Flexor Digitorum Superficialis Tenodesis for Traumatic Digit Amputation at the Level of the Proximal Phalanx

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Abstract

Background: Traumatic amputation of the digit requiring revision amputation at the level of the proximal phalanx provides the opportunity to improve flexor function via tenodesis of the remaining flexor digitorum superficialis (FDS) tendon. Salvage of the remaining FDS and performing flexor tenodesis to the proximal phalanx allows increased flexion at the metacarpophalangeal (MCP) joint. **Methods:** This series reviews FDS tenodesis, outlining its surgical technique with clinical and functional outcomes. Institutional review board–approved retrospective study was performed. Twelve digits in 8 patients were included. **Results:** Average flexion-extension arc of affected MCP joint was 82°, and average grip strength was 70% of unaffected extremity. No patients required revision surgery or revision amputation. One patient had a minor wound infection treated successfully with oral antibiotics. **Conclusions:** FDS tenodesis is a reliable motion-preserving procedure for patients with amputations at the level of the proximal phalanx to maintain flexion at the MCP joint.

Keywords: flexor digitorum superficialis, proximal phalanx, tenodesis, traumatic digit amputation, FDS

Introduction

An estimated 541 000 upper extremity amputations occur annually in the United States, representing approximately 3% of all amputees.¹² The majority of these are caused by trauma (92%).¹² Major upper extremity amputation is defined as occurring proximal to the wrist, with minor amputation involving the hand or digits. In 2005, 92% of upper limb amputations involved the hand and digits.¹²

Traumatic injuries of the upper extremity present a challenging problem to the surgeon. Limb salvage or replantations are the preferred management to preserve optimal function for the injured patient whenever possible. Certain circumstances preclude these options, and revision amputation is necessary. When revision amputation at the level of the proximal phalanx is indicated, these patients may have limited flexion at the metacarpophalangeal (MCP) joint due to impaired function of the intrinsic apparatus. This often results in decreased hand function and serves as a poor post for prosthetic digits.

In this article, we report on a flexor digitorum superficialis (FDS) tenodesis to improve proximal phalanx flexion at the MCP joint. We describe the surgical technique and post-operative clinical outcomes.

profundus (FDP) attachment is the primary indication for FDS tenodesis (Figures 1a–1d). Although the central slip inserts on the middle phalanx, the dorsal extensor aponeurosis and the interossei have fibers which insert at the proximal phalanx and contribute to the extensor mechanism. For an amputation at the level of the proximal phalanx, these attachments exert sufficient force to extend the phalanx. Loss of these extensor tendon attachments would preclude tenodesis as FDS would overpower the extensor function resulting in a fixed flexion deformity. This technique can be used in open wounds once a satisfactory debridement of devitalized tissues has been performed. This procedure is contraindicated in patients where there is an active infection present.

Surgical Technique

The amputation is designed as a “fish mouth” incision with equal palmar and dorsal skin flaps. Alternatively, the incision can be fashioned with a larger palmar skin flap to ensure that the thicker palmar skin covers the bony surface.

Materials and Methods

Indications

Amputation at the level of the proximal phalanx with intact extensor insertion but loss of FDS and flexor digitorum

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Supplemental material is available in the online version of the article.

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Figure 1. a, Injury radiograph. b-d, Clinical photographs at the time of operative intervention show traumatic amputations of index, long, and ring fingers.

Limb exsanguination is performed by arm elevation and compression of the brachial artery for cases of infection or tumor. Otherwise, the arm is elevated and exsanguinated using an Esmarch bandage. The skin is incised and the extensor tendon cut at the proximal interphalangeal (PIP) joint, if applicable. On the palmar surface, the neurovascular bundles are identified and the digital vessels isolated and

cauterized. The digital nerves are dissected and then cut under tension so they retract proximally. All devitalized or infected tissue is debrided. The FDP tendon is cut under tension and allowed to retract proximally. In cases where the amputation is performed proximal to the joint line, the proximal phalanx is cut using a reciprocating saw and the ends smoothed with a rasp. The remaining proximal

