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Operative Techniques in
Orthopaedics

Tendon Repair: Zone I and II Flexor Tendons and Extensor Tendons

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Tendon injuries in the hand are common, yet represent some of the most challenging problems in the hand to both patient and surgeon. The goal is for a repair or reconstruction to be strong enough to allow for early active range of motion, yet to retain its anatomic morphology to allow for smooth gliding. This review will discuss optimal repair characteristics and will offer a suggestion of techniques that are effective and applicable to the daily practicing hand surgeon. The focus will be on zones I and II flexor tendon repairs and reconstruction and extensor tendon repair. The anchor button technique for zone I injuries and reconstruction, cross-locked cruciate–interlocking horizontal mattress repair method for zone II injuries, and the running-interlocking horizontal mattress method for extensor tendon repair provide excellent biomechanical characteristics that allow for early active range of motion. Rationale for these techniques with specific descriptions will be presented.
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Tendon injuries are among the most common hand injuries and can be very challenging for the patient and surgeon. Excellent outcomes are not universally achieved, and research continues to be produced in an attempt to improve results. In particular, zone I, zone II, and extensor tendon repair and reconstructive methods will be discussed with a particular attention made to repair methods that are strong enough to allow for early active motion while maintaining anatomical properties for optimal gliding.

Zone I

For zone I injuries where there is inadequate distal tendon length for tendon to tendon repair and advancement of the flexor digitorum profundus will be <1 cm, tendon repair to the distal phalanx is the standard treatment. The use of bone suture anchors for flexor digitorum profundus repair to the distal phalanx may partly supplant the original Bunnell pull out button repair method[1] and its modifications.[2] When reviewed critically, the outcome of the Bunnell suture button method does not have universally good outcomes.[3,4] The main reason is because of excessive gapping. In a cadaveric model of button repair, Schreuder et al[5] showed that gap formation after 500 cycles was greatest with Prolene (Ethicon, Somerville, NJ) suture (6.8 mm) followed by Supramid (S. Jackson, Inc, Alexandria, VA) suture (4.0 mm) and was smallest for Ethibond (Ethicon, Somerville, NJ) suture (1.7 mm, SD 1.7) ($P < 0.05$). Although not specifically tested for zone I, gapping >2-3 mm is unacceptable for tendon healing and gliding resistance in zone II.[6,7]

Zone I repair with bone suture anchors where there is no need for suture pullout allows for the use of a locking suture method with a multifilament suture material, which is stronger and stiffer than monofilament suture materials. Other advantages of the suture anchor technique is that it is better tolerated by patients, and it avoids the risks associated with the pullout button suture technique of permanent nail deformity, skin necrosis from button pressure, and rupture due to catching of the button on objects.[8-11]

Schreuder et al[8] studied the effect of bone suture anchor orientation. The results of this study showed that the 45 degree retrograde angle was superior, based on the "deadman's" theory originally introduced by Burkhart.[12] This was a cadaveric biomechanical model using 3 anchor angles, 1 micro Mitek anchor, 3-0 Ethibond, and Bunnell suture method. Gapping with the 45 degree retrograde angle was 2.0 mm; for

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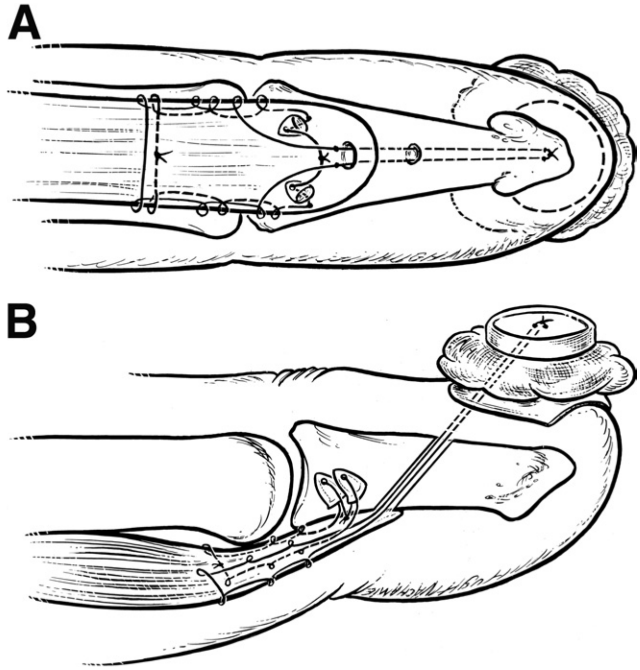

Figure 1 AB technique of tendon fixation to the distal phalanx. (A) AP view, (B) lateral view.[14]

the 90 degree angle, 4.7 mm; and for the 45 antegrade angle, 5.0 mm. Ultimate load to failure was 30 N for all groups, although this model only used 1 micro Mitek anchor. In the 45 degree retrograde group, 100% failed by the suture cutting through the anchor eyelet. For the other groups, 33% failed by anchor pullout.[8] Other conclusions that we extrapolate from this study are (1) more than 1 micro Mitek anchor is required, and (2) use of a stronger suture material that does not cut through the anchor eyelet should improve overall construct strength.

