MODIFICATION OF EXTRASYNOVIAL TENDON BY CARBODIIMIDE DERIVATIZED HYALURONIC ACID (CD-HA) GELATIN FOR FLEXOR TENDON GRAFT (SHORT TERM IN VIVO STUDY)

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INTRODUCTION

Hand injuries affecting tendon function are common in young adults, and commonly result in significant disability. Adhesion formation continues to be a difficult problem after flexor tendon repair, although the outcome has been improved with newer suture techniques and postoperative therapies. The tendon graft still plays a very important role in reconstruction to restore the finger function. Extrinsicovial tendons are most often used as donor tendons to replace the injured or deficient flexor (intrasynovial) tendon. However, clinical and experimental studies have demonstrated that restrictive adhesions and poor digital motion are frequent sequelae of extrasynovial tendon grafting to the intrasynovial environment 1, 2. In addition to anatomic and biological differences between intrasynovial and extrasynovial tendons, recent studies have shown a significant difference in friction, with the extrasynovial tendon having the rougher gliding surface 2. Chemical modified hyaluronic acid (HA) has been reported to improve the tendon gliding ability and reduce the friction compared to the HA alone 3, 4. However, it is not clear that this positive outcome from the in vitro study would translate into improved tendon graft motion or reduced adhesion formation in vivo. The purpose of this study was to test the hypothesis that carbodiimide derivatized HA gelatin (cd-HA-G) improves the gliding of extrasynovial tendon grafts within short term (one week) in vivo using canine model.

METHODS

A total of 16 flexor digitorum profundus (FDP) tendons from 2nd and 5th digits from 8 dogs were used in this study. A proximal radial neurectomy was performed through a lateral humeral incision. This would denervate the triceps muscle and thus prevent elbow extension and thereby weightbearing on the operated forelimb. Two peroneus longus (PL) tendons (extrasynovial tendon) from both hindpaws were harvested and transplanted to the surgical digits to replace the FDP tendon. One of the PL tendons was immersed in cd-HA-G (1% HA + 10% gelatin + 0.25% EDC/0.25% NHS), while the other will be preserved in saline solution until the time of tendon grafting. The distal tendon graft was first secured by a pull-out suture of 3/0 nylon suture passed through drill holes in the distal phalanges and fixed to a tie-over button dorsally, and then, the proximal ends of the grafts was sutured to the proximal FDP tendons using a Pulvertaft weave secured with two sutures of 4/0 braided Dacron. A special canine sling was used to hold the operative paw underneath the chest. Postoperative rehabilitation was started at day 5 with modified synergistic motion protocol. The dogs were sacrificed at day 7, and the digits from cd-HA gelatin, saline, and contralateral non-operative digits were harvested for testing.

Work of Flexion (WOF) Measurement

The digit was mounted on the testing apparatus by a pin which fixed to the MCP joint in extension position. The transferred FDP tendon at the palm level was attached to a force transducer which connected to an actuator which pulled FDP tendon proximally to flex the digit. During testing, a video fluoroscopy was used to record the digit motion from extension to flexion, and then the images were digitized using Analyze Software to determine the joint range of motion. The WOF data were normalized by PIP and DIP range of motion 5.

Gliding Resistance Measurement

Following WOF measurement, the digit was further dissected with FDP tendon, proximal pulley with proximal and middle phalanxes preserved. The specimen was mounted to the testing device described by Uchiyama 6, and the gliding resistance between FDP tendon and proximal pulley was measured.

Quantification of HA Hinding on Tendon Surface

After gliding resistance measurement, the FDP tendon around proximal pulley portion was incubated in 1% hydrogen peroxide for 5 min. Biotinylated HA binding protein was used for the tendon surface immunochemistry staining. The staining intensity of HA on the tendon surface was measured from the images using Scion Image software. In this image 0 grayscale value was white, minimum color intensity, and 255 grayscale value was black, maximum color intensity.

RESULTS

WOF in the tendon graft groups was significantly higher than the contralateral normal group (p<0.05). The graft treated with cd-HA-G was significantly lower than the saline group in WOF (p<0.05) (Figure 1). The comparison of the gliding resistance among these three groups resulted in the same pattern as the WOF (Figure 2). Intensity of the cd-HA-G was significantly greater than the saline group (p<0.05) (Figure 3).

DISCUSSION

Hyaluronic acid is a natural polysaccharide present in the intercellular matrix of most vertebrate connective tissues, especially in synovial fluid. The unique properties of HA result in a molecular network which, in highly hydrated conditions, is extremely viscoelastic and pseudoplastic. These rheological properties are responsible for the biological function of HA and its medical applications. Exogenously applied HA has been used both clinically and experimentally to prevent adhesions between the flexor tendon and surrounding tissue following tendon repair, but the in vivo results have been contradictory. As the half-life of HA in tissues is short and contact binding strength with tendon is weak, it is possible that native HA is eliminated too rapidly, especially during repetitive motion, to serve as a long-lasting physical barrier between opposing tissues. Momose et al 7 reported that the gliding resistance of extrasynovial tendon treated by carbodiimide derivatized HA was decreased even after 100 cycles of repetitive motion of the tendon against a normal pulley in vitro. In the current short-term in vivo study, we found that cd-HA-G not only increased the HA half-life but also binding strength by chemically binding carboxyl groups in the HA with the amino groups on the tendon surface. By this chemical modification, the tendon frictional force decreased due to improved surface smoothness, and improved digit function which was indicated by a lower WOF compared with saline treatment.

REFERENCE


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