

Flexor Tendon Injuries: II. Operative Technique

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Abstract

The repair of flexor tendons (zones I and II) is a technique-intensive surgical undertaking. It requires a strong understanding of the anatomy of the tendon sheath and the normal relationship between the pulleys and the flexor digitorum superficialis and flexor digitorum profundus tendons in the digit. Meticulous exposure, careful tendon retrieval, and atraumatic repair are extremely important, and the repair should be of sufficient strength to resist gapping and permit the early postrepair application of motion forces. Whenever possible, the tendon sheath should be preserved or repaired, and a smooth gliding surface should be reestablished. The author describes an effective method of tendon retrieval and a simplified technique for a four-strand tendon repair with a supplementary peripheral running-lock suture. The repair is considered to maintain sufficient strength throughout healing to allow a postrepair rehabilitation protocol that will impart passive and modest active stress forces to the repaired tendons. Complications include tendon rupture, digital joint flexion contractures, and adhesions that restrict tendon gliding and ultimately necessitate tenolysis.

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The restoration of function to a digit following flexor tendon interruption and repair may be a long and tedious undertaking. Strong rapport must be developed between the surgeon, the patient, and the therapist. When initiating the care of a patient with such an injury, the surgeon must spend considerable time explaining the inherent problems, the likelihood of achieving success, and the fact that several procedures may be necessary to maximize the recovery of digital function.

The exposure of the tendon stumps, the preservation or repair of the sheath, and the suturing of the tendon require considerable experience and skill. Early postrepair therapy must be carried out with the use of protocols that apply sufficient stress to ensure rapid healing and satisfactory gliding while protecting

the repair from rupture throughout the entire healing process.

General Considerations

All surgeons embarking on flexor tendon repairs should adhere to the time-honored advice of Sterling Bunnell, who stated that tendon repair must be carried out using meticulous, atraumatic technique in an effort to lessen adhesion formation.¹ The use of $\times 2$ to $\times 4$ loupe magnification is an important adjunct in performing flexor tendon and sheath repair, and small delicate instrumentation is a prerequisite for this type of surgery. Pinching, crushing, and excessive touching of the tendon sheath or flexor tendons must be avoided. It usually is not necessary to debride or shorten tendon ends.

When planning the surgical exposure, the surgeon must appreciate the fact that the severed flexor tendon ends will retract well away from the laceration site. When the digit is in flexion at the time of injury, the distal stumps of the severed tendons may come to rest a centimeter or more distal to the level of sheath disruption. While there is no fixed rule for the incisions that should be used to expose the flexor tendons, there is no advantage in trying to carry out these complicated repairs through existing unextended wounds or through small incisions along the length of the digit.

The surgeon should select incisions that will not compromise the viability of skin flaps and that, when healed, will not create contracting or cosmetically unsightly scars. Zigzag or midaxial incisions are often utilized. The selection should be based on the position, length, and direction of the original laceration; the need to gain access to other injured structures; and the personal experience and preference of the surgeon.

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Zone I

In zone I (distal to the insertion of the flexor digitorum superficialis [FDS] tendon over the middle phalanx), when only the flexor digitorum profundus (FDP) tendon has been severed, there is usually little difficulty in finding the proximal tendon end, which is at least temporarily retained in the finger by its vinculum and can usually be located in the distal portion of the proximal phalanx or at the level of the proximal interphalangeal joint. Careful dissection will expose the distal half of the flexor tendon sheath. The entire A_4 annular pulley should be preserved.

If the distal interphalangeal joint was flexed at the time of injury, the tendon will probably have a short distal stump over the base of the distal phalanx, which can be exposed by opening the C_3 - A_5 pulley complex. It will also be necessary to open the C_2 or C_1 cruciate-synovial sheath segments proximal to the A_4 pulley in order to retrieve the proximal stump of the divided FDP tendon. After the proximal FDP has been delivered into the appropriate cruciate-synovial sheath interval, a core suture is placed in the tendon, allowing it to be passed distally under the A_4 annular pulley without the need for further instrumentation of the tendon. The proximal tendon is usually maintained in position by the passage of a transversely oriented 25-gauge hypodermic needle. The repair is completed distal to the A_4 pulley with an end-to-end tendon suture if enough distal tendon remains to accept a suture (Fig. 1).

