INDICATIONS, METHODS, POSTOPERATIVE MOTION AND OUTCOME EVALUATION OF PRIMARY FLEXOR TENDON REPAIRS IN ZONE 2

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Abstract

In recent years, our unit has put into practice of flexor tendon repairs a number of novel concepts, which we hope address some critical difficulties in primary flexor tendon repairs in Zone 2, thus pointing the way towards predictable surgical outcomes. In this article, I present my practical views on indications, techniques, post-surgical treatment and outcome measures, and describe our methods of sheath-pulley release, tendon repair, postoperative motion and outcome evaluation.

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The advent of primary flexor tendon repairs within the synovial sheath region should be credited to those pioneers, such as Verdän (1960) and Kleinert et al. (1967), nearly half a century ago. Prior to that, over a long period of the previous half century, primary tendon repair was not advocated and surgeons followed Bunnell’s advice to remove the tendons entirely and graft in new tendon (Bunnell, 1918, 1922). The reports of Verdän and Kleinert and his colleagues on primary flexor tendon repairs established that the lacerated digital flexor tendon can be treated by direct end-to-end repairs when wound conditions are favorable. However, most surgeons have noted that the outcomes of primary repairs remain hard to predict, particularly in respect of restrictive adhesion formation and rupture of repairs (Cullen et al., 1989; Elliott et al., 1994; Small et al., 1988; Strickland and Glogovac, 1980; Tang et al., 1994). Over the last two decades, surgeons have tried to identify flexor tendon repairs which yield optimal outcomes consistently. Considerable research and clinical effort has been expended and the number of reports on this subject probably surpasses those on any other single topic in Surgery of the Hand during this period. While the overwhelming number of investigations reflects the elaborate nature of the basic science and clinical practice regarding digital flexor tendon repairs, the volume of work also indicates that a path leading to satisfactory and predictable treatment outcome has not yet been identified.

In recent years, our unit has put into practice a number of novel concepts which we believe may ensure more predictable surgical outcomes and help to address some critical difficulties in primary flexor tendon repair. We hope that they eventually point the way towards optimal flexor tendon repairs. In this article, I present our practical views on indications, techniques, post-operative mobilisation and outcome measures.

INDICATIONS

"Clean-cut" wounds, the simplest clinical situation associated with digital tendon lacerations, are a prime indication for primary flexor tendon repair. I consider a wound to be such when cut cleanly and tidily, usually as a single transverse, or oblique, wound in the fingers or distal palm, and produced by a knife or a piece of glass. The cut is also "clean" in terms of minimal potential for contamination and infection. Anatomically, the tendon(s) is only "severed", and without tissue defect. The cut tissues may even align well. This is the best indication for primary repair, with the greatest likelihood of relatively uncomplicated repair, rehabilitation and satisfactory outcome. Such wounds are very often accompanied by divisions of the digital nervous structures, which does not contraindicate primary repair of the tendons.

Crush injuries to a very limited segment of the fingers, or palm, produce untidy skin and subcutaneous injuries and tendon wounds. It is accepted that such wounds are also good candidates for primary repairs, because the soft tissue wounds and tendons can be made "similar" to those associated with a clean-cut wound through debridement of nonviable tissues and direct wound closure. However, these injuries have a greater potential for contamination. Primary tendon surgery is possible, although more difficult than with a truly "clean-cut" wound. Phalangeal fractures are rarely associated with a clean-cut flexor tendon laceration, but can become part of a crush injury. A simple and stable fracture in the phalangeal shaft can be securely fixed internally and, so, presents no contraindication to primary tendon repair.

The borderline indications for primary repairs have been less thoroughly addressed and I have seen no clinical investigations devoted solely to this topic. Nevertheless, it is in such cases that we must explore
Fig 3: Our method of making a six-strand repair (the so-called "M-Tang Repair"); two separated looped nylon are used to make a M-shaped repair configuration within the tendon (shown in A); cross-sectionally these suture strands are evenly placed and form the points of a triangle. Use of this suture and the outcome are illustrated in B to G in a case of ruptured primary flexor tendon repair which was referred to the author. We performed direct repair of the ruptured flexor tendon 3 weeks after the first tendon repair (B). The ragged tendon stumps were trimmed and the A2 pulley was adequately released, although preserving a part of the A2 pulley (C). The FDP tendon was repaired with the M-Tang technique and the FDS tendon was removed (D) and (E). (F) and (G) show the range of finger motion six months after this surgery.

