MECHANICAL TESTING OF TENDON IN TRANSVERSE COMPRESSION

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INTRODUCTION

Tendons primarily experience tensile loading along their fibre-aligned direction. They may at the same time also undergo compression and shear. Some of these complex loadings occur normally, as when a tendon wraps around a bone and is subjected to longitudinal tension and transverse compression. Other complex loadings are abnormal and may lead to rupture, as occurs at the rotator cuff (Józsa and Kannus, 1997).

Most mechanical testing of tendon has been performed in tension along the fibre-aligned direction. Testing in the transverse direction is far less common and has only been performed in tension (Bonifasi-Lista et al., 2005; Lynch et al., 2003; Quapp and Weiss, 1998). There appear to be no data in the literature on the transverse compressive properties of tendon. Such information is very important for the creation of finite element models of tendon.

The aim of this study was to measure the mechanical properties of tendon in compression transverse to the fibre-aligned axis.

METHODS

Ten digital extensor tendons from the bovine foot were dissected immediately after slaughter and frozen at -18°C. Samples were defrosted the day before testing and soaked in 10% sucrose solution overnight. Prior to testing, samples were rinsed with phosphate buffered saline (PBS).

Mechanical tests were done on ten specimens using a specially designed rig which also allowed measurement of tendon cross-sectional area (Salisbury et al., 2006a, 2006b). The tendon sample hung under its own weight and was compressed at mid-substance between two glass backing plates, one a window (40mm×50mm) in a paddle used to compress the tendon (*Y*-displacement). Paddle movement was measured with an LVDT (RDP Electronics DCT-500A, UK). A digital video camera (Basler A631f, Germany) recorded the change in transverse width of the specimen through the glass window (*X*-displacement) every 5s. All tests were carried out at room temperature.

Each sample was first preconditioned by applying a 20.8 N compressive load ten times for 10s at a time with 10s recovery between each successive load. Then sample cross-sectional area was measured at five sections along the tendon at the same level as the glass window, after which the tendon was placed in a 10% sucrose solution bath for 1 hr while still mounted in the test rig.

Subsequently, for three of the tendon samples, six load profiles were applied, each lasting 13 min, with 1 hr recovery time in the sucrose solution between each. The load magnitudes were 2.8 N, 20.8 N, 39.7 N, 2.8 N, 20.8 N, and 39.7 N. Each load was applied for 120s followed by 660s of recovery. Prior to the application of each load profile, a 0.9 N compressive load was applied for 5s and then removed. The peak value of displacement during this time was taken as the zero point. From this data, repeatability was calculated using the method advocated by Hayward (1977).

For the remaining seven tendon samples, ten load profiles were applied. The procedure was the same as for the previous three tendons; however, the load magnitudes were 0.9 N, 2.3 N, 3.8 N, 5.7 N, 8.5 N, 12.3 N, 17.0 N, 22.7 N, 30.2 N, and 39.7 N.

RESULTS AND DISCUSSION

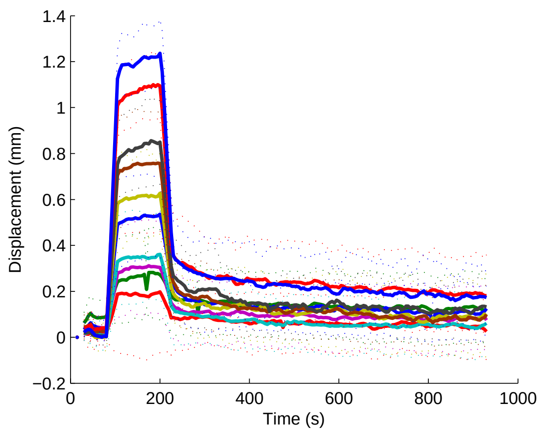

Figure 1: Mean *X*-displacement ± one standard deviation vs. time curves for seven tendon samples under ten load magnitudes.

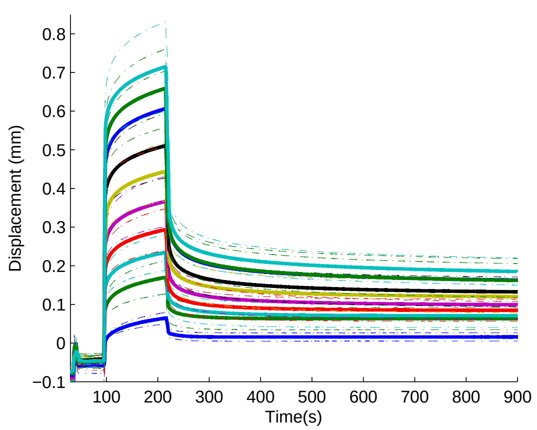

Figure 2: Mean *Y*-displacement ± one standard deviation vs. time curves for seven tendon samples under ten load magnitudes.

Loading responses are shown in Figures 1 and 2. For a given load, variability was found in mechanical response between tendon samples. This is due to variation both in tendon shapes and in mechanical properties. Tendons did not recover fully upon removal of load – the amount of plastic deformation increased in both the *X*- and *Y*- directions as greater loads were applied. The mean cross-sectional area of the samples was 39.1 mm^2. Repeatability of displacements in the *X*-direction was ±0.04 mm 10s after load application, ±0.05 mm 100s after load application, and ±0.02 mm in recovery.

SUMMARY/CONCLUSIONS

A new method for studying transverse compressive creep of tendons has been presented. With the load, displacement, and sample shape data collected, enough information is available to perform finite element simulations of the test, and hence obtain constitutive model parameters by inverse analysis.

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