui Kang, MBBS, MRCSEd, MMed(Surg), MEng
Andrew Yam, MBBS, MRCSEd, MMed(Surg)
Jonathan Yi-Liang Lee, MBBCh, MRCSEd, MMed(Surg)
Lam-Chuan Teoh, MBBS, MMed(Surg), FRCS(Glas)
Department of Hand Surgery, Singapore General Hospital,
Outram Road, Singapore 169608.
E-mail address for G.C. Kang: gavinkangcw@yahoo.com

Ee San Phoon, MBBS, MRCSEd, MMed(Ortho)
Department of Hand and Reconstructive Microsurgery,
National University Hospital, 5 Lower Kent Ridge Road,
Singapore 119074

References

1. Bekler H, Gokce A, Beyzadeoglu T. Avulsion fractures from the base of phalanges of the fingers. Tech Hand Up Extrem Surg. 2006 Sep;10(3):157-61.

2. Lee JY, Teoh LC. Dorsal fracture dislocations of the proximal interphalangeal joint treated by open reduction and interfragmentary screw fixation: indications, approaches and results. J Hand Surg Br. 2006 Apr;31(2):138-46. Epub 2005 Nov 15.

3. Lister G. Intraosseous wiring of the digital skeleton. J Hand Surg Am. 1978 Sep;3(5):427-35.

4. Sakuma M, Nakamura R, Inoue G, Horii E. Avulsion fracture of the metacarpophalangeal joint of the finger. J Hand Surg Br. 1997 Oct;22(5):667-71.

5. Shewring DJ, Thomas RH. Avulsion fractures from the base of the proximal phalanges of the fingers. J Hand Surg Br. 2003 Feb;28(1):10-4.

6. Jupiter JB, Sheppard JE. Tension wire fixation of avulsion fractures in the hand. Clin Orthop Relat Res. 1987 Jan;(214):113-20.

7. Bischoff R, Buechler U, De Roche R, Jupiter J. Clinical results of tension band fixation of avulsion fractures of the hand. J Hand Surg Am. 1994 Nov;19(6):1019-26.

8. Kozin SH, Bishop AT. Tension wire fixation of avulsion fractures at the thumb metacarpophalangeal joint. J Hand Surg Am. 1994 Nov;19(6):1027-31.

9. Watanabe K. A simple method of osteosynthesis for avulsion fractures of the thumb metacarpophalangeal joint. Hand Surg. 2005;10(2-3):209-11.

10. Teoh LC, Lee JY. Mallet fractures: a novel approach to internal fixation using a hook plate. J Hand Surg Eur Vol. 2007 Feb;32(1):24-30. Epub 2006 Nov 28.

11. Leddy JP, Packer JW. Avulsion of the profundus tendon insertion in athletes. J Hand Surg Am. 1977 Jan;2(1):66-9.

12. Strickland JW. Results of flexor tendon surgery in zone II. Hand Clin. 1985 Feb;1(1):167-79.

13. Wilson JN, Rowland SA. Fracture-dislocation of the proximal interphalangeal joint of the finger. J Bone Joint Surg Am. 1966 Apr;48(3):493-502.

14. Chew WY, Cheah AE. Volar plate and screw fixation for dorsal fracture-dislocation of the proximal interphalangeal joint: case report. J Hand Surg Am. 2010 Jun;35(6):928-30. Epub 2010 Apr 15.