If the distal stump is insufficient to hold a suture, the proximal FDP stump may be reattached by first elevating an osteoperiosteal flap from the base of the distal phalanx and then drilling an oblique hole beneath the flap, directed so as to penetrate the dorsal cortex just beneath the proximal fingernail. A double-

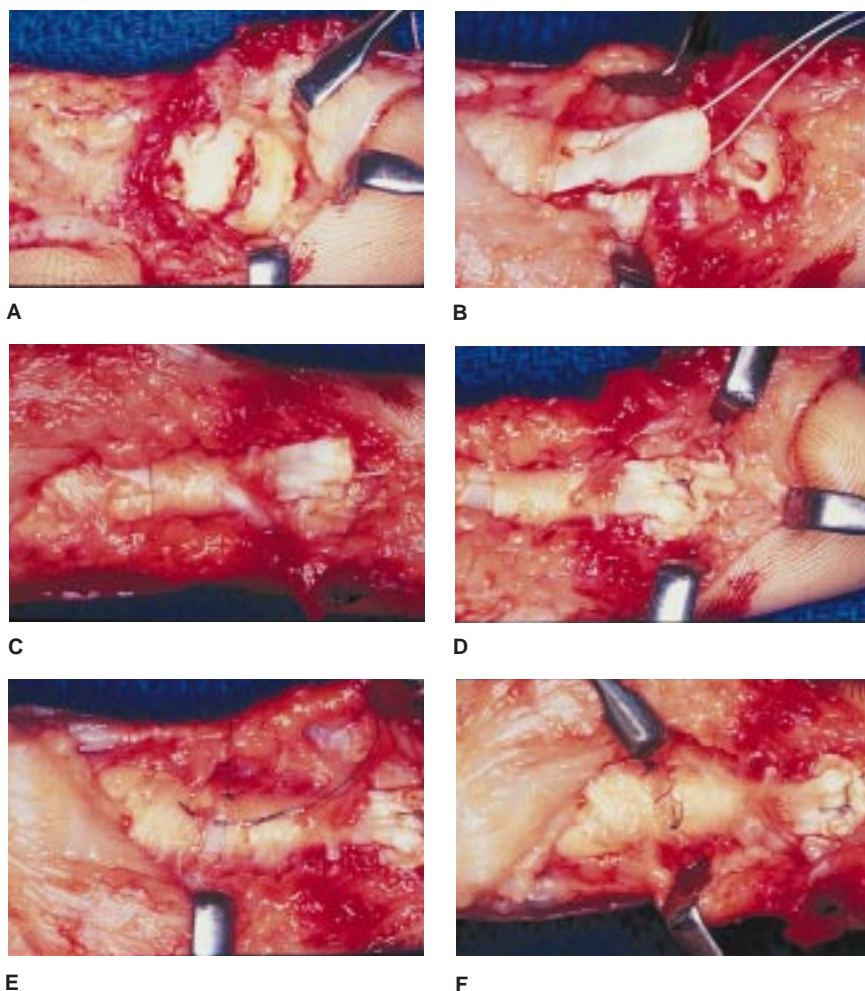


Fig. 1 Flexor digitorum repair in zone I. The patient had suffered a laceration at the level of the distal interphalangeal joint with severance of the FDP. **A**, Appearance of the short distal tendon stump. **B**, Core suture has been placed in the proximal FDP stump. **C**, Proximal tendon stump has been passed beneath the A_4 pulley. **D**, Completed repair. **E**, Repair of the C_2 window with use of a fine monofilament suture. **F**, Appearance of the completed tendon and sheath repair. The patient had excellent recovery of digital flexion at 4 months.

armed (straight needles) 3-0 suture is placed in the proximal tendon stump and passed through the bone hole. In this instance, it is best to use a synthetic monofilament suture placed in a crisscross (unlocked) fashion, so that the suture can be pulled out after bone-tendon healing has occurred.

The sutures are then used to pull the tendon beneath the periosteal flap and are tied over a cotton pad-button combination over the nail. On some occasions, it may be helpful

to use one of the several commercially available bone-anchor sutures to secure the proximal stump to the distal phalanx. When possible, the tendon attachment should be supplemented by sutures through the adjacent sheath or periosteum.

Zone II

In zone II (from the origin of the flexor tendon sheath to the insertion

of the FDS tendon over the midportion of the middle phalanx) flexor tendon repairs, it is always necessary to make proximal and distal extending incisions that provide satisfactory exposure of the repair site. Dissection proceeds with identification and protection of the digital nerves and arteries. If these structures have been severed, their ends are mobilized and brought into proximity for subsequent suturing. An assessment of the level and extent of sheath injury should be made, as well as assessment of the probable position of the tendon ends.