However, in cases in which primary repair is considerably delayed, when the FDS tendon cannot be passed

FDS tendon is still better left unrepaired, even if the major part of the A2 pulley has been vected. Repair of one slip of the FDS tendon, or demi-FDS tendon repair, is an alternative option should a surgeon be enthusiastic to restore FDS function and if it is hard to pass the complete FDS tendon under the A2 pulley.

POSTOPERATIVE MOBILISATION

The central dogma that primarily repaired flexor tendons should be mobilised soon after surgery is well known to most surgeons dealing with digital flexor tendons. However, one finds a perplexingly variety of motion protocols are efficient. Past reports on the outcomes of the surgery appear to indicate that variants based on certain essential design principles eventually lead to comparable clinical outcomes. This illustrates the fact that slight alterations in the angles to which the joints should be flexed, or the number of repetitions of exercise in each episode of mobilisation, are relatively insignificant. On the other hand, we may need to consider modification of certain fundamental concepts in protocol design to reach the ultimate goal of restoration of a close-to-normal range of active motion without repair rupture. Currently, early controlled
active finger flexion is becoming the mainstay of motion exercise (Anaduo et al., 2005; Bakir et al., 1996; Elliot, 2002; Pettengill, 2005), and early passive flexion by rubber band traction may be on its way to being abandoned. Our own clinic has shifted from passive flexion to early controlled active finger flexion over the last two decades. Our protocol in recent years has noticeable differences from documented protocols.

The following protocol was designed to actively flex the finger in a controlled manner but incorporates a number of maneuvers based on conclusions derived from mechanical studies. Essentially, the hand is protected in a dorsal thermoplastic splint, with the wrist in slight flexion (20°-30°), the metacarpophalangeal (MCP) joints in slight flexion and the interphalangeal joints in extension (or minimal flexion), for the first 2.5 weeks (Fig 4). We do not encourage patients to move the finger during the first few postoperative days, because, at this time, the hand is painful, oedema is more prominent and, more importantly, adhesions do not form. Decreasing the days of motion decreases the chance of repair rupture. Exercise starts at 3 to 5 days (at 4 or 5 days in most cases) after surgery. Before each episode of active digital flexion, the fingers are passively flexed 10 or more times to lessen the overall resistance of the finger joints and soft tissues—a “warming up” process—after which active flexion should encounter lower resistance. The patient is then instructed to flex the fingers actively with gentle force 20 to 30 times during each morning, noon, evening and before sleep, up to the range with which the patients feels comfortable. The motion range is usually from full extension to one-third, or half, of the full flexion range, although this may even increase to two-thirds of the full range if this can be achieved with ease. Active flexion over the full range is not encouraged, unless it can be achieved very easily. Patients may increase the number of motion episodes up to 5 or 6 per day, but we do not necessarily require patients to move hourly. In this 2.5-week period, full active extension is particularly encouraged and the fingers are passively stretched against the splint if full extension is not achieved. Prevention of extension

![Diagram of hand positions and splinting](image)

Fig 4 Illustration of the positions of splinting of the hand and postoperative exercise. In the first 2.5 weeks, the wrist is splinted in about 20° to 30° of flexion and the MCP joints are maintained in slight flexion. Complete extension of the finger joints is emphasised during this period. Active flexion may be only up to the mid-range and no forceful active flexion is encouraged. However, the fingers should be flexed passively over the full range. In the second 2.5 weeks, the wrist is splinted in extension and the MCP joints are maintained in the functional position. Active and passive finger flexion are emphasised during this period. Full passive flexion is ensured and active finger flexion is encouraged, but not forced to the full flexion range. The thumb is included in the splint to prevent unintended pinch or other use of the hand, so protecting against rupture of the repairs. This is not an absolute requirement for cooperative patients who follow the guidelines of therapies.
deficits rather than full active flexion is emphasised during this period.

