Release of the A4 Pulley to Facilitate Zone II Flexor Tendon Repair

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During primary or delayed primary repair of the flexor digitorum profundus tendon, surgeons often face difficulty in passing the retracted tendon or repaired tendon under the dense, fibrous A4 pulley. The A4 pulley is the narrowest part of the flexor sheath, proximal to the terminal tendon. Disrupted tendon ends (or surgically repaired tendons) are usually swelling, making passage of the tendons under this pulley difficult or even impossible. During tendon repair in the A4 pulley area, when the trauma is in the middle part of the middle phalanx and the A3 pulley is intact, the A4 pulley can be vented entirely to accommodate surgical repair and facilitate gliding of the repaired tendon after surgery. Venting the pulley does not disturb tendon function when the other major pulleys are intact and when the venting of the A4 pulley and adjacent sheath is limited to the middle half of the middle phalanx. Such venting is easily achieved through a palmar midline or lateral incision of the A4 pulley and its adjacent distal or/and proximal sheath, which helps ensure a more predictable recovery of digital flexion and extension. *(J Hand Surg Am. 2014;39(11):2300–2307. Copyright © 2014 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Flexor tendons, pulleys, tendon gliding, pulley venting, postoperative digital motion.

Surgical Technique

PRIMARY OR DELAYED PRIMARY REPAIR of the digital flexor tendon is a common practice, but in the area of the A4 pulley the passage of the retracted flexor tendon stump under the narrow A4 pulley is often difficult or even impossible. When the repair site glides under this pulley, reconnected tendons are constricted. Traditional teaching has emphasized the importance of the A2 and A4 pulleys, accentuating the need to preserve them.

It has been a practice of the author and some other surgeons to vent the A4 pulley to simplify surgery and eliminate constriction of the often swollen and edematous repaired tendon.[1,2] I have not yet seen a negative functional impact of this surgery on tendon function when such pulley venting is performed judiciously with proper indications. The A4 pulley can be vented completely when the trauma is localized in or around the A4 pulley area and the A3 pulley is intact and when the venting length of the pulley-sheath does not exceed 1.5 to 2 cm. In my experience, this creates space for surgical repair and eases postoperative gliding of the repaired tendon.

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INDICATIONS AND CONTRAINDICATIONS

Venting of the A4 pulley is intended to facilitate primary or delayed primary flexor tendon repair in the area of the middle phalanx. It is not intended for secondary tendon grafting or reconstruction, for which pulley reconstruction should usually be considered.

Indications

Venting of the A4 pulley is indicated in the following situations:

1. The ends or the severed flexor digitorum profundus (FDP) tendon are difficult to pass under the pulley.

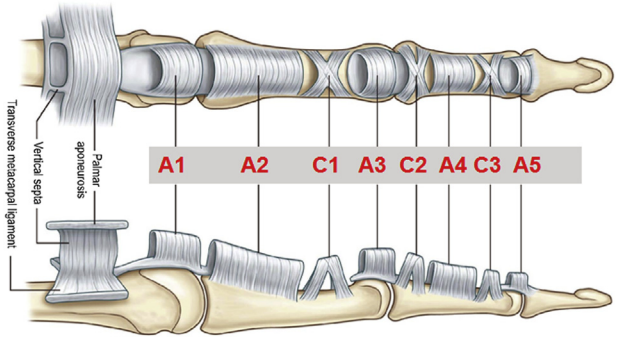

FIGURE 1: Pulleys in the fingers. There are 3 pulleys in the middle phalanx area. The A4 pulley is located in the middle, with one weak cruciate pulley at each side.

2. The tendon laceration site is in the immediate area of this pulley; the pulley has to be opened to allow surgical tendon repair.
3. The pulley blocks gliding of the surgically repaired portion of the tendon during extension-flexion tests to verify quality of surgical repair.

Contraindications

1. Destruction of other major pulleys, such as A3 and A2.
2. Lengthy sheath loss over the proximal interphalangeal (PIP) joint.
3. Loss of all or almost the entire flexor sheath distal to this pulley.

