INTRODUCTION: Not only static forces but also dynamic forces are loaded on the Achilles tendon of the healing process with ankle motion and/or weightbearing. However, the regenerating tendon has been assessed only by the static biomechanical properties, and there are few reports of the dynamic biomechanical properties of the regenerating Achilles tendon. Therefore, the purpose of this study is to evaluate both the static and dynamic properties of the regenerating Achilles tendon after tenotomy and analyze the differences among them.

MATERIALS AND METHODS: Forty-two male Japanese white rabbits (mean body weight 2700 g) underwent Achilles tenotomy in the right limbs. All animals were allowed unrestricted cage activity after tenotomy. At each of 3, 6 and 12 weeks after tenotomy, 14 rabbits were euthanized and bilateral Achilles tendons with calcaneus (Bone-Tendon Complex: BTC) were obtained. The left Achilles tendons were served as controls. Seven rabbits (14 BTCs) were used for static biomechanical evaluation, and the other 7 rabbits (14 BTCs) were used for dynamic viscoelastic testing. Tensile strength, Young’s modulus and tangent phase-shift angle \( \delta \) were analyzed statistically using one-way ANOVA, student’s t-test and paired t-test.

RESULTS: 

[Static biomechanical properties] For the tensile strength of the regenerating tendon, the values at 3 weeks were significantly lower than those at 6 weeks (p<0.01), which were significantly lower than those at 12 weeks (p<0.01). At 12 weeks, the values were significantly lower than those of the controls (Fig. 1) (p<0.05). For Young’s modulus, the values at 3 weeks were significantly lower than those at 6 weeks (p<0.01), which were significantly lower than those at 12 weeks (p<0.01). At 12 weeks, the values were significantly lower than those of the controls (p<0.05)(Fig. 2). 

[Dynamic biomechanical properties] For the tan the regenerating tendon, the values at 3 weeks were significantly greater than those at 6 and 12 weeks at frequency rates of 0.8~10 Hz (p<0.05). There were no significant differences at between 6 and 12 weeks at all frequency rates. At 3 weeks, the values were significantly greater than those of the controls at frequency rates of 0.8~4 Hz (p<0.05). The values at 6 and 12 weeks, there were no significant differences between the regenerating tendon and the controls at all frequency rates (Fig. 3).

DISCUSSION: The factors that have great influences on the biomechanical properties of the tendons are orientation, collagen type, density and diameter of the collagen fibers, and proteoglycane, protease and water content of the matrix (1). According to the histological studies (2), very few crimp patterns and randomly oriented collagen fibers are seen in the regenerating tendon 3 weeks after tenotomy. Longitudinal parallel arrangements of collagen fibers and regular crimp pattern in longer cycles are seen in the regenerating tendon 12 weeks after tenotomy. However, the diameter of the collagen bundles is still thinner than that of control. Supported by the histological findings, static biomechanical properties of the regenerating tendon at 12 weeks after tenotomy were greater than those at 3 and 6 weeks, and still lower than that of the controls. On the other hand, the values of the tan\( \delta \) were recovered to those of the controls at 6 weeks after tenotomy. The tan\( \delta \) is the parameter of the damage of the high density molecules (the collagen molecules in the Achilles tendon in this study). The low values of the tan means tight junction of inter-collagen molecules, low mobility of collagen molecules and low loss of energy (3). Therefore, the present study showed that, the junction of inter-collagen molecules which was lost at 3 weeks was tightened until the level of the controls at 6 weeks. These results suggested that dynamic properties could be recovered earlier than the static properties.

REFERENCES


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