It will then be necessary to open either the C_1 (between A_2 and A_3) or C_2 (between A_3 and A_4) cruciate-synovial sheath windows by means of connecting incisions along one end and one side. When opening the intact components of the sheath, every attempt must be taken to preserve the annular components (A_1 , A_2 , A_3 , and A_4), which are often difficult to repair. Tendon suture should be performed in the cruciate-synovial sheath windows, which can usually be restored following tendon suture.

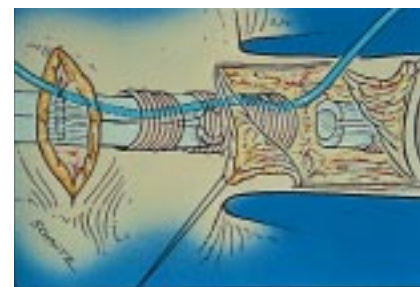
By acutely flexing the distal interphalangeal joint and, to some extent, the proximal interphalangeal joint, it is usually possible to deliver the distal FDP and FDS stumps into a cruciate window. If 1 cm or more of the tendons can be exposed, core sutures can be placed in the FDP tendon and two superficial slips without great difficulty. If a lesser length of tendon end is present in the window, the next most distal cruciate-synovial sheath interval must be opened for core suture placement. The actual joining of the tendon ends can then be carried out in either window, depending on the most distal point that can be achieved for the proximal tendon stumps and the length of the distal tendons and their most proximal position during distal interphalangeal joint flexion.

Retrieval of the proximal tendon ends may be difficult. Repeated blind grasps down the sheath with an instrument will often fail to retrieve the proximal stumps and may, in fact, damage the synovial lining of the pulleys and theoretically can provoke adhesions. Such efforts are appropriate only if the tendon or tendons can be visualized in the sheath and are sufficiently close to the cruciate-synovial sheath window to ensure that an end can be atraumatically pinched with forceps and delivered distally.

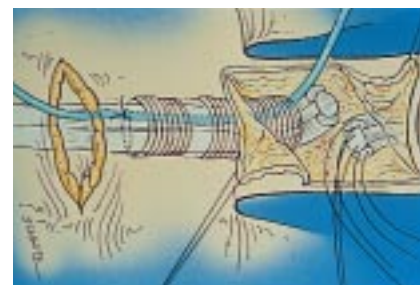
Many clever tactics have been suggested to facilitate tendon capture and repositioning. These methods include proximal-to-distal "milking" of the tendons toward the repair site and the use of various types of catheters and silicone rods, which are sutured to the ends of the tendon stumps in the palm and passed through the sheath in an effort to pull the tendons back into their distal position. The two methods that are perhaps the most reliable techniques for proximal tendon retrieval are the following:

In the first method, used if the tendon end is visible in the sheath, a skin hook is employed as described by Morris and Martin.² The hooked end is slid along the surface of the sheath until it is past the tendons. The hook is then turned toward the tendons and pressed into the most superficial one. When the hook engages a tendon, the instrument is pulled distally. Both tendons will usually follow. They can then be held in position by a 25-gauge hypodermic needle.

The second method, described by Sourmelis and McGrouther,³ is excellent for proximal tendon stumps that cannot be visualized and are still located in the proximal sheath (Fig. 2). A small catheter is passed from the distal wound into the palm (or vice versa) beneath the annular pulleys. An important feature of this method is that the flexor tendons are left in



A



B



C



D

Fig. 2 Sourmelis and McGrouther's method of retrieving flexor tendons. **A**, Polyethylene catheter is passed distal to proximal along the flexor tendons, which are left in situ. Catheter is sutured in both tendons 2 cm proximal to the A_1 pulley through a palmar incision. **B**, Catheter is advanced distally to deliver tendon ends into repair site. **C**, A 22-gauge hypodermic needle is passed transversely through the annular sheath to maintain tendon position. **D**, Catheter-tendon suture is cut in palm and withdrawn.

situ in the sheath. Through a mid-palm incision, the catheter is sutured to both tendons several centimeters proximal to the A_1 pulley. The catheter is then pulled distally, easily delivering the tendon stumps into the distal repair site. A transversely oriented needle will secure the tendons for repair. The connecting suture can then be severed in the palm, and the catheter can be withdrawn. Core sutures can then be placed in the proximal FDP stump and the FDS slips, and the tendons can usually be brought into juxtaposition with the distal stumps for repair.