SURGICAL ANATOMY

The A4 pulley is located in the midportion of the middle phalanx.[1,3] The length of this pulley is about 5 mm and its diameter is the narrowest in the entire digital sheath system (except at the distal tendon insertion). The pulley is composed of strong fibrous bands appearing as a rigid, condensed annular band over the FDP tendon, holding the tendon close to the palmar aspect of the phalanx. This pulley causes the FDP tendon to curve slightly over the curvature of the bone surface. Located palmar to the PIP joint, the A3 pulley is much smaller (3 mm in length).[3] The A5 pulley is located more distally over the distal interphalangeal (DIP) joint, which is weak and hard to identify during surgery, and its location may vary between patients. There are synovial sheath and clinically indistinguishable cruciate pulleys between the A3 and A4 pulleys or distal to the A4 pulley (Fig. 1).

Distal to the PIP joint, the A4 and A3 are 2 biomechanically important pulleys, but only removal of the A4 has an insignificant effect on tendon movement.[4]

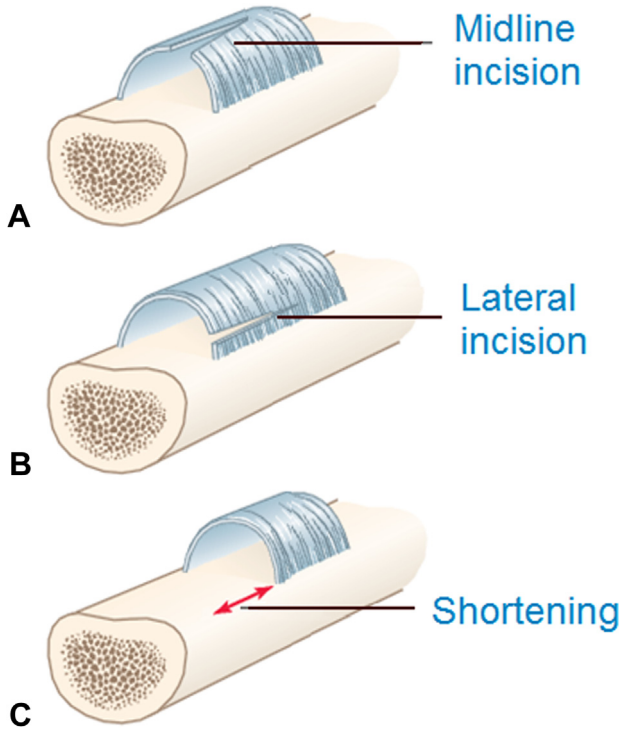

FIGURE 2: Three methods of venting: **A** palmar midline incision, **B** lateral incision, and **C** excision. The palmar midline or lateral incision can be partial or complete.

When only 1 of the 2 pulleys is removed, the synovial sheath, together with the cruciate pulleys in the sheath, serves to prevent tendon bowstringing.

SURGICAL TECHNIQUE

Step 1: tendon exposure

In the patient diagnosed with a flexor tendon cut in the area of the middle phalanx, the tendon is exposed with a Bruner incision extending over the level of the middle phalanx. The site and severity of sheath laceration are assessed. Usually an incision in the sheath is necessary to find the tendon ends. The laceration in the sheath, either distal or proximal to the A4 pulley, is opened. Then the DIP joint is passively flexed to assess the level of tendon laceration and its relation to the A4 pulley. The metacarpophalangeal and PIP joints are flexed to assess whether it is possible to bring the proximal tendon stump into the operative field. If not, the skin incision should be extended proximally but the A3 pulley and more proximal sheath should be preserved. A small sheath incision can be made just distal to the A2 pulley to help locate the proximal stump, delivering the stump distally to approximate the distal stump. The integrity of the A2 and A3 pulleys and the sheath over the proximal phalanx should be confirmed.

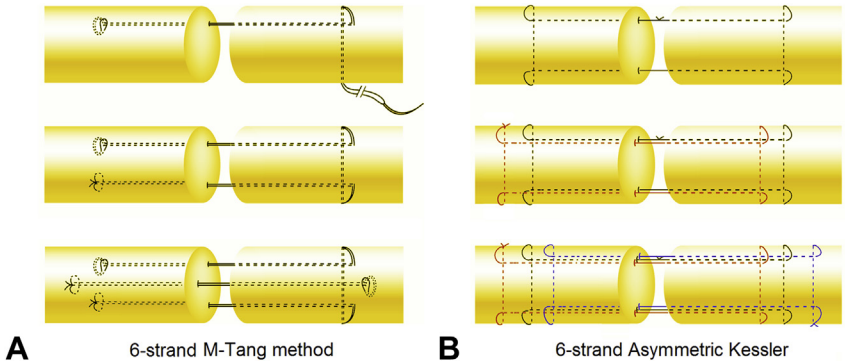

FIGURE 3: Two methods of 6-strand core tendon repair that the author has employed in recent years using 4-0 sutures. **A** M-Tang repair. **B** Asymmetric triple Kessler repair.

