BIOMECHANICS OF TENDON GLIDING

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INTRODUCTION: When tendon excursion occurs through a pulley, drag and friction are encountered at the interface. It has been hypothesized that the repetitive exposure to such friction and attrition could be detrimental. A system has been developed which enables us to measure the friction or drag resistance when tendon excursion takes place through pulley or bony tunnel. This presentation will report the biomechanics of tendon gliding and the factors affecting the gliding resistance.

METHODS: A tendon sliding through the pulley is analogous to a belt wrapped around a fixed mechanical pulley (Fig. 1). Assume that the total arc of contact between the belt and pulley is ?, (a + ß), and the tensions in the belt on each side of the pulley are $F_2$and F_1. If the impending motion of the cable is from F_1 to F_2, then F_2 is greater than F_1,

$$F_2 = F_1 e^{\mu ?} \qquad (1)$$

the frictional force

$$f = F_2 - F_1 = F_1 (e^{\mu ?} - 1) \qquad (2)$$

$$\mathrm{Ln}\, F_2 / F_1 = \mu ? \qquad (3)$$

where μ is a frictional coefficient.

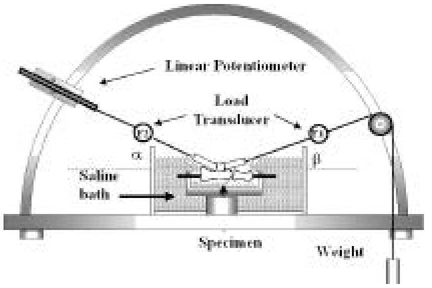

Figure 1 Device for measuring gliding resistance measurement between the tendon and pulley system.

The measurement system developed has been verified by comparing with that of theoretical derivation using the ideal Dacron and rod model.

FRICTION COEFFICIENT BETWEEN TENDON AND PULLEY: Nine normal index digits from nine fresh-frozen cadavers were used. Each specimen was prepared preserving the A2 fibrous pulley bony insertion but eliminating all bony contact with the FDP tendon. The specimen was mounted on the testing device. Continual irrigation with saline solution was performed to keep the specimen moist. The frictional coefficient, μ, of the specimen was obtained based on equation (3). The friction coefficients has been found to be 10.027±0.014 for flexion (R^2=0.85) and 0.075±0.017 (R^2=0.95) for extension. The relationship of tendon-pulley friction and angle was almost identical to the theoretical model. This measured frictional coefficient of the A2 tendon-pulley surfaces was somewhat greater than that of cartilage in a diarthrodial joint.

EFFECT OF HYALURONIDASE TREATMENT: To better understand the precise lubrication mechanisms at the tendon-pulley interface, the hypothesis that hyaluronidase-sensitive lubrication exists between the tendon and the pulley was evaluated. Fresh-frozen digits from 21 donors were used. The specimens were randomly divided into two groups. In group 1 the first test was performed immediately after dissection. Then, the surface of the

FDP tendon was washed thoroughly using saline solution and retested. After the second test the tendon was again taken out of the pulley and treated with 400U/ml hyaluronidase at room temperature for two hours, after which, the third test was performed. In group 2 the test sequence was the normal tendon, followed by the hyaluronidase treated tendon, and then the tendon washed with saline. In both groups, the resistance increased only after the hyaluronidase treatment.

EXTRASYNOVIAL AND INTRASYNOVIAL TENDON:

Extrasynovial tendon had coomonly been used as tendon graft for reconstruction of intrasynovial tendon. Gliding ability of the flexor digitorum profundus tendon (FDP) and the palmaris longus (PL) tendon through the A2 pulley was compared. Fourteen digits and the ipsilateral palmaris longus tendons from fourteen donors were used. The gliding resistance of the PL was significantly greater than that of the FDP. Gliding resistance of the FDP tendon changed less with increasing tendon tension than did that of the PL tendon. The PL tendon is an extrasynovial tendon and thus does not have a synovial membrane. Instead, it has a paratenon of loose connective tissue.

SURFACE MODIFICATION BY cd HA: Further investigation was performed to improve the gliding surface using hyaluronic acid (HA). Chemically binding of hyaluronic acid (HA) to extrasynovial tendon was considered. In this study, canine peroneus longus (PL) tendons were immersed into one of three different solutions (saline, 1% HA, 1% chemically modified HA) for 2 hours. The gliding resistance of treated PL tendons was measured at 1, 5, 10, 20, 50, and 100 cycles in a saline bath. After treatment with unmodified HA and chemically modified HA, the gliding resistance of the PL tendons decreased significantly compared to the saline treated tendons ($p<0.05$), and this effect of the two HA treatments persisted through 10 cycles. (Fig. 2). For cycles 20-100, the gliding resistance of PL tendons treated with chemically modified HA remained significantly lower than that of tendons treated either with saline or unmodified HA.

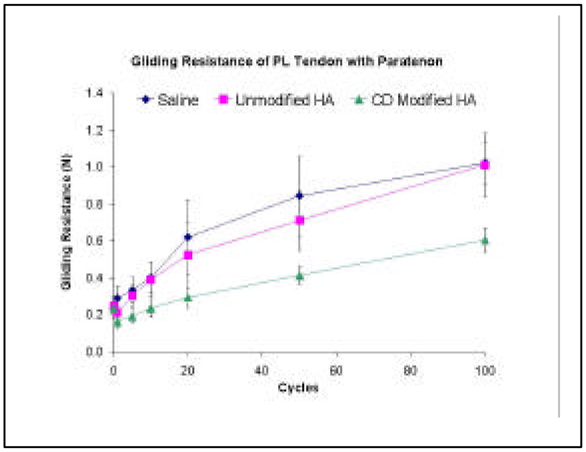

Figure 2. Gliding resistance of peroneus longus tendon with paratenon after repetitive excursion. After treatment with unmodified HA or chemically modified HA, the gliding resistance decreased significantly compared to the saline treated tendons.

SUMMARY: The knowledge of tendon gliding biomechanics would provide better understanding of the potential etiology and the development of treatment modalities of tendon disorders associated with repetitive loading. Techniques and material used for tendon repair will all affect the gliding resistance and thus the outcome of tendon surgery. Improving of tendon gliding surface using chemical treatment or genetic therapy is the potential consideration for future investigation.

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