segment is under motor control of the intrinsic muscles and the extensor digitorum communis. This provides active MCP joint flexion of approximately 45°. The remaining proximal phalanx will participate in gripping and help keep small objects in the palm. To improve flexion at the MCP joint, the FDS tendon is then tenodesed to the end of the proximal phalanx. Kirschner wire holes are made through the distal end of the proximal phalanx and the FDS tendon sutured at its resting length to the phalanx, which provides almost 90° of flexion with grasp (Figures 2a-2d). Care is taken to set the flexor tendon at an equivalent tension to match the tension of the extensor forces, evaluating the digit with the wrist in flexion and extension. Although the patients in this series were sedated, wide-awake anesthesia is an attractive option to ensure appropriate soft tissue tensioning of the repair with patient's active participation at this stage of the procedure. Once appropriate tension is determined, the tendon is sutured through Kirschner wire drill holes at the end of the phalanx using 4-0 nonabsorbable sutures. The tourniquet is deflated, hemostasis obtained, and the wounds closed with a 4-0 nonabsorbable suture. A soft dressing is applied and sutures are removed at 2 weeks following which range of motion exercises are initiated.

An institutional review board (IRB)-approved retrospective study was performed of all patients undergoing FDS tenodesis for amputation at the level of the proximal phalanx by the senior author. At latest follow-up, data including range of motion, grip strength, and need for revision surgery were recorded. Inclusion criteria included patients who were treated with FDS tenodesis with greater than 2 months of follow-up. Range of motion of the operative digit was measured using a goniometer. Data are reported as the total degrees of flexion/extension arc at the last follow-up visit. Grip strength was measured as the average of 3 consecutive attempts at maximal grip using the dynamometer (Jamar Hand Dynamometer; Sammons Preston Rolyan, Bolingbrook, Illinois) and is reported as percentage of the contralateral side. Complications, including postoperative infection, delayed healing, or need for revision amputation, were recorded. Complications requiring return to the operating room were defined as major; minor complications were defined as those that did not require reoperation.

Results

The series includes 12 digits in 8 patients (7 male, 1 female) with an average age at surgery of 57 years (range, 15-92); additional demographic data are listed in Table 1. Average follow-up was 15 months (range, 2-25). All patients sustained open, traumatic amputations to the digits that were not replantable. At final follow-up, average flexion-extension arc of affected MCP was 82° (range, 45°-95°) and average grip strength was 70% of unaffected extremity (range, 50%-100%;

Figures 3a-3d, Video 1). None of the patients required revision surgery or revision amputation. One patient had a wound cellulitis that was treated with oral antibiotics.

Case Report

A 15-year-old right-handed boy was using a wood planer and sustained a severe crush injury with complete amputation to the left index, long, and ring fingers at the level of the proximal phalanx. On evaluation, there were no phalanges distal to the proximal phalanx in the 3 digits, and the patient was not deemed to be a suitable candidate for replantation (Figures 1a-1d). His thumb and small finger were intact without injury. The patient was taken emergently to the operating room where a second look deemed he was not a candidate for replantation due to loss of digital tissue. He underwent a revision amputation and FDS tenodesis to the index, long, and ring fingers to improve digital function and aid in possible prosthetic fitting or toe-to-hand transplantation.

At 10 days postoperatively, the patient was transitioned to removable intrinsic plus splint and therapy was initiated for range of motion and edema control. He demonstrated excellent flexion at the MCP joints on the index, long, and ring fingers and was fitted for digital prostheses (Table 2). Given his function, the patient and his family were not interested in any further digital reconstruction.

Discussion

A recent study reviewing complete and subtotal amputations at or proximal to the distal interphalangeal (DIP) joint over 10 years at a tertiary trauma center found an amputation rate of 54%, replantation rate of 30%, and revascularization of 16%.⁸ Factors associated with the decision to replant, revascularize, or amputate were related to mechanism of injury, affected digit, zone of injury, and the surgeon.⁸ Ultimately, the decision to amputate is made when limb salvage would lead to a less functional result than amputation and the patient understands and agrees to this approach.⁵ Factors that should be considered when deciding whether to replant or amputate include overall clinical status, patient suitability for long-term rehabilitation, condition of amputated part, complexity of microsurgery required, and the significance of the amputated part to the overall function of the upper limb.²

Moran and Berger⁷ detailed the biomechanics of the hand after trauma. The most basic function of the hand is a stable wrist and at least 2 digits that can oppose with some power.⁷ One digit should be able to provide motion to grasp objects; the other digit needs to act as a stable post for the mobile digit. For prehensile motion, the digits require some form of cleft between them to allow accommodation of objects. The digits should be sensate and pain free; otherwise, they provide little benefit over prosthesis.⁷ Requirements for

Figure 2. Images show FDS tenodesis operative technique. (a) Drill holes are created through the dorsal cortex of the proximal phalanx, (b) FDS tendon is isolated, (c) nonabsorbable suture is passed through the drill holes and attached to remaining FDS tendon, and (d) resulting in secured flexor tenodesis.