FIGURE 4: Protective position with slight flexion after surgery.

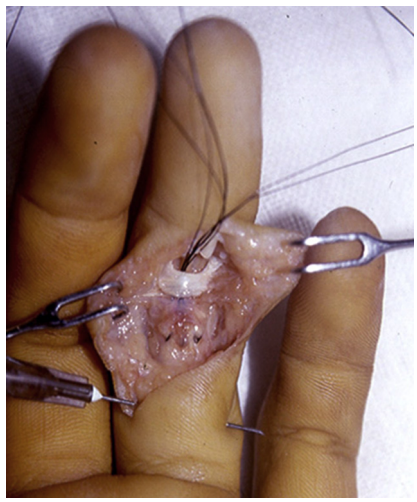

FIGURE 5: Unable to pass the tendon under the A4 pulley.

Step 2: clinical judgment, decision making, and venting of the pulley

If the tendon laceration is directly under or at the edge of the area covered by the A4 pulley and the passage of the tendon ends under the pulley is difficult or impossible, the A4 pulley is incised entirely through its volar midline. This also makes surgical repair much easier, including tendon end approximation and placing sutures into the tendon. The proximal tendon end is temporarily fixed with a transverse needle if the tension is high, and the tendon is then repaired with either a 4-strand or 6-strand core suture using 3-0 or 4-0 suture, supplemented with a simple running peripheral suture.

If the tendon laceration is farther away from the A4 pulley and one tendon end is under the A4 pulley (or can pass underneath easily), the tendon can be repaired without venting. Then an extension-flexion test is performed. If the repair site is blocked or the tendon motion is constricted by the pulley, a part or the entire A4 pulley should be vented to decrease impingement of the repair site; in most cases, the entire A4 pulley needs venting to allow free tendon motion.

The author vented the A4 pulley through a palmar midline incision (Fig. 2), which can also be achieved through a lateral incision of the A4 pulley instead of a palmar midline incision (Fig. 2). The tendon repairs contain a 6-strand core suture (Fig. 3).

Step 3: extension-flexion test before skin closure

The extension-flexion test is repeated to confirm smooth and free gliding of the tendon before skin

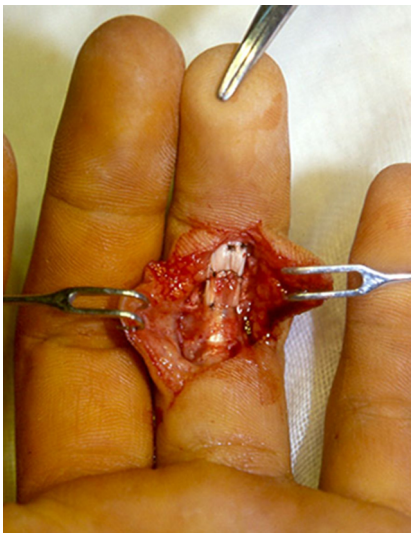

FIGURE 6: The A4 pulley was vented to enable tendon repair and free tendon gliding.

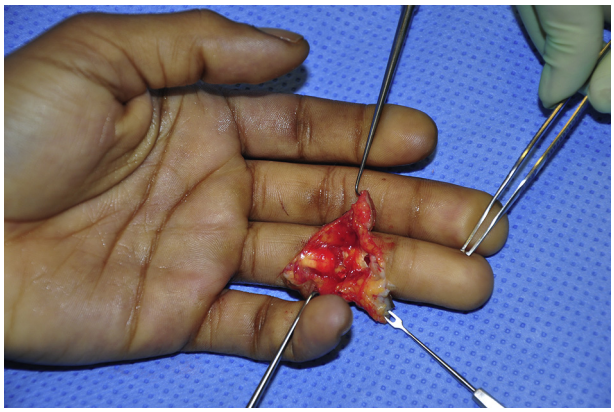

FIGURE 7: The FDP tendon was found to be cut at the A4 pulley area.

