The boundary lubricating ability of phospholipid on flexor tendon of rabbit

Introduction

A tendon is one of the most ingenious biotribosystems which has a very low friction coefficient. However, it is highly susceptible to adhesion in pathological conditions. The effectiveness of exogenously administration of sodium hyaluronate (HA) on reduction of postoperative adhesions has been reported. Even though little is known of its mechanism, besides the biochemical effects, one of the effects appears to depend on fluid film lubrication. However, it seems to be difficult to maintain fluid film during postoperative phase in which inflammation and swelling are severe. Boundary lubrication may play an important role, particularly in such a phase. The aim of this study is to examine the effectiveness of Ln-dipalmitol phosphatidylcholine (DPPC) for a tendon lubrication.

Materials and Methods

Japanese white rabbits weighing 3.0 to 4.0 kg were used. These animals were sacrificed by an overdose of pentobarbital sodium. The synovial sheath of the flexor digitorum profundus (FDF) tendon of the third digit was removed and the FDF was marked with a pen at the distal edge of the distal pulley at full flexion and full extension of the proximal and distal interphalanxial joints. The range between two marks represented the excursion of the pulley, from 8 mm to 12 mm. The FDF, the middle phalanx and tendon pulleys which were attached to both ends of the bone were harvested. Then the tenon was set to our original friction tester (Fig. 1). Both ends of the tendon were clamped to acrylic plates and connected to stainless steel plates equipped with strain gauges. A pretension of 1.96 N was applied in order not to loosen the tendon. The middle phalanx was fixed to an acrylic plate on the actuator, taking care that the gliding surface should be horizontal and parallel to the tendon's longitudinal axis. The proximal mark of the FDF was adjusted to the distal edge of the distal pulley, while the actuator gave 8 mm of transfer on the acrylic plate at a speed of 2 mm/sec, applying the load L on the distal pulley. Then the tendon glided within the marked excursion range, creating the friction force. The preloading time was defined as loading duration before gliding. The friction force could be obtained from the difference between the tension of both ends of the tendon as measured by strain gauges. Theoretically, the friction coefficient μ of FDF at the distal pulley was calculated from the measured force F1 and F2 and the applied load L (Fig. 2). Although the friction force included gliding resistance at the proximal pulley - FDF interface, the extra force was constant and not affected by load change. Therefore it was equal to the force F1 when no load was applied. F is sum of f (the friction force between the tendon and the pulley) and f' (the friction force between the tendon and the bone). Since the friction coefficient can be obtained from the following equation

\[ \mu = (\frac{f1 - f2 - F0}{2L}) \]

In the experiment, lubricant was varied and the load (1.17N) and preloading time (10sec) were kept constant. Saline solution, HA (1X10^6 molecular weight, 1.0 g/dl) and DPPC (0.1 g/dl) + HA were used as lubricants. At first, experiments were carried out lubricated by saline, next, were carried out lubricated by HA solution. After these experiments, tendons were rinsed with the saline solution of 10wt% polyoxyethylene p-t-octylphenyl ether (Triton X-100). After these treatments, next experiments were carried out lubricated by HA solution and HA+DPPC solution.

Measurements were repeated five times under each condition, and an average of five measurements was used for evaluation. The data were analyzed using the Student t test.

Result

The friction coefficient decreased significantly with HA solution. The value of friction coefficient was 0.034±0.010 (mean±S.D.) in saline, and was 0.018±0.005 in HA solution (Fig. 3a). In the experiment after surface treatment with detergent, the friction coefficient increased significantly with HA solution. The value was 0.036±0.004 (Fig. 3b). The addition of DPPC to HA solution was effective to keep lower friction coefficient even after treatment with detergent. The value was 0.022±0.009 (Fig. 3c).

Discussion

We have developed a new device to measure the friction force of a tendon. In this study, we have used detergent successfully to remove the adsorbed film on flexor tendon. The boundary lubricating ability of HA solution was improved by addition of DPPC. Our study suggests that, after tendon injury, the administration of DPPC added into HA may be effective to tendon healing without adhesion formation from the standpoint of biotribology. Moreover, early passive mobilization may be going along better by assist of the administration of DPPC; however the study in vivo is necessary.

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