Note. FDS = flexor digitorum superficialis.

functional sensation are 2-point discrimination of less than 10 to 12 mm.⁶ After traumatic injury, the thumb is the most important digit to salvage as it accounts for more than 50%

of hand function.^{7,11} The second most important is the index finger due to its proximity to the thumb, capability for independent flexion and extension, and ability to

Table 1. Demographic Data.

Total no. of patients (no. of digits)	8 (12)
No. of digits involved in injury, average (range)	3 (1-5)
Gender (no. of male:female)	7:1
Follow-up months, average (range)	15 (2-25)
Age, y, average (range)	57 (15-92)
Dominant side involved, n (%)	4 (50)
Smoker, n (%)	2 (25)
Worker's compensation, n (%)	2 (25)
Traumatic amputation, n (%)	8 (100)

abduct.⁷ When comparing index ray resection with index amputation at the level of the proximal phalanx, amputation at the proximal phalanx provides benefit in terms of grip strength.⁷ Thus, maintenance of digital length is of utmost importance. Amputation through the PIP joint leaves the remaining flexion of the proximal phalanx under the control of the intrinsics, allowing flexion to 45°. The goal of the FDS tenodesis is to improve the flexion arc to closer to 90°, thereby increasing the use of the proximal phalanx stump for grip strength and hand function.

Within the digit, each joint contributes a varying amount to overall flexion of the hand. The DIP joint contributes 15% of intrinsic digital flexion but only 3% of overall flexion arc of the digit.⁷ The PIP produces 85% of intrinsic flexion and 20% to overall arc of motion.⁷ The MCP joint contributes 77% to the total arc of finger flexion and is arguably the most important joint for hand function.⁷ Fusion of the MCP joint results in 45% impairment of the involved digit according to the American Medical Association's (AMA) guide to evaluation of permanent impairment.^{1,10} The interossei and lumbrical contribute to MCP joint flexion and allow for approximately 45° of flexion. A biomechanical study has shown that the mean range of motion (ROM) of finger MCP joints of the index, middle, ring, and little fingers required to perform common functional activities ranged from -10° to 60°, -10° to 75°, -10° to 80°, and -10° to 85°, respectively.³ Importantly, the MCP flexion angle needed to perform daily functions increases moving from the radial to ulnar digits.³ As noted in our study, the mean MCP joint range of motion was 82° with the addition of the FDS tenodesis, resulting in an average of 70% grip strength of the unaffected hand.

With improved material technology, recent studies have demonstrated that digital prostheses can provide important functional benefit and can improve grip and pinch strength and functional Disabilities of the Arm, Shoulder and Hand (DASHs).⁴ Preserving bony length improves the successful, effective use of prosthesis by the patient. A minimum stump length of 12 mm measured distally from the interdigital webspace is required to adequately fit a digital prosthesis.⁹ The added flexion at the

Figure 3. a-d, Postoperative motion of 92-year-old male 4 years after sustaining a table saw injury to the hand.

Video 1. Video showing clinical motion of 44-year-old male at 15 months postoperative due to injury at work with hand caught between blocks of wood (video available in the online version of the journal).

Table 2. Clinical Outcomes of Case Report.

	Affected wrist	Unaffected wrist	% of unaffected
Wrist flexion-extension arc, degrees	150	150	100
Postoperative grip strength, kgf	9	18	50
MP motion			
Index	0-90		
Ring	0-85		
Long	0-80		

Note. MP, metacarpal phalangeal joint.

MCP joint afforded by FDS tenodesis has the potential to improve prosthesis function in digit amputees. In addition, it provides an improved function of the MCP joint in patients who may be considered candidates for microsurgical reconstruction.

There are limitations with this study including its retrospective design, limited patient numbers, and lack of a control group. Future study is planned to collect a control group for appropriate comparison. For this study, historical information within the literature is used as a control.

Notwithstanding these issues, we feel that the procedure adds value to patient function. It is our intent to further study its merits by conducting a prospective randomized trial in appropriate patients.

Ethical Approval

This study was approved by our institutional review board (IRB No. 15-001630).

Statement of Human and Animal Rights

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Statement of Informed Consent

Informed consent was obtained from all patients for being included in the study.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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