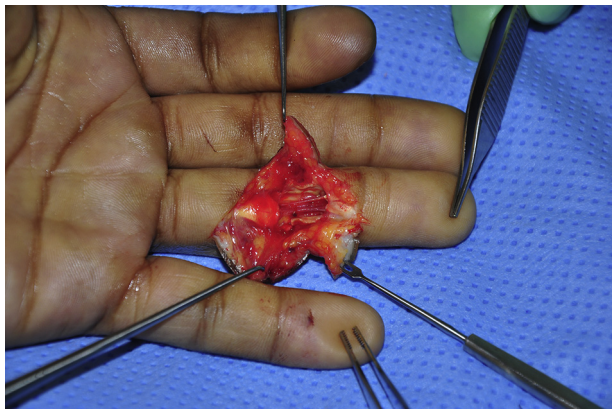

FIGURE 8: The A4 pulley is vented entirely, and the adjacent synovial sheath is opened.

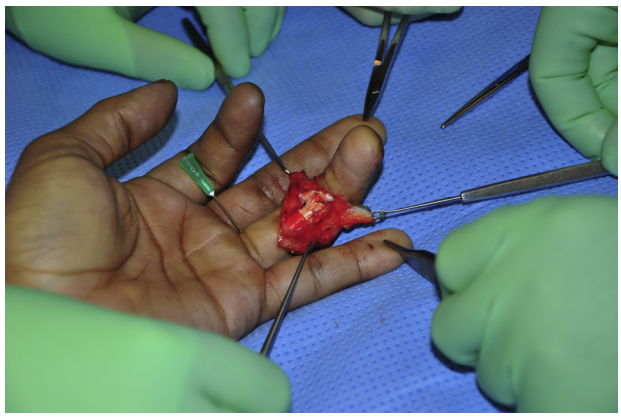

FIGURE 9: The tendon was repaired with 6-strand asymmetric triple Kessler repairs with 4-0 nylon.

closure. This measure is important to ascertain that repair surgery is satisfactory and that the patient can proceed to early active tendon motion postoperatively.[5–7] Briefly, the repaired digit is first fully extended passively or actively to ensure no gapping between tendon ends. Next, the digit is flexed to determine whether the tendon gliding is smooth, and finally the digit is markedly flexed to ensure the repair site is not caught by or rubs against the pulley and the pulley has been sufficiently vented.[6] This test verifies the strength of the surgical repair and the smoothness of tendon gliding before early active tendon motion.

REHABILITATION AND POSTOPERATIVE CARE

A short forearm orthosis is usually sufficient and the wrist position can be any with which the patient feels comfortable. Slight wrist flexion is favored in my practice (Fig. 4). Early passive-active motion starts from day 3 to day 5 after surgery. Four to 6 exercise sessions are prescribed daily (more sessions can be allowed); in each exercise session, 10 to 30 repetitions of a full range of passive digital motion are completed before active finger flexion, reducing finger joint stiffness upon subsequent active motion.[2,8] In the first 3 or 4 weeks, active digital flexion starts from full extension but covers only the initial one-third or two-thirds of the digital flexion range. Extreme active digital flexion is avoided during that period.[2,8] After 3 or 4 weeks, active digital motion is gradually increased to full flexion with passive digital motion before and after active digital flexion.[2,8] Passive digital motion can be combined with active digital flexion, but passive motion of the digits for multiple times is critical before active digital motion. The number of exercise sessions can be increased as the patient wishes, and out-of-orthosis active or passive motion is allowed for compliant patients.