In a cadaveric model, Brustein et al[13] compared the button repair with 3-0 nylon, 1 mini Mitek (DePuy Orthopaedics, Inc, Warsaw, IN) 2-strand repair with the Bunnell suture pattern using 3-0 Ethibond, and 2 micro Miteks and 4-strand modified Becker suture with 3-0 Ethibonds. The 2 micro Mitek technique was stronger (69.6 N) than the button (43.3 N) and the single mini Mitek (44.6 N). No gap information was reported.

Further support comes from a clinical study by McCallister et al[1] comparing the outcome of patients treated with a modified pull out button suture technique vs a suture anchor. The suture anchor group returned to work significantly earlier. There were no significant differences in active range of motion, grip strength, sensibility, or flexion contracture.

For zone I repair and for tendon fixation to the distal phalanx in secondary tendon reconstruction, we sought a repair method with even better strength and gapping characteristics. This led us to the anchor button (AB technique), which is a 4-strand repair with a combination of anchors (2 micro Mitek) and a button for a "belt and suspenders" type repair (Fig. 1). We tested this technique in 24 fresh-frozen human cadaveric fingers randomized to 4 groups: group 1, 2-strand Bunnell suture button pullout technique; group 2, modified Kessler suture and 2 retrograde anchors; group 3, locking Krakow suture with 2 retrograde anchors; group 4, AB technique incorporating a 2-part repair consisting of 2 retrograde anchors and a button. Tendon-to-bone gapping was measured after cyclical loading. Ultimate load to failure was measured at the end of 500 cycles. We found that the AB technique resulted in significantly less gapping (0.02 mm after 500 cycles) when compared with the other techniques. It also resulted in a significantly stronger repair compared with all the other groups with an average load to failure (115N), which is comparable with the native tendon-to-bone interface. The benefit of the anchors is low gapping since the fixation point is close to the bone. The benefit of the button is increased strength since fixation is across a bone tunnel. The AB combination therefore grants low gapping and high strength.[14] We now use this technique clinically. The technical details are as follows. We clear the palmar distal phalanx of soft tissue distal to the volar plate, defining the radial and ulnar borders of the bone. We then drill the holes for the Micro Mitek suture anchors just distal to the volar plate, aiming approximately 30-45 degrees retrograde and slightly toward midline. The Ethibond in the Micro Mitek anchors is then removed and replaced with stronger 3-0 FiberWire (Arthrex, Inc, Naples, FL) for the anchor portion. We perform a Krakow suture on the dorsal side of the tendon end up and down, 3 throws on each side.

On the palmar side of the tendon, we then place a Bunnell suture with 2-0 Prolene up and down, 3 throws on each side. The original biomechanical study used Mersilene (Ethicon, Somerville, NJ) sutures for the button portion; the mechanical advantage being that it is a braided multifilament nonabsorbable suture material. Clinically, however, we had an infection issue when the suture was cut at the nail plate level and did not recede underneath the nail bed. We have therefore switched to using 2-0 Prolene and the Bunnell suture method for the button portion since the suture can then be pulled out, and therefore there will be no possibility for an opening to be left in the nail bed to possibly introduce infection.

We then thread the FiberWire sutures through 2 different Micro Mitek anchors and place these anchors in the bone. The Keith needle for the button is drilled distal to the Micro Mitek anchors and in the center of the bone. The sutures through the anchor are then pulled on one side of the Keith needle (not diverging), which slides the suture through the anchor eyelets and pulls the tendon to the bone. The Bunnell suture is then threaded in the Keith needle eyelet and pulled dorsally out the nail plate to further snug the tendon down to bone. The anchor sutures are then tied, followed by the button sutures. My preference to stabilize the button is 2 ply cotton on the nail plate side, the button placed convex side down on the nail plate, then Xeroform (Covidien Kendall, Mansfield, MA) folded longitudinally and wrapped around between the button and cotton, followed by a 2-0 silk suture to hold the construct in place and stabilize the button. A dorsal block splint is placed with the wrist at 20 degrees of extension, metacarpophalangeal joints flexed to 60-70 degrees, and interphalangeal joints at 0-20 degrees. Controlled