TENDON SURFACE MODIFICATION BY CHEMICALLY MODIFIED HA COATING AFTER FLEXOR DIGITORUM PROFUNDUS TENDON REPAIR

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INTRODUCTION

Tendon injuries are often encountered in daily life. Especially in the hand, the challenge is to balance motion, and its associated risk of rupture of the repair, with protection of the repair, and the consequent risk of motion-restricting adhesions. Strategies which reduce the gliding resistance of the repaired tendon would allow motion with lower loading, and might thereby reduce the rupture risk. Hyaluronic acid (HA) is a high molecular weight polysaccharide, which has a significant lubricating function. Surface has been used as an adjunct to tendon repair in the past, but the results have been contradictory, possibly due to variations in degradation rate or adherence to the tendon surface. We speculate that tendon adhesions could be reduced if the HA could be fixed to the tendon surface in such a way as to minimize enzymatic degradation and mechanical removal. Carbodiimide derivatized HA (cd-HA), is less soluble in water than normal HA, and therefore has an increased tissue residence time. In our own (unpublished) tests, we have found that gelatin combined with this cd-HA (cd-HA gel) reduces friction of intact tendons beyond that of HA or cd-HA alone, and that the effect persisted in vitro over as many as 500 repetitions. The addition of a laceration and repair adds complexity, but is closer to the clinical situation. The effect of this cd-HA gel on tendon repair is unknown. Thus, the purpose of this study was to study the effect of cd-HA gel on gliding and repair integrity during simulated repetitive motion of a repaired tendon in vitro.

METHODS

**Specimen:*** Twelve hindpaws were obtained from six adult mongrel dogs. A total of 36 flexor digitorum profundus (FDP) tendons were used. The tendons were randomly divided into three groups; A) Control group – no surface modification after tendon repair; B) Simple HA group – surface of the repaired tendon was covered with 1% HA solution, and C) cd-HA group – surface of the repaired tendon was covered with a carbodiimide derivatized HA/gelatin membrane. The in situ tendon excursion range was measured using the proximal pulley edge as a landmark. A complete laceration in the FDP tendon was made 6 mm distal to the proximal tendon marker, in order to allow the repair site to travel the full length of the proximal pulley during normal excursion. The tendon was repaired with a modified Kessler technique.

**Digit Resistance Test:**

The gliding resistance between the FDP and the proximal pulley, FDS, and bone was measured using the method of Uchiyama et al (Figure 1)[1]. The measurement system consists of a mechanical actuator linear potentiometer, two tensile load transducers, and a mechanical pulley. A 500-gram weight was attached to the distal end of the FDP tendon through the mechanical pulley to maintain tension. The tendon was pulled proximally by the actuator against the weight to simulate flexion. The actuator movement was then reversed under the pull of the 500g weight to simulate extension. Load from the two transducers (F1, F2) and excursion, measured by the linear potentiometer were recorded at a sampling rate of 10 Hz. Gliding resistance was measured at 1, 5, 10, 50, 100, 200, 300, 400, and 500 cycles for each group.

**Strength testing:** After gliding testing, failure load, tendon stiffness (linear slope of the force-tendon elongation curve), and resistance to gap formation (linear slope of the force-gap formation (DVRT displacement) curve) were measured.

**RESULTS**

The average maximum gliding resistance of all tendons prior to laceration was 0.21±0.08 Newtons, and after repair was 1.08±0.32 Newtons. Following treatment, the change in gliding resistance over the 500 cycles showed similar patterns in each of the 3 groups.

**DISCUSSION**

The unique properties of HA result in a molecular network, which, in highly hydrated conditions such as occur in vivo, is extremely viscoelastic and pseudoplastic. These rheological properties are responsible for the biological function of HA and its medical applications. The use of HA to improve the results of tendon repair in an animal model in vivo study had an encouraging result, but a clinical trial was not so successful. In an effort to increase the increase in friction of HA on the tendon surface, we considered biocompatible agents that could increase the cross-linking of the HA mixture to proteins (primarily collagen) on the tendon surface. Gelatin was effective in pilot tests, and thus was chosen for this study. From our results, as the gliding cycle increase in the control group, there was no weakening of the repair after 500 cycles, but the friction between repair site and A2 pulley did increase almost 16%, while friction was unchanged in the cd-HA gel group. Results in vivo might, of course, be different, but we believe that the increase in friction in the control group may reflect ablation effect of the repair on the pulley surface, which has also been shown in an animal model in vivo. Reducing this abrasion effect could benefit tendon healing and reduce adhesions. The results of this study open the possibility of the use of this substance as an aid to improved tendon healing, and we believe deserves testing in an in vivo model in the future.

**Table 1**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Maximum Force (N)</th>
<th>Stiffness (N/mm)</th>
<th>Resistance to Gap Formation (N/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>30.28 ± 4.56</td>
<td>16.67 ± 2.84</td>
<td>49.91 ± 20.95</td>
</tr>
<tr>
<td>Simple HA</td>
<td>33.57 ± 7.85</td>
<td>17.17 ± 3.83</td>
<td>65.57 ± 39.50</td>
</tr>
<tr>
<td>Modified HA</td>
<td>32.59 ± 7.30</td>
<td>16.07 ± 2.85</td>
<td>43.16 ± 14.98</td>
</tr>
</tbody>
</table>

**ACKNOWLEDGEMENTS**

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**REFERENCE**