When the proximal tendon ends have retracted into the palm, it is extremely important to reestablish the proper anatomic relationship of the FDP and FDS tendons. To accomplish this goal, the FDP has to be passed back through the hiatus created by the FDS slips so that it will lie palmar to Camper's chiasma and will recreate the relative positioning that was present at the level of tendon laceration. Failure to restore the correct relationship will create an impediment to unrestricted tendon gliding after repair. Once the proper tendon anatomy has been reestablished, a catheter passed retrograde from the cruciate window is attached to the tendons, and (usually with some difficulty) the tendons are entered into the sheath and delivered distally, where they can be maintained with a transversely oriented hypodermic needle (Fig. 3).

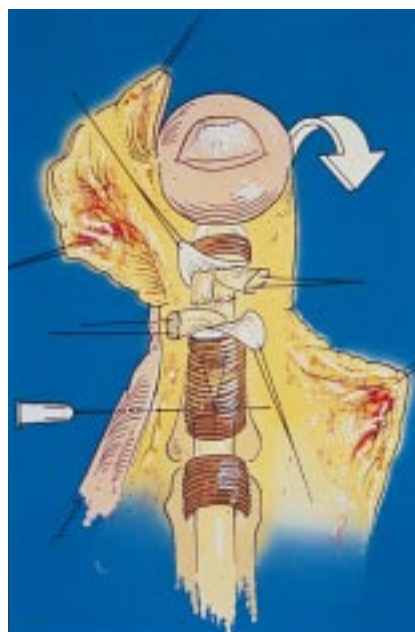
The technique used for the core sutures is based on the preference of the surgeon. Variations of the Kessler grasping technique^{4,5} enjoy the most popularity. If one prefers not to employ the more complex four-strand repair methods, the simple addition of a horizontal-mattress suture across the tendon ends will complete a four-strand repair (Fig. 4). A running-lock stitch may then be used as a peripheral epitendinous stitch (Fig. 5). This is usually easier to place than some of



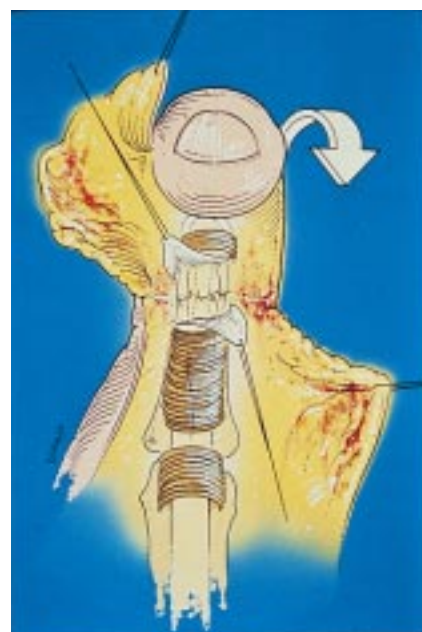
A



B



C



D

Fig. 3 A, Altered relationship of the two proximal tendon ends in the distal palm following proximal retraction. It is important to reestablish the correct anatomic position of the FDP and FDS stumps before passing them back into the digit. B, The proximal FDP and FDS stumps are retrieved proximal to the A_1 pulley and, following the placement of tendon sutures, are delivered distally through the intact portion of the flexor sheath with use of a small catheter or an infant gastrostomy feeding tube. C, The proximal tendon stumps are maintained at the repair site by means of a transversely placed small-gauge hypodermic needle. Repair of the FDS slips is then carried out. D, After completed repair of both flexor tendons, sheath can be closed.

