# Sensitivity of the Material Properties of the Lateral Collateral Ligament of the Porcine Stifle Joint to Strain Rate

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## I. INTRODUCTION

Human ligament injuries are common and can cause significant morbidity and long-term disability [1]. Understanding traumatic mechanisms and injury patterns can aid in the prevention, reconstruction and rehabilitation of ligament injury. The aim of this study was to determine the relationship between material properties of ligament and strain rate in tension across rates of loading that may occur during a full range of different knee-ligament injuries.

## II. METHODS

Sixty lateral collateral ligaments (LCLs) were harvested from porcine stifle joints. A 15 × 15 × 30 mm bone block was cut around the LCL origin. A thin longitudinal segment of the ligament was isolated by blunt dissection in order to acquire a long thin middle section of fixed cross-sectional area and broad anchor at either end. Cross sectional area was measured by casting the mid-substance in alginate paste [3]. The bone blocks were secured in aluminium pots by alignment screws and bone cement.

Tensile tests were carried out at target strain rates of 0.01, 0.1, 1, 10 and 100/s using screw-driven, (Instron 5866), servo-hydraulic (Instron 8872), and drop-weight (Instron Dynatup 9250-HV) testing machines. A custom-made impact tensile adaptor (ITA) was used for tests at 10 and 100/s in the drop-weight machine. Two bi-axial strain gauges were bonded to the pots to measure force. For all tests video extensometry (Phantom V12.1, frame rate 27-47,000fps) was employed to calculate strain using multiple dots that were made across the ligament with permanent black ink immediately prior to testing.

## III. INITIAL FINDINGS

A bilinear relationship was found between both tensile modulus ($R^2$=0.76) and stress at failure ($R^2$=0.68) with strain rate. Specifically:

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|---|---|---|---|
| Tensile modulus, $E$ = | $384\psi+292, \quad \psi < \psi_0 = 1.3/s$ | Failure stress, UTS = | $32\psi+44, \quad \psi < \psi_0 = 0.97/s$ |
| | $0.68(\psi- \psi_0) +790, \quad \psi > \psi_0$ | | $0.05(\psi- \psi_0) +75, \quad \psi > \psi_0$ |

where $\psi$ is the strain rate.

## IV. DISCUSSION

Sensitivity of ligament tissue to strain rate at low strain rates has been established by previously [2] and confirmed by this study, but our results demonstrate that this effect diminishes at approximately 1/s, beyond which further increase in strain rate affects the material properties only slightly. The bilinear fit is a better fit to our data (higher $R^2$ value) than the logarithmic, and, importantly allows for a strain-rate sensitivity limit to be determined beyond which the ligament properties can be deemed effectively insensitive to strain rate.

## V. REFERENCES

[1] Gelber et al, Ann Intern Med, 2000. [2] Masouros et al, J Strain Analysis for Engng Design, 2009. [3] Goodship & Birch, J Biomech, 2005.

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