Use of Low-profile Palmar Internal Fixation in Digital Replantation

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Abstract: There are multiple surgical techniques to stabilize the bone in digital replantation. Various criteria need to be considered when choosing appropriate bony fixation including operative time, ease of exposure, stability, limitation of the area of dissection, and reproducibility. We describe our technique using internal fixation with a low-profile plate on the palmar aspect of the proximal or middle phalanx during replantation of a digit. This technique allows coverage of the plate with no risk of compromising the dorsal venous anastomosis. In our experience, using this technique we have observed no complications including no secondary displacement of the fragments or extensor tendon rupture and no incidence of infection. In addition, this technique allows adequate bony fixation to enable an early active range of motion rehabilitation program.

Key Words: internal fixation, digital replantation, traumatic, early rehabilitation

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HISTORICAL PERSPECTIVE

Digital replantation has become increasingly successful and accessible in industrial countries. Microsurgical techniques and instrumentation have improved resulting in not only a focus on survival but also improved clinical and functional outcome.[1]

The main goal of replantation is improvement of function when compared with amputation. To have good range of motion and dexterity after a digital replantation, an early active range-of-motion protocol may be beneficial. Late mobilization after internal fixation with associated tendon repair can lead to joint stiffness and tendon adhesions.[2,3] One of the reasons for a poor functional result after replantation might be a conservative rehabilitation program, due either to transarticular Kirschner wires (K-wires) or insufficient bony stability.

Many techniques for internal or external fixation are used with varied success. One of the most common techniques is to use K-wire fixation. However, in transverse (and or comminuted) phalangeal fractures, rigid fixation with K-wires can be difficult. K-wire fixation in digits and metacarpals is also associated with prolonged fracture healing and higher complication rates.[4] Achieving bone stability with adequate fixation is often one of the first steps in replantation as circulation needs to be reestablished as soon as possible. As K-wire fixation is quicker, it is often preferred by some surgeons compared with internal fixation with a plate.[4] Takigami and colleagues compared internal fixation with plates with K-wire fixation of phalangeal and metacarpal fractures. They found that surgery time was significantly shorter in the K-wire group, but the internal fixation group needed significantly less postoperative immobilization.[5] Whitney and colleagues compared different K-wire fixation techniques in replantation. They reviewed 500 digital replantations and found that bony complications were seen in nearly 50% of cases. Complications included secondary displacement and nonunion.[6]

Some authors perform intramedullary fixation with headless screws.[7–9] There is a paucity of literature on the long-term results on intramedullary implants with respect to outcomes and complications including nonunion or revision surgery.

Moreover, newer implants with locking screws are low profile and have been reportedly easier to handle surgically and more stable. Ochman et al[10] compared locking and nonlocking plates for metacarpal fractures and showed that locking plates achieve a higher stability for fixation in metacarpals. According to Meuli et al,[11] the implanted fixation should avoid interference with joint and tendon function, but achieve adequate stability. Nunley et al[12] reviewed various different fixation methods and found promising results using a AO H-plate (4-hole fixation). Currently, the newer low-profile implants (1.5 mm) with locking screws have the benefits of allowing an easier and more stable fixation.

We propose that palmar placement avoids bulky material on the dorsal side of the digit where the venous anastomosis is located, and where there is limited space under the extensor tendon. We describe our palmar approach using low-profile internal fixation. We have found that using a plate on the palmar aspect combines the advantages of minimal dissection, stability, and coverage of the plate to minimize hardware complications such as interference with tendon gliding. The advantages of performing this technique could ultimately result in better functional outcomes because of commencement of early rehabilitation, which outweighs the possible longer operative time. In fact placement of the plate on the amputated part on the back table during preparation of the part by a second team can simplify fixation.

INDICATIONS/CONTRAINDICATIONS

Palmar internal fixation with plates is best used in transverse amputations, but can be used in comminuted fractures as a bridging plate. Even in very short proximal or distal fragments this technique can be used with a 1.5-mm "T" or "L" locking plate. However, if there is not enough bone stock for adequate fixation, other techniques may be more suitable (K-wires, arthrodesis). In children with open growth plates, internal fixation with plates should be avoided and K-wires may be preferable, where there is close proximity to the physis.

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SURGICAL TECHNIQUE

The patient is placed under a general anesthetic or axillary block. A tourniquet is positioned and inflated up to 250 mm Hg.