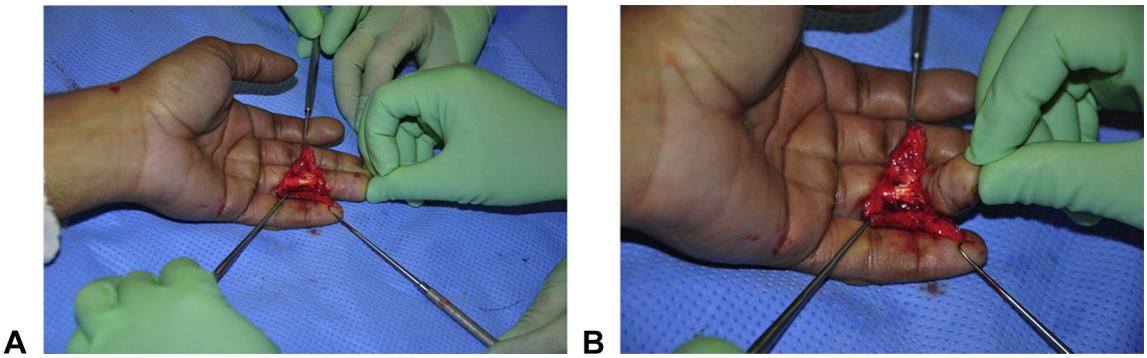

FIGURE 10: Extension-flexion test. **A** Full extension to confirm no gapping at the repair site. **B** Finger flexion to confirm smooth tendon gliding with no pulley impingement or resistance.

COMPLICATIONS

Venting of the A4 pulley itself does not lead to complications but tendon repair in this area may result in tendon adhesions and digital joint stiffness, and infrequently, repair ruptures.

CASE ILLUSTRATIONS

Case 1

A 32-year-old man had the left ring finger cut in the middle phalanx area. The injury was repaired 2 weeks after trauma when the skin wound had healed. Exploration of the wound revealed complete laceration of the FDP tendon right at the A4 pulley area. I found it impossible to pass the proximal tendon stump under the pulley (Fig. 5), so the pulley was vented to allow tendon passage and facilitate surgical suture of the tendon (Fig. 6). The tendon was repaired with 6-strand core sutures with 4-0 looped sutures[2,8] supplemented with a few stitches of peripheral suture using 6-0 nylon. In making the core suture, the core suture purchase is 7 to 10 mm with a sufficient lock diameter of 2 mm; we add some tension to the repair site to prevent gapping.[8,9] The postoperative motion regimen was passive–active motion initiated on postsurgical day 4. The patient had full recovery of digital function at 4-month follow-up.

Case 2

A 21-year-old man sustained a cut on the left ring finger. During delayed primary repair 1 week after injury, the FDP tendon was found to be cut just proximal to the A4 pulley (Fig. 7) and surgery on the tendon required additional space through venting the A4 pulley. The pulley was vented (Fig. 8) and the tendon was repaired using a 6-strand core suture using 3 groups of Kessler repair with 4–0 nylon (Fig. 9), which were placed with asymmetrical suture purchases (12 and 8 mm, 10 and 12 mm, and 8 and 10 mm core suture purchases in the distal and proximal stumps for the 3 Kessler repairs, respectively) to reduce tendon deformity at the suture anchoring site in both stumps.[10] The extension-flexion test was fine (Fig. 10). Early active motion was started 4 days after surgery (Fig. 11). The patient had recovered full range of digital motion at 3 months.

PEARLS AND PITFALLS

The following practice pearls and pitfalls are important to surgeons who vent the A4 pulley:

1. Venting the pulley by a volar midline incision is easiest, but lateral incision of the pulley works similarly.
2. Technically, partial venting is possible and efficient. However, in my practice I vent the entire pulley in almost all cases requiring venting before surgical repair, because the A4 pulley is too short (5 mm) to leave any portion unvented and I find the remaining pulley rim sometimes still constrictive.
3. Incision of only the A4 pulley while keeping all the adjacent sheath intact usually creates an insufficient opening in the sheath for surgical suturing of the tendon. Therefore, a part of the intact adjacent sheath either proximal or distal to the A4 should be incised together with the A4 pulley, creating a sheath-pulley opening of about 1.5 cm, adequate for suturing the tendon. However, it is important that such a sheath-pulley opening not exceed 2 cm (Fig. 12); otherwise tendon bowstringing becomes a concern.
4. Extensive or crush injuries and multiple pulley damage in the digits are completely different from clean or near-clean cuts; A4 pulley venting may not be applicable or should be practiced judiciously. If the A2 and A3 pulleys are already

