SCIENTIFIC ARTICLE

Analysis of a Knotless Flexor Tendon Repair Using a Multifilament Stainless Steel Cable-Crimp System

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Purpose To compare the biomechanical and technical properties of flexor tendon repairs using a 4-strand cruciate FiberWire (FW) repair and a 2-strand multifilament stainless steel (MFSS) single cross-lock cable-crimp system.

Methods Eight tests were conducted for each type of repair using cadaver hand flexor digitorum profundus tendons. We measured the required surgical exposure, repair time, and force of flexion (friction) with a custom motor system with an inline load cell and measured ultimate tensile strength (UTS) and 2-mm gap force on a servo-hydraulic testing machine.

Results Repair time averaged less than 7 minutes for the 2-strand MFSS cable crimp repairs and 12 minutes for the FW repairs. The FW repair was performed with 2 cm of exposure and removal of the C-1 and A-3 pulleys. The C-1 and A-3 pulleys were retained in each of the MFSS cable crimp repairs with less than 1 cm of exposure. Following the FW repair, the average increase in friction was 89% compared with an average of 53% for the MFSS repairs. Six of the 8 MFSS specimens achieved the UTS before any gap had occurred, whereas all of the FW repairs had more than 2 mm of gap before the UTS, indicating that the MFSS was a stiffer repair. The average UTS appeared similar for both groups.

Conclusions We describe a 2-strand multifilament stainless steel single cross-lock cable crimp flexor repair system. In our studies of this cable crimp system, we found that surgical exposure, average repair times, and friction were reduced compared to the traditional 4-strand cruciate FW repair. While demonstrating these benefits, the crimp repair also produced a stiff construct and high UTS and 2-mm gap force.

Clinical relevance A cable crimp flexor tendon repair may offer an attractive alternative to current repair methods. The benefits may be important especially for flexor tendon repair in zone 2 or for the repair of multiple tendons. *(J Hand Surg 2013;38A:677–683. Copyright © 2013 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Biomechanics, crimp, flexor tendon, stainless steel, suture.

DESPITE MANY RECENT improvements in the biomechanical parameters of repair technique and sutures, there are still challenges facing surgeons who perform flexor tendon repairs.[1–10] An optimal tendon repair should be simple to perform and provide accurate coaptation of the tendon ends. The repair should also provide strength for early active range of motion,[11–16] stiffness to resist gap formation during rehabilitation,[17–20] and compactness for smooth gliding through the pulley system. There has been little

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TABLE 1. Strength and Mode of Failure of MFSS Attached to a Cadaver Flexor Digitorum Profundus Tendon by a Single Cross-Lock Stitch Starting 1.2 cm From the Cut Tendon End*

Sample Number	UTS (N)	Failure Mechanism
1	90	Pull through tendon
2	119	Pull through tendon
3	111	Pull through tendon
4	124	Pull through tendon
5	93	Pull through tendon
6	89	Pull through tendon
7	126	Suture broke
8	110	Suture broke
9	107	Suture broke
Average	108	
Standard deviation	14	

Suture size, 3-0, 0.012 in (0.3083 mm).

*Measured on a servo-hydraulic testing machine (Mini-Bionix 858; MTS). This cross-lock was used for group 2.

discussion about the technical difficulty and complexity of performing these repairs that require 4 or 6 locking configurations. In addition, surgical exposure and the difficulty in attaining exact tensioning and coaptation of tendon ends without gap or overlap are important considerations. Many biomechanical properties of repair technique have been studied and include suture caliber, strength, stiffness, number of strands, method of attachment, and distance of the suture from the tendon's transected end. Other important considerations include strength and stiffness of the knot and friction of the repair with excursion through the flexor tendon sheath. These properties are all interdependent, and a system that addresses all of these parameters simultaneously is required.

A multitude of techniques exist for attaching sutures to tendon.[21] Our prior studies found the strongest attachment to be this single cross-lock (Table 1). We used a 3-0 multifilament stainless steel (MFSS) cable, a stainless steel crimp, and a single cross-lock attachment to the tendon to achieve a favorable combination of biomechanical parameters for a 2-strand repair of flexor digitorum profundus tendons in cadaver hands.

We have previously reported on the biomechanical parameters of MFSS suture[22] and stainless steel crimps.[9] In this study, we investigated the performance of this repair construct in cadaver tendon repairs and compared the biomechanical properties with a FiberWire (FW) (Arthrex, Naples, Florida) cruciate repair, which is the strongest repair reported in the literature.[23–27] The goal of this study was to analyze whether the cable crimp method would have technical advantages of reduced repair time, less surgical exposure, and low force of flexion (friction) while still producing a strong repair with high ultimate tensile strength (UTS) and 2-mm gap force.

MATERIALS AND METHODS

We compared the parameters of the MFSS cable-crimp repair with a 4-strand cruciate FW repair. We measured the force of flexion of the intact tendon and then measured the force of flexion following repair. The percent change in this force was then calculated. We also measured the ultimate load and load at 2-mm gap,[17,27–35] which likely correlates with clinical performance.[1,16] We measured the time for the tendon repair and measured the length of surgical exposure needed.

Force of flexion (friction), ultimate tensile strength, and 2-mm gap force

Flexor digitorum profundus tendons were used in the index, middle, and ring fingers of cadaver hands, with 8 samples in 2 groups. The force of flexion was determined by mounting the hands to plastic boards using Steinmann pins that were drilled through the radius and ulna. The skin was removed from the palmar surface of the finger and palm from the distal interphalangeal joint crease to the mid palmar crease, leaving the tendons and the entire pulley system intact. The flexor digitorum profundus tendons were then dissected and separated at the wrist. Each tendon was connected to a custom motor system that flexed the finger though a repeatable excursion 50 times. To measure and record the force needed for full excursion of the tendon, an inline load cell was connected between the tendon and the motor. We marked a point on the tendon 1 cm distal to the A2 pulley and initially measured the baseline force required for this point on the tendon to travel to a point proximal to the A1 pulley. To extend the finger, a suture was passed through the nail of each finger and connected to a 100-g weight that was hung over the end of the board.

Each tendon was transected 1 cm distal to the A2 pulley and then repaired.

Group 1 received a 4-strand, cruciate repair, using 3-0 FW with a knot consisting of 5 throws, and group 2 received a 2-strand, single cross-lock cable-crimp repair, using 4-0 MFSS (double suture).

For the MFSS cable-crimp repairs, we used MFSS with a specifically designed stainless steel crimp that we have previously described.[9,22] For the MFSS crimp repairs, we used a single cross-locked repair configura-