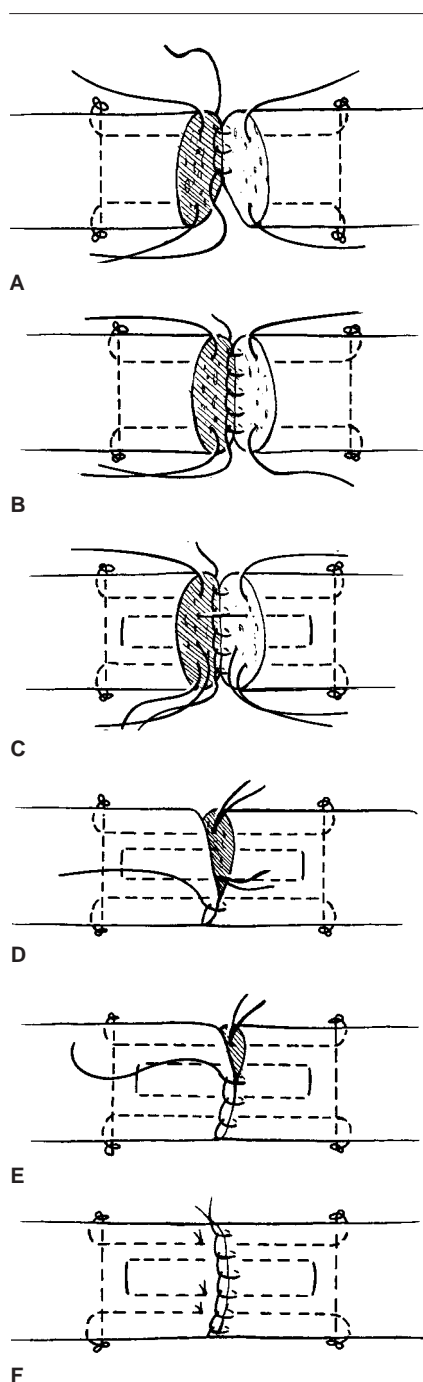


Fig. 4 Simplified four-strand repair in which a basic two-strand core suture is supplemented by a horizontal-mattress suture and a running-lock stitch. **A**, Tajima core sutures in place. Back-wall (dorsal) running-lock peripheral epitendinous stitch in progress. **B**, Back-wall suture completed. **C**, Mattress core suture added in palmar tendon gap. **D**, All core sutures tied. **E**, Completion of running-lock peripheral epitendinous suture. **F**, Repair complete.

the more complicated methods described in recent articles.

At the conclusion of the tendon repair, the surgeon has the option

of repairing the flexor sheath with the use of 6-0 nylon suture on a small needle. At this point, the distal interphalangeal joint can be

