EDITOR'S CHOICE

Bone-Prosthesis Junction for Active Tendon Implants: A Biomechanical Comparison of 2 Fixation Techniques

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Purpose To study the biomechanical characteristics (percent stretch, stiffness, and ultimate load) of 2 distal fixation techniques for an active tendon implant used in the reconstruction of flexor tendons.

Methods We evaluated percent stretch after cyclical loading and at failure, stiffness during load-to-failure, and peak load of 28 bone-prosthesis junctions using cadaveric canine middle phalanges to study 2 fixation techniques: metal cleat and screw versus polyester cords secured with a knot.

Results The knot constructs displayed greater percent stretch during and following cyclical loading between 2 N and 50 N and at peak load. The screw construct showed greater stiffness from 50 N to 150 N during load-to-failure. Both fixation techniques failed at a mean peak load greater than 340 N.

Conclusions Both fixation techniques for active tendon implants withstood loads seen with passive and active motion in the immediate postoperative period. Knot constructs displayed significant stretch during cyclical and load-to-failure testing, which would need to be compensated for during surgery. The screw constructs showed greater stiffness than the constructs secured with the surgeon's knot, but failure created an intra-articular fracture.

Clinical relevance The results may aid the surgeon in choosing which fixation technique to use, during tensioning of cords, and in permitting active motion following surgery. *(J Hand Surg Am. 2016;41(4):526–531. Copyright © 2016 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Active tendon implant, Hunter rod, staged-tendon reconstruction, tendon biomechanics, tendon repair.

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End-to-end repair of lacerated tendon is not possible in many instances. Boyes grades 2 to 5 flexor tendon injuries are often managed with staged flexor tendon reconstruction.[1–3] This is a valuable method of addressing complex flexor tendon injuries when the patient presents late or has failed primary repair or when the injury mandates it.[1,3–16] In 2-staged flexor tendon reconstruction, the first stage is used to remove and release scar tissue, reconstruct annular pulleys, and finally, insert an implant. The flexible implant allows passive motion of the joint to reduce stiffness and to stimulate pseudosheath

formation.[17–19] After the soft tissues have recovered and the pseudosheath has formed, free tendon grafting is performed.[2,19–22]

Silicone implants have been used for staged flexor tendon reconstructions.[17–19] The technique was described by Bassett and Carroll[23] and later refined by Hunter and Salisbury in 1971.[20] The silicone implant's role is a passive one and allows for pseudosheath formation. Passive but not active motion of the digit(s) is allowed during stage I. Bader et al[24] and Hunter and Jaeger[22] demonstrated that silicone implants could be used as active implants and, therefore, possibly serve as a permanent prosthesis. Later, Hunter et al[25] published results using active tendon implants in staged reconstructions in humans. Whereas some implants failed at 1 year after implantation, more than two-thirds remained functional up to 14 months after surgery. Some active silicone implants have remained functional up to 25 years after reconstruction.[26] Stage II has also been delayed up to 18 years after stage I without affecting the outcome.[27] An active prosthesis could possibly lead to a permanent 1-stage procedure.[25]

Early active motion and less immobilization is encouraged after tendon injuries in the hand. Traditionally after tendon reconstruction, the digit is immobilized to protect the implant fixation at both ends because rupture is not uncommon. Thompson et al[28] studied the strength of 2 proximal junction methods using a commercially available active tendon implant. They noted a mean ultimate load failure of 220 N.[28] The purpose of this study was to compare 2 distal fixation techniques, a screw fixation and a knot fixation, using an active tendon implant in a canine model.

MATERIALS AND METHODS

Cadaveric digits (n = 28) from 14 forepaws (7 right and 7 left) from 8 adult canine specimens (6 matched pairs and 2 unmatched paws) were obtained from an unrelated canine physiology experiment. The average weight was 22.7 kg. Forepaws were kept frozen in a moist wrapping in airtight specimen bags. The forepaws were thawed, the middle phalanges of the third and fourth toes were harvested, and all soft tissues were excised. The middle versus the distal phalanx was selected for analysis owing to anatomical considerations because the distal phalanx is small. It was also felt that the middle phalanx would be a more accurate representation of the human distal phalanx in length and width. Specimens were designated for the distal fixation method such that the fixation method selected on the left third toe would be the opposite fixation on the right third toe of the matched pairs. Two forepaws were unmatched but did, however, allow for an equal number of toes from right and left forepaws to be tested.

Two fixation methods were examined to attach the commercially available tendon implant (Model ATPC Hunter Active Tendon Implant; Wright Medical Technology, Inc., Arlington, TN) to the middle phalanx. The model ATPC Hunter active tendon implant has a metal cleat on one end and polyester cords on the other end, which permitted testing of both junction types with 1 implant. The implant length ensured that neither junction was affected by testing of the other. For the screw fixation method, the phalanx had a 1.5-mm bone tunnel placed in the middle phalanx 3 to 4 mm distal to the articular surface. The bone tunnel was drilled from the volar cortex to the dorsal cortex approximately 15° off perpendicular and sloping proximally in accordance with Wright Medical's technique guide for models AT and ATPC, which feature metal cleats for distal fixation.[29] Two 1.6-mm K-wires were then placed distally and bent into a U-shape to allow for mounting into the Instron 1321 biaxial servohydraulic testing machine (Instron Corp., Canton, MA) retrofitted with MTS TestStarII digital controls (MTS Systems, Eden Prairie, MN). The tendon implant was affixed to the bone with a 2.0-mm bicortical screw (TriMed, Inc., Santa Clara, CA). To permit noncontact, optical measurement of the stretch experienced by the construct, the bone was painted white with a black circle colored on the bone 7 mm distal to the center of the screw. Two more black marks were placed on the silicone rod 1.5 cm and 2.5 cm from the bone mark. The U-shaped K-wires were then clamped to the Instron actuator. The proximal end of the implant was placed in a custom-designed clamp under no load at the time of fixation (Fig. 1).

For the knot fixation method, the opposite end of the active tendon implant used during the screw testing was used to test the biomechanical properties of fixation with the polyester cords. The fixation was carried out by drilling a 2.0-mm bone tunnel in the anteroposterior plane of the middle phalanx approximately 3 mm distal to the articular surface. A heavy nylon suture was then used to pass the polyester cords through the bone tunnel until the distal end of the silicone implant became flush with the volar surface of the middle phalanx. The cords were wrapped around the bone from dorsal to volar and tied using a surgeon's knot, allowing the knot to sit on the bone and not the silicone implant. The fixation method was in accordance with Wright Medical's technique guide for models ATDC and ATBC, which have polyester cords for the distal fixation.[26] The K-wire placement, bone