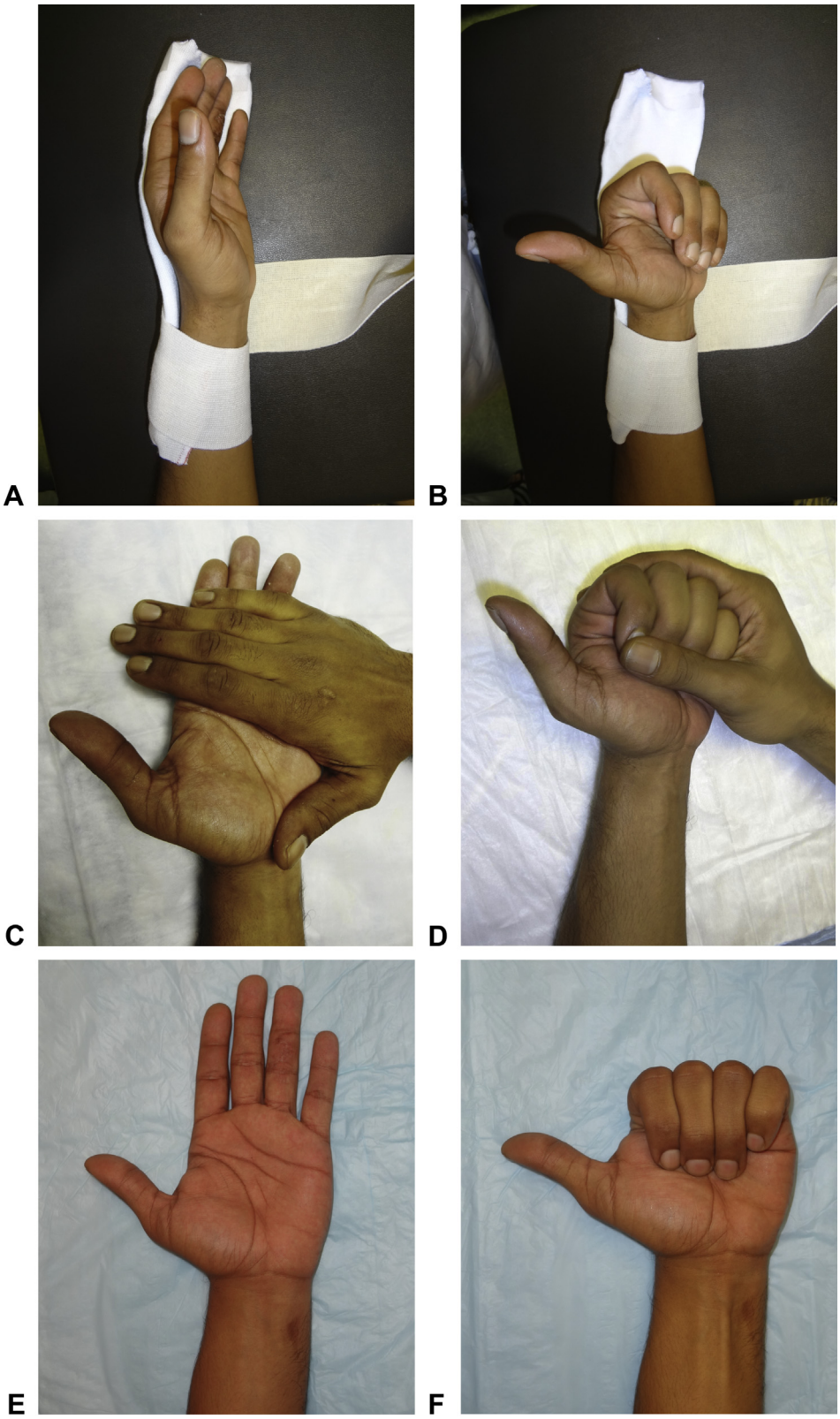

FIGURE 11: Methods of postoperative motion and outcomes. **A** Early full active extension. **B** Early partial active flexion. **C** Late exercise of DIP joint motion. **D** Full DIP joint flexion exercise. **E, F** Postoperative extension and flexion 3 months after surgery.