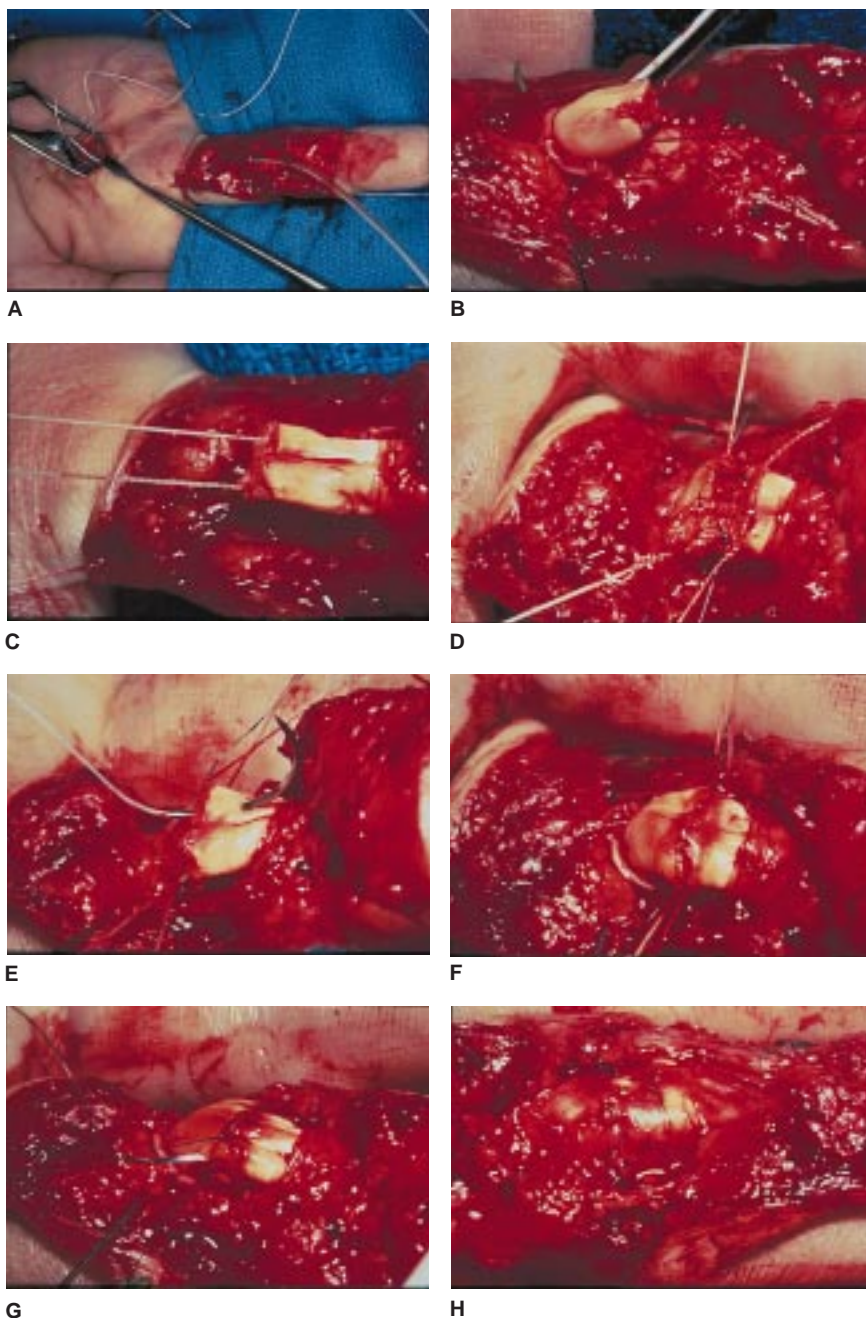


Fig. 5 Tajima core suture plus horizontal-mattress four-strand repair with running-lock peripheral epitendinous suture was used in this patient with a laceration at the proximal interphalangeal joint that severed both flexor tendons. **A**, Tendon retrieval using Sourmelis and McGrouther's method. **B**, Tajima core suture in proximal stump. **C**, Tajima core suture in distal stump. **D**, Back-wall repair with running-lock stitch. **E**, Additional horizontal-mattress core suture added. **F**, Tying of Tajima and mattress sutures results in a four-strand repair. **G**, Front-wall repair with running-lock stitch. **H**, Sheath repaired.

extended to deliver the repair distally. The repaired sheath usually serves as a smooth conduit for the repair as it moves under an annular pulley. If it is elected to leave the flexor tendon sheath open, up to 1.5 cm of sheath may be excised to permit unrestricted gliding of the repaired tendon.

On occasion, the process of flexor tendon suture is complicated by the need to use two adjacent windows (usually C_1 and C_2) for core-suture placement. The final repair is carried out in the most appropriate window after the proximal or distal stumps have been delivered into position by passing the ends of their core sutures under the intervening annular pulley (usually A_3) and gently pulling the tendon ends into

position. Flexor sheath repair is facilitated if the bulk of the tendon juncture can be minimized and careful sheath incisions have been utilized. To ensure the passage of the repaired tendon beneath the annular pulleys, it is helpful to close the overlying cruciate-synovial sheath before extending the interphalangeal joints (Fig. 6).

At the conclusion of the repair, digital nerves and, if necessary, digital arteries are repaired. The skin is then closed using fine nonabsorbable sutures. A large, bulky, compressive dressing immobilizing all the digits and the thumb is used postoperatively with the wrist in midflexion, the metacarpophalangeal joints in full flexion, and the proximal interphalangeal and distal

interphalangeal joints in extension. The use of antibiotics depends on the personal philosophy and discretion of the surgeon.

Postoperative Management

As a result of the publication of numerous articles demonstrating the superior results that followed flexor tendon repairs managed by one of several mobilization programs, almost all hand surgeons currently employ some type of early motion protocol. As the development of these methods has evolved, emphasis has been placed on techniques that employ not only a greater amount of composite digital motion but also the use of "syn-