Initial management includes irrigation and debridement of the amputated digit and the replantation site. The initial exposure is guided by the mechanism and extent of the injury, which guides further dissection. Brunner incisions may be required to expose the proximal and distal neurovascular bundle and are marked for further reconstruction. The artery is exposed as proximally as necessary, to allow good blood flow before anastomosis. The palmar aspect of the proximal and middle phalanx is covered by periosteum in a layer, which is continuous with the flexor sheath pulley system. This layer can be easily elevated subperiostally with sharp dissection as far as needed to enable adequate positioning of the plate (Fig. 1). Usually, bone shortening is necessary to compensate for the tissue defect and to prevent tension on any microsurgical and/or tendon repairs.[13] In digits 5 to 10 mm is usually sufficient.[14] Shortening can also simplify fixation by converting oblique fractures to transverse fractures. If bone shortening cannot be performed (as it will compromise joint function) vein grafts need to be considered for arterial and venous anastomosis. Generally, 2 distal and 2 proximal screws are used for fixation. This may be with a straight 4-hole plate in diaphyseal injuries or either a T-plate or H-plate in periarticular injuries. The amount of shortening required is determined by careful assessment of the zone of injury and dissection of the neurovascular structures before commencing the osteosynthesis. Shortening is determined in part by the width of the zone of injury and the relative nature of the injury, that is, crushing-type versus sharp-type amputations. We have found it reasonably straightforward to make this assessment of the required amount of shortening by dissecting and debriding the neurovascular structures under the microscope on either side of the amputation initially. In most cases there is sufficient bone on the proximal side of the amputation to allow further shortening to be undertaken in the event that this assessment has been inadequate. Usually, the distal bone end undergoes minimal shortening with the preparation simply to create a transverse surface and then the plate is applied distally to the amputated part. When the amputated part is brought for fixation to the proximal bone stump, a quick assessment before proximal screw placement will rapidly reveal whether there is adequate length in the prepared neurovascular structures. If there is not, in the majority of cases it is relatively simple to achieve further shortening by performing further transverse resection of the proximal bone stump before screw fixation. We would usually use a nonlocked screw to fix the plate to the distal part and then place a second locked screw in the distal part. When the plate is then applied to the proximal part, a nonlocked compression screw is used first, followed by a locked screw.

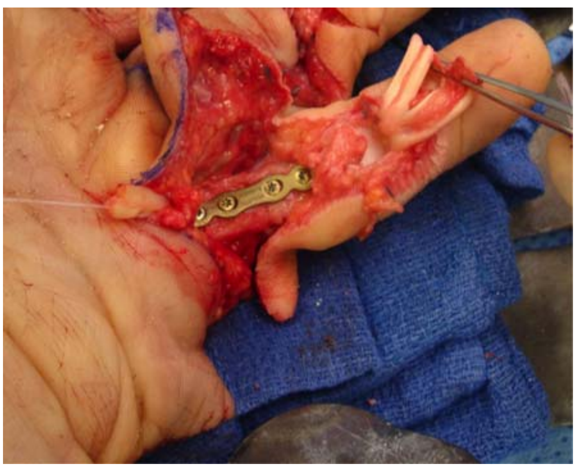

FIGURE 1. Plate applied to volar aspect of proximal phalanx with reflection of periosteum, tendon sheath, and flexor tendons proximal and distal. full color online

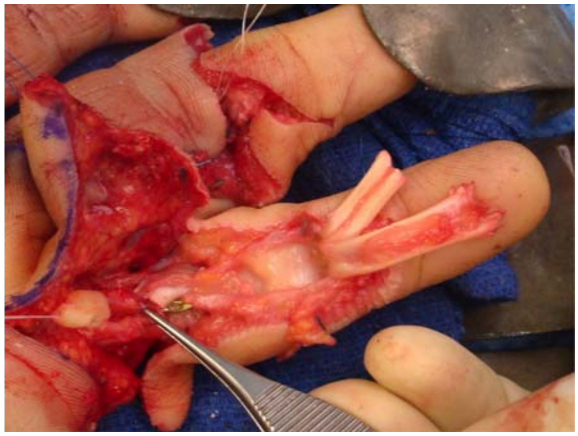

FIGURE 2. Almost complete coverage of the plate with the periosteum and floor of the flexor sheath. full color online

In rare circumstances where the amputation is extremely close to the more proximal joint and shortening proximally is not possible because of compromise of proximal fixation, then more attention is paid to performing adequate shortening on the distal amputated part before attachment of the plate. The use of volar plate fixation means that the fixation may be applied during preparation of the amputated part. This makes shortening and fixation to the proximal fragment simple and when 2 teams are working (ie, one to prepare the amputated part); it saves considerable time. In periarticular injuries with insufficient bone stock, arthrodesis may be considered. Care is taken with screw length as this may compromise extensor tendon function. The plate can then be almost covered completely by the periosteal layer (Fig. 2), further preventing tendon adhesions. In the middle phalanx, the insertional slips of the flexor digitorum superficialis (FDS) merge with this

FIGURE 3. Bilateral multiple digit amputation through P2 of a 19-year-old male. full color online