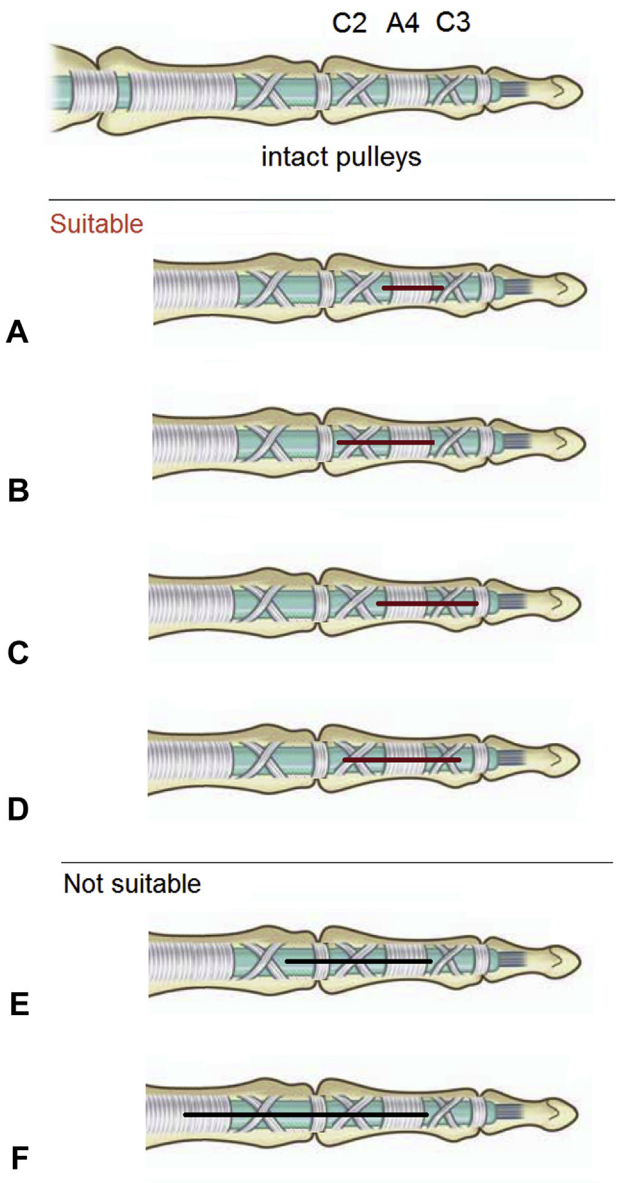

FIGURE 12: Safe lengths and areas of pulley sheath are shown in solid dark red lines from **A** to **D**. Venting shown in **E** and **F** should be avoided; they will cause bowstringing.

damaged, the surgeon should not vent the A4 pulley.

5. An intact A2 pulley and intact sheath at the PIP and DIP areas are basic requirements for venting the A4 pulley. In other words, when other major pulleys and synovial sheath are intact, venting a sheath-pulley for 1.5 to 2 cm centered on the A4 pulley is safe and causes no tendon bowstringing.

FUTURE PERSPECTIVES

Although great emphasis has been given to the area where both the profundus and superficialis tendons are cut, specific discussion of FDP tendon repair at or around the A4 pulley is rare. This area deserves special attention. Because it is narrow and the FDP tendon is pulled by vinculae, the proximal stump cannot usually be retracted far; in most cases, flexion of the PIP joint brings it into the surgical field. A Bruner incision can be limited to the middle phalanx area, which is actually less invasive surgery than more proximal tendon repair. I do not find it necessary to make a lengthy Bruner incision. Because the repair is distal, and given strong surgical tendon repair, wrist positioning after surgery is not as important and a dorsal orthosis can extend only a little proximal to the wrist. Out-of-orthosis unprotected digital active motion exercise is possible for patients when there is confidence in the tendon repair. I encourage well-motivated patients to perform such active finger flexion. During exercise intervals, the hand is placed in an orthosis to prevent unexpected injuries or unwanted hand motion. The small incision for surgical exposure, greater freedom in setting postoperative wrist positioning, and unprotected out-of-orthosis active digital motion may be worthy of future study. Tendon injury in this specific area is different from the more conventional care for zone II flexor tendon injuries.

Because postsurgical edema is almost inevitable, I often see PIP and DIP joint stiffness for a few weeks after surgery in my patients; however, such stiffness is reversible after rehabilitation. Rehabilitation directed toward relieving finger joint stiffness takes weeks or up to 1 or 2 months to restore normal finger motion. Moderate finger joint stiffness can be a concern in patients for 4 to 6 weeks after surgery, but persistent rehabilitation over the subsequent weeks or months restores active DIP and PIP joint motion in compliant and well-motivated patients.

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