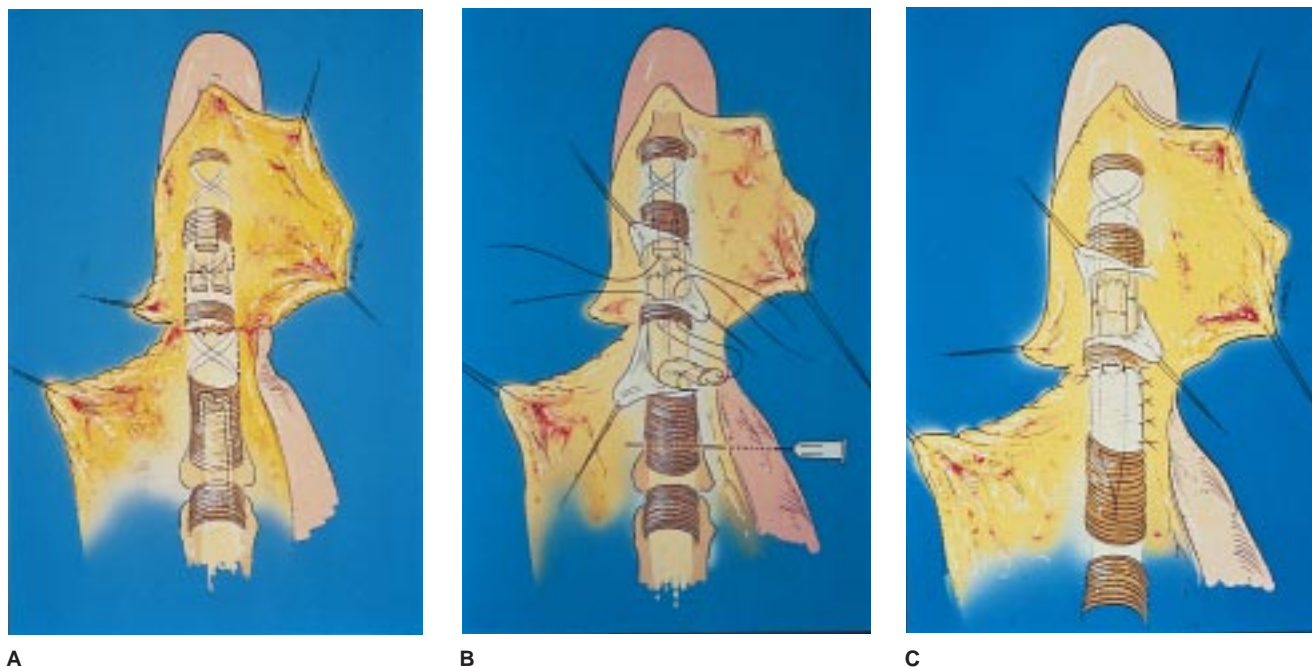


Fig. 6 Situation in which more distal severance of the FDP and FDS tendons has resulted in the inability to deliver 1 cm of the distal stumps into the C_1 window. Incisions in both the C_1 and C_2 intervals will be necessary to provide adequate exposure for suture placement and repair. **A**, Appearance of the flexor sheath after flexor tendon interruption at a level just proximal to the proximal interphalangeal joint and the A_3 pulley. Passive flexion of the distal interphalangeal joint will not provide adequate length of the distal stump in the C_1 window for placement of the core sutures and repair. Dotted lines indicate the appropriate incisions in both the C_1 and C_2 windows. **B**, After placement of sutures in the distal tendon stumps in the C_2 window and in the proximal stumps in the C_1 opening, proximal tendon stumps can be delivered distally beneath the A_3 pulley. (The FDS tendon stumps have been repaired.) **C**, Appearance of the digit after repair of both the FDP and FDS tendons and the C_1 cruciate-synovial sheath. Repair of the C_2 sheath should now be possible.

ergistic" wrist extension in an effort to gain the greatest amount of excursion of the repaired tendon.

As has been discussed in the accompanying article, it now appears that light active digital flexion carried out with the wrist in extension should be relatively safe for flexor tendons repaired with a four-strand core-suture technique augmented by a strong peripheral epitendinous suture (Fig. 7). Most of these postoperative programs permit the active mainte-

nance of passively achieved composite digital flexion once the wrist is brought from flexion to extension.⁶

Complications

Rupture of one or both flexor tendon repairs is a significant complication. It occurs most frequently when patients abandon the prescribed rehabilitation protocol and attempt to make a strong fist or lift a heavy

object. The preferred treatment for tendon-repair rupture is prompt reexploration and repair. The most frequent late complication following early postoperative mobilization programs is the development of flexion contractures at the proximal and/or distal interphalangeal joints. Prompt recognition of the development of contractures, modification of the motion program to permit greater extension, and judicious use of static and dynamic splints can