FIGURE 4. Plain radiographs of bilateral multiple finger amputations of a 19-year-old male.

layer. Repair of one or both flexor tendons is dictated by the nature of the injury and the level of the amputation. If the zone of injury is extensive and ragged with poor-quality tendon, we would be more likely to repair flexor digitorum profundus (FDP) alone and excise FDS. This is due to the greater likelihood of swelling and tendon adhesions. In circumstances where there is less tissue damage such as in a sharp amputation or where the zone of injury is narrow and damaged tissue may be resected following bone shortening, then we may choose to perform repair of both FDP and FDS tendons. In terms of the repair, we perform a 6-strand repair using the technique described by Tsai and Li.[15] This technique uses a loop core suture to achieve the 6-strand repair which is augmented with a running epitendinous suture using 6° prolene. This is our standard repair for zone 2 flexor tendon injuries, and we have

FIGURE 5. A 19-year-old male who had bilateral multiple finger amputations. Right hand fixation consisted of straight plate fixation of P2 ring finger; L-plate fixation of more metaphyseal fracture of P2 middle finger; K-wire arthrodesis of injury through distal interphalangeal joint.

FIGURE 6. A 19-year-old male who had bilateral multiple finger amputations. Left hand fixation.

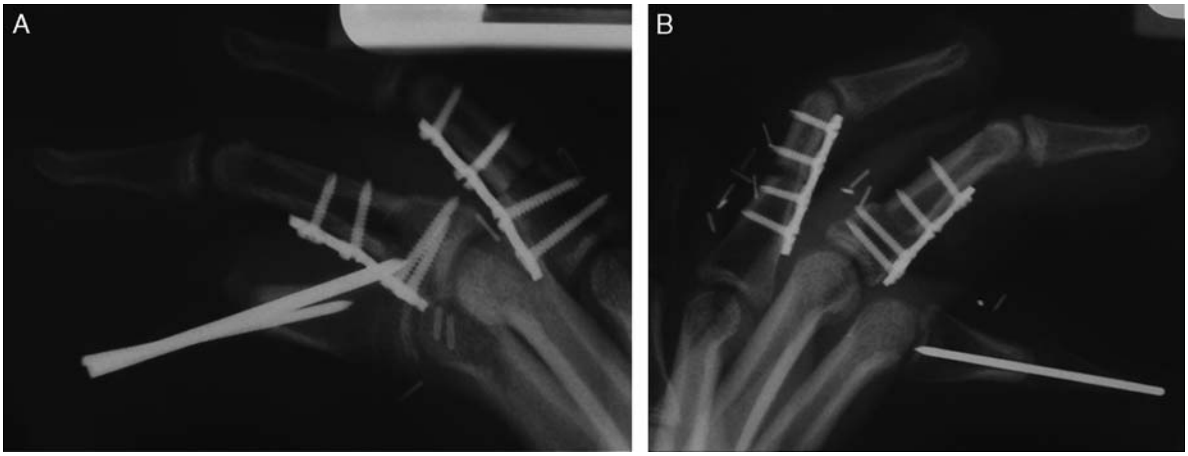

FIGURE 7. Left and right lateral x-rays of bilateral finger amputations.

FIGURE 8. A 19-year-old male at 6 weeks after replantation of multiple digits bilaterally. full color online

FIGURE 9. Finger extension at 6 weeks after replantation of multiple digits bilaterally for a 19-year-old male. full color online

had no problems commencing an immediate early active rehabilitation protocol (either in the setting of an isolated tendon injury or one associated with neurovascular repairs or

FIGURE 10. Finger flexion at 6 weeks after replantation of multiple digits bilaterally for a 19-year-old male. full color online

digital replantation). We perform our neurovascular repairs without tension. This is achieved either through bone shortening or the use of interposition grafts. Under these circumstances, we do not believe that there is any undue tension on the repairs in the course of early mobilization. In addition, we have not observed any vascular compromise through the commencement of early active mobilization. The exact progression of the early mobilization and the range of motion targeted in the joints mobilized are individualized according to the specific nature of the injury and the degree of swelling. If there were any doubt regarding risk of FDS causing tethering we would have a low threshold for repairing only FDP.

We found it worth noting that in amputations through the proximal half of the middle phalanx that the flattened decussated FDS tendon is quite useful. It may be elevated as part of the distal periosteal sleeve, and the FDS tendon forms a good soft-tissue covering over the plate on the volar aspect of the middle phalanx. At this level the FDS tendon is essentially inserted onto the middle phalanx distal to the proximal interphalangeal joint, and its extensive insertion in this region allows it to be elevated distally. It provides excellent coverage of the plate, however, there is no need for motion of the FDS tendon distal to the proximal interphalangeal joint. In addition, it is also the case that the FDS tendon then creates a healthy

FIGURE 11. Thumb amputation through P1. full color online

smooth bed for the FDP repair to glide in. On the dorsal side extensor tendon repair, venous anastomosis and skin closure without compression of the veins is performed. After reconstruction on the palmar aspect, the skin is closed.