At 2.5 weeks, a new thermoplastic splint is made, with the wrist splinted in 30° of extension (Fig 4). Finger flexion, both passively and actively, is emphasised during the period from 2.5 to 5 weeks. The patients are instructed to actively flex after a passive warm-up, as earlier. Active flexion up to the mid-range is required as a minimum and is encouraged further, up to two-thirds, or the full range of flexion, depending on the patient’s ability to perform resistance-free motion. Digital flexion from the mid-range to the full range, in particular over the final one-third of the flexion range, is usually carried out passively if the fingers encounter resistance. Our studies show that finger flexion over the final one-third of the full range of motion range encounters resistance 5 to 10 times that in the previous two-thirds of the range of motion, so ruptures are much more likely in this final part of the flexion range, even if the repair has survived the previous (and greater) part of the range of motion. In addition, the strength of repaired tendons moving over the final one-third of the flexion range can be much lower, because the ultimate strength and gap resistance decreases as the curvature of the gliding arc increases (Tang et al., 2002). This adds to the risk of repair failure. Ensuring full passive flexion, to prevent dorsal ligament tightening and extensor tethers, and encouraging finger flexion actively, while avoiding flexing the finger forcefully over the final flexion range, are guidelines during this second period. Differential FDS and FDP motion exercise is encouraged through the first 5 weeks when two flexor tendons are repaired at the same level. The method of achieving this is, basically, by separated active flexion of the two interphalangeal joints. After 5 weeks, full active finger flexion is encouraged. This can be started earlier if flexion in the final part of the flexion range is judged to have less resistance. After 5 to 6 weeks, the splint is discarded or used only at night. The patients can return to normal use of the finger from 8 weeks.

This type of exercise regimen, incorporating passive and active elements within each exercise episode and each cycle of finger motion, is based on understanding of the mechanics of movement of repaired tendons during finger flexion and shifting the tension on the flexors according to the wrist position. By changing the wrist position at 2.5 weeks, emphasis can be shifted from achieving full extension to achieving full flexion, enabling the full range of intended motion to be achieved with relative ease while diminishing the risk of joint contractures of both the wrist and the finger joints and also diminishing the risk of rupture of tendon repairs. The mechanical basis behind the protocol design is synergy between wrist and finger actions; with the wrist flexed, full finger extension is achieved with less tension on the flexor tendons, while full finger flexion can be achieved with less tension on the repairs with the wrist extended. Savage (1988) first pointed out that wrist extension is not harmful during motion of the interphalangeal joints and an experiment by Amadio and his colleagues highlighted the merits of synergistic wrist extension in reducing the tension of the finger flexors during active finger flexion (Tanaka et al., 2005). Active finger flexion to full flexion encounters much less resistance when the wrist is extended than when the wrist is flexed. This effectively avoids overload of the repaired tendons. However, we do not encourage maximal active flexion of the finger when the exercise meets remarkable resistance, but, instead, incorporate active finger flexion up to the mid-range and passive motion from mid- to maximal flexion into individual motion cycles. We believe that repair rupture can be minimised using the above regimen of exercising, aimed at avoiding high levels of tension on the repairs, while achieving sufficient active motion, together with the above described releases of the sheath and pulleys and an increase in surgical sutures strength.

EVALUATION OF OUTCOMES

The most commonly used evaluation system used in the last two decades has been the Strickland criteria (Strickland and Glogovac, 1980). The TAM and Buck-Gramcko (1976) methods are also used extensively (Kleinert and Verdun, 1983). It is somewhat hard to believe that the TAM method was not as popular as the Strickland criteria, even among hand surgeons in America. The modified Strickland (1985) criteria, have not enjoyed popularity because they are too lenient. Previously, I have used the original Strickland criteria, the TAM method and the White criteria, but I favoured the original Strickland criteria. However, range of motion as the only measure of functional status is insufficient. I would suggest that range of motion, grip strength, finger motion arc and activities performed by the finger flexors should be combined into one, yet simple, formula defining the functional status of the fingers after flexor tendon injury. Clinically, I use the method shown below, which includes three items, to record the outcome of finger flexor tendon repairs, viz: (1) active range of motion, (2) grip strength and (3) quality of motion.

In evaluating active range of motion, I adopt a percentile distribution of range of active motion, which is not exactly as Strickland suggested. I use the ranges of active motion from the contralateral hand as the normal values, if the contralateral hand is normal. I think the range of active motion for a finger categorised as "excellent" should be more stringent than in Strickland's original criteria, to allow cases with truly excellent recovery to be distinguished from "very good" cases. In my experience, the inclusion of cases of active range of motion not exceeding 90% of the normal in the "excellent" category appears lenient. I have also created a category of "failure", to identify, specifically, the cases