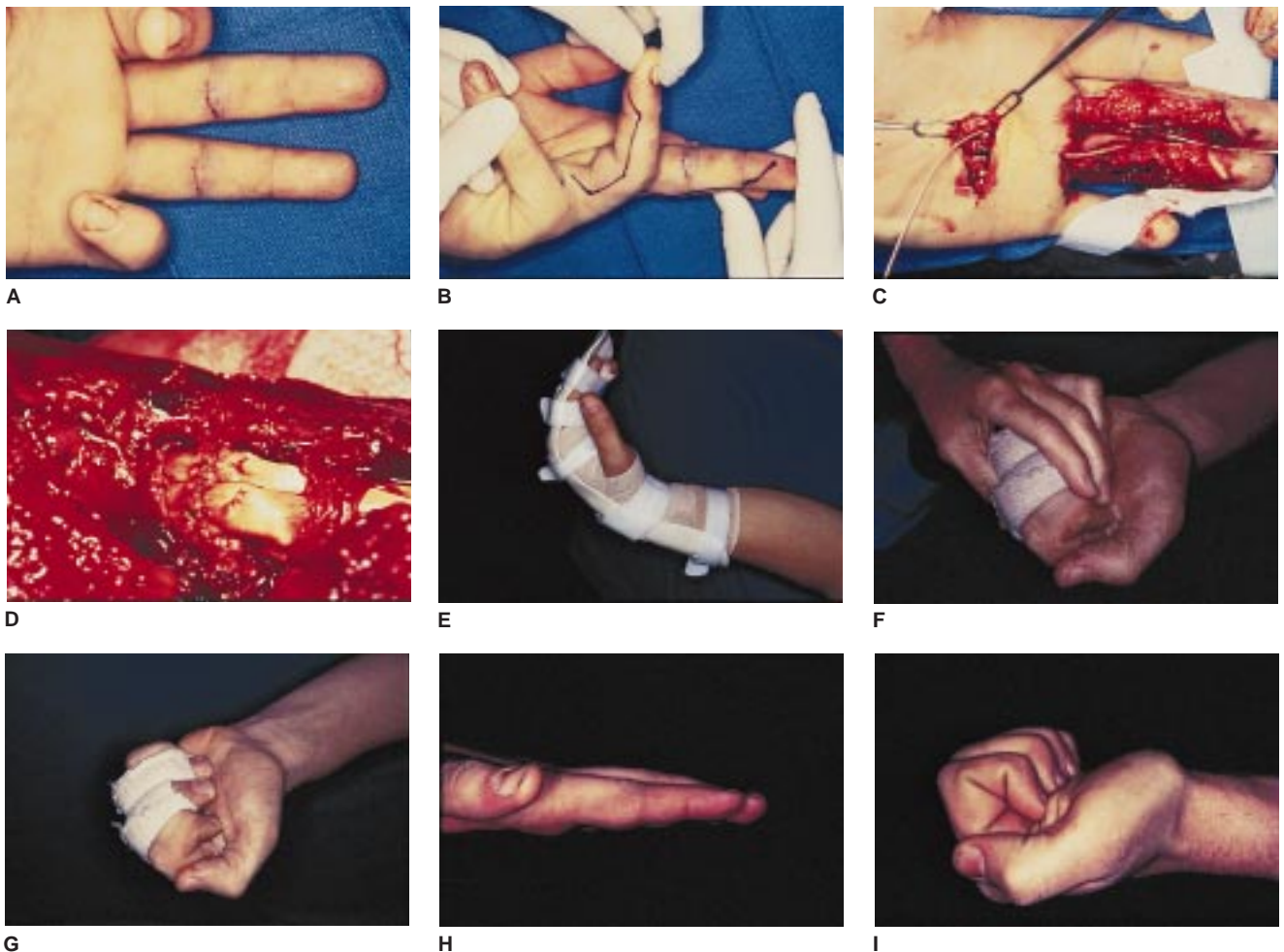


Fig. 7 A, Left hand of a 29-year-old man 24 hours after severance of FDS and FDP tendons in the middle and ring fingers. B, Outline of midaxial excisions on the ulnar side of both digits. C, Sourmelis and McGrouther's method of retrieving proximal tendons in the middle finger. D, Completed four-strand core suture plus continuous horizontal-mattress epitendinous stitch. E, Position of wrist and digits in postoperative splint 3 days after repair, at the time of the initiation of therapy. F, Passive flexion of digits with wrist in flexion. G, Active maintenance of composite digital flexion with wrist extension. H, Nearly full digital extension at 4 months. I, Excellent composite flexion of both digits at 4 months.

help prevent or overcome these deformities before they progress.

In some cases, despite the best possible repair and strong cooperation on the part of the patient, the tendons may become adherent and fail to glide sufficiently to reestablish adequate digital function. A secondary tenolysis procedure may be necessary if repeated joint measurements indicate that there has been no appreciable improvement for several months. The procedure should not be considered until all wounds have reached "equi-

librium," with soft, pliable skin and subcutaneous tissues and minimal reaction around the scars. Joint contractures must have been mobilized, and a normal or near-normal passive range of digital motion is desirable.

Summary

Success is ultimately dependent on the participation of a knowledgeable surgeon, who has spent time in the cadaver laboratory to develop the

technical skills for the four-strand repair and the running-lock peripheral epitendinous stitch, and a well-trained therapist who thoroughly understands the rationale for the rehabilitation protocol and its pitfalls and is prepared to spend a great deal of time with the patient explaining the details of the rigorous therapy program. These methods of primary repair cannot succeed without the cooperation of an intelligent, motivated patient who adheres rigidly to the protocol.

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