FIGURE 12. X-ray of thumb amputation through P1.

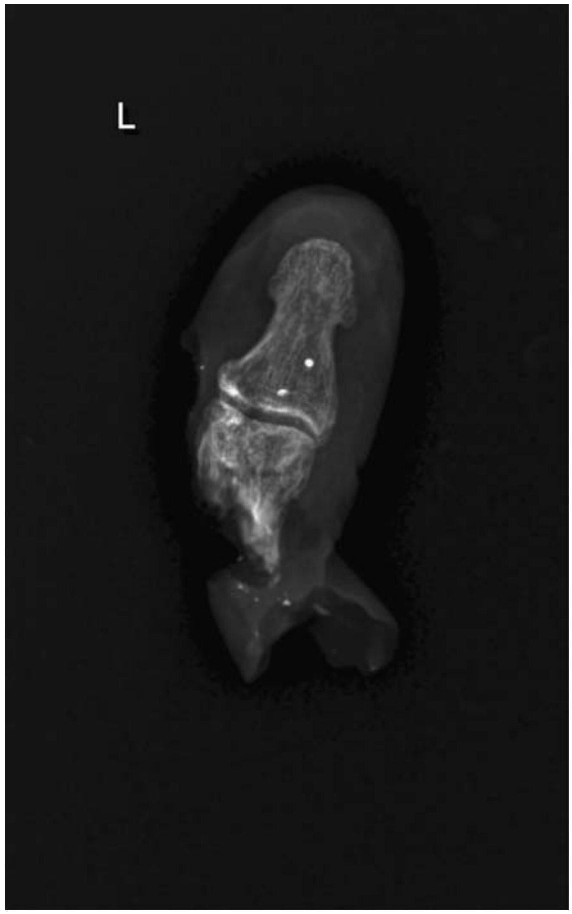

FIGURE 13. Amputated distal portion of the thumb.

REHABILITATION

An early active rehabilitation protocol is commenced on the second postoperative day. This involves commencement of passive and active range of movement. Focus on regaining function is paramount. In replantation we use a rehabilitation protocol focused on active flexion. Volar plating of the phalanges allows the benefits of stable plate osteosynthesis without the problems related to extensor tendon adhesions and soft-tissue crowding contributing to venous compression that is seen with dorsal plate fixation.

EXPECTED OUTCOMES

This technique allows early active movement and rehabilitation to be commenced. Our experience is that early rehabilitation assists in regaining finger dexterity and grasp. Early commencement of functional tasks also helps with regaining functional sensibility in the digit. As the primary goal of replantation is to obtain a superior functional result over amputation, it is imperative that early rehabilitation can be commenced. K-wire and interosseous wire fixation does not predictably maintain bony stability, thereby allowing early range of movement to be safely commenced in the early postoperative stage.

We have performed this technique on 30 amputated digits since 2001. One case involved a 19-year-old male who sustained bilateral multiple digit amputations in an industrial accident (Figs. 3, 4). Fixation with a 4-hole straight plate

FIGURE 14. Osteosynthesis plate applied to the palmar aspect of the proximal phalanx of the thumb. Mobilization was started after 3 days and protected with a removable splint.

(Figs. 5–7) allowed an early active rehabilitation program to be commenced. Range of movement at 6 weeks is pictured in Figures 8 to 10. The second case involved a 19-year-old male who sustained a nondominant hand thumb amputation (Figs. 11–13). An osteosynthesis plate was applied to the palmar aspect of the proximal phalanx of the thumb (Fig. 14). Mobilization was started after 3 days and protected with a removable splint.

COMPLICATIONS

Complications are similar to those expected when utilizing any bone fixation, including infection, secondary displacement, nonunion, and hematoma. We are aware that a nonunion with a palmar plate positioning is more difficult to manage. However, this potential complication would be rare and the apparent advantages outweigh this risk. In the series of 1080 digits reviewed by Waikakul and colleagues, 46 digits were stabilized with a plate and none of these cases had a failure of fixation.[16] Whereas, Touliatos and colleagues concluded that K-wire fixation was the method of choice as they had 7 nonunions with plate fixation of 18.[17] In their series the osteosynthesis material was clearly not as evolved as the modern angular stable implants and comparison is difficult. In addition, we have taken particular care to ensure good apposition of bony surfaces and plate application with compression.

We have not observed nonunion or secondary displacement in the 30 digits where we have used this technique.

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