Surface Modification Counteracts Adverse Effects of Repaired Tendon Immobilization

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INTRODUCTION:
Flexor tendon injuries are common, and primary surgical repair combined with postoperative rehabilitation is the gold standard for treatment. Rehabilitation should be initiated as early as possible to optimize function and to prevent adhesions (1,2). However, the rehabilitation can also cause the repaired tendon to gap or even rupture (3,5). However, in some clinical scenarios postoperative rehabilitation must be delayed because of associated injuries or patient age and compliance. Recently, surface modification with carbodiimide derivatized hyaluronic acid and lubricin (cd-HA-Lub) has been shown to effectively reduce adhesions in combination with standard tendon rehabilitation in an animal model (4). This pilot study investigates the use of this novel intervention technique to prevent adhesions after flexor tendon repair with immobilization postoperatively in a canine in vivo model.

METHODS:
Tendon Repair and Treatment: Six mixed-breed adult dogs weighing 20 to 25 kg were used with the approval of our Institutional Animal Care and Use Committee. Following general anesthesia, the 2nd and 5th FDP tendons were approached and completely lacerated at 5 mm distal to the proximal pulley and repaired using a 2-strand modified Pennington technique with 3/0 Ethibond (Ethicon, Inc., Somerville, NJ). A simple running circumferential epitenon suture of 6-0 nylon (Ethicon Inc., Somerville, NJ) was used to reinforce the repair. Following tendon repair, one tendon was randomly selected for tendon surface modification with cd-HA-Lub (4). Briefly, a solution of 1% sodium hyaluronate (HA) (95%, 1.5x10^6 MW, Acros), 10% gelatin (Sigma), 1% 1-ethyl-3-(3-dimethylaminopropyl) carbodiimide hydrochloride (EDC) (Sigma) and 1% N-hydroxysuccinimidine (NHS) (Pierce), 0.1 M Mes pH 6.0 was prepared. Then, the repaired tendon was coated with this compound for 5 minutes, after which 0.2 ml of 260 μg/ml lubricin was applied to the surface. In the control group, the surface of the repaired tendons was rinsed with saline only. Following flexor tendon repair, a forearm cast was applied to fully immobilize the digit in neutral position and the wrist in 45 degrees of flexion. The animals were allowed immediate cage activity. The cast was removed at day 3 and 7 postoperatively for wound care, and then placed back until the animals were sacrificed at day 10.

Evaluation: Following sacrifice, the 2nd and 5th digits in the operated paws and contralateral normal paws were dissected for work of flexion (WOF) evaluation. The digit was mounted onto a custom jig with a K-wire that fixed the MCP joint and allowed free PIP and DIP motion. Six reflective markers were mounted on the distal, middle, and proximal phalanges to measure the DIP and PIP joint motion (Motion Monitor System, Motion Analysis Corporation, Santa Rosa, CA). The proximal FDP tendon was connected to a load transducer and a motor that pulled the tendon to flex the digit. Work of flexion data were calculated from the area under the tendon displacement vs loading curve during digit flexion. Since the PIP angle was variable, the normalized WOF (nWOF) was calculated by dividing the sum of PIP and DIP angles based on previous reports, truncating DIP motion at 40 degrees to eliminate any effect of joint laxity (4).

After measuring WOF, the repaired tendons were further dissected, keeping the proximal pulley intact. The gliding resistance between the tendon repair site and normal pulley was then measured using a custom tendon-pulley frictional testing device, as previously described (4). Finally, the repaired tendons were secured to a servohydraulic testing machine (MTS Systems, Eden Prairie, MN) and distracted to failure at a rate of 20 mm/min. A differential variable reluctance transducer (DVRT, Microstrain, Williston, VT) was attached to the tendon to measure gap formation during testing. Maximum breaking force was recorded. Repair stiffness was then calculated from the slope of the linear region of the force versus gap formation (as measured by the DVRT) to measure the resistance to gap formation.

A paired t-test was used to analyze the differences on nWOF, gliding resistance, repair strength, and stiffness between repaired FDP tendons. Any p-value smaller than 0.05 was considered statistically significant.

RESULTS:
The nWOF of the normal digit from the non surgical contralateral paw was significantly lower than the digit with the FDP repaired regardless of cd-HA-Lub treatment status (p = 0.01). The nWOF of the FDP tendon treated with cd-HA-Lub was significantly lower than the repaired FDP tendon treated with saline (p = 0.01) (Figure 1). The gliding resistance of the normal FDP tendon was significantly lower than the repaired FDP tendon regardless of cd-HA-Lub treatment status (p = 0.05). The gliding resistance of cd-HA-Lub treated tendons was significantly lower than the control group (p = 0.03) (Figure 2). However, there was no significant difference in maximum failure strength and stiffness between repaired tendons with or without cd-HA-Lub.

DISCUSSION:
The surface treatment of repaired flexor tendon with cd-HA-Lub, a bio-lubricant with anti-adhesive properties, has been previously reported to increase the tendon gliding ability and decrease the adhesion formation following repair in a canine model (4,5) which included postoperative rehabilitation. This study for the first time investigated whether this surface modification could have the same effect with the repaired tendon immobilized. The results demonstrated that repaired flexor tendons had decreased friction and adhesions on postoperative 10 day, even with immobilization, using this treatment adjunct. The repair strength was not affected by the surface treatment, which is consistent with a previous report (4). Our findings are also consistent with a previous report of impaired digit function if the repaired flexor tendon is immobilized for 10 days postoperatively and no adjunctive treatment is provided (6). The major limitation of this study was that we only studied one short-term time point. Therefore, we don’t know how long these effects can last, which will be studied in the future.

SIGNIFICANCE:
Surface treatment with cd-HA-Lub following flexor tendon repair increases the tendon gliding ability, decreases adhesions, and improves digit function with postoperative immobilization at 10 days postoperatively. This treatment may provide an opportunity to improve outcomes for patients in whom the post operative therapy must be delayed after flexor tendon repair.

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REFERENCES: