IN VITRO LIGAMENT STRAIN MEASUREMENT: CAN IMPLANTABLE AND NON-INVASIVE METHODS YIELD COMPARABLE RESULTS?

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INTRODUCTION

Experimental measurement of ligament strain behaviour is made challenging by the complex geometry of the tissue and the often-invasive nature of measurement devices. There is no gold standard for measurement method, and no direct comparison of the results obtained by implantable and non-invasive measurement methods has ever been made. In this study, two methods for measuring ligament strain *in vitro* were compared: non-invasive optical measurement (OPT) and the implantation of a differential variable reluctance transducer (DVRT).

METHODS

The equivalence of DVRT and OPT was first tested in an isolated tensile test. The anterior fibres of the medial collateral ligament (MCL) were resected from 8 bovine stifle (knee) joints and mounted in a Zwick Z010 materials testing machine. A sub-miniature DVRT (Microstrain, VA.) was implanted parallel to the primary ligament fibre direction. Two optical markers were painted at the extremities of the device (10 mm apart), and also at each end of the ligament (35 mm). A uniaxial tensile load was applied to the ligament at 30 $N.s^{-1}$ until 150 N of force was reached. The ligament was allowed to relax to 30 N of internal force and the process repeated for 3 cycles. Each ligament was tested 4 times at 10 min intervals. DVRT data was sampled at 50 Hz using a National Instruments BNC connector block and 12-bit DAQ card. The optical markers were tracked using a 50 Hz digital camcorder and SIMI Motion Analysis software. Tensile strain (ε) was computed using reference MCL length at 0 deg (l_0) and instantaneous length (l): $\varepsilon = (l-l_0)/l_0$. Strain change (Δε) was defined as the difference between peak and minimum strain.

Quasi-static tests were conducted using intact bovine stifle joints (n=3). Ten cycles of passive flexion and extension were applied via a customised rig at 30 deg s^{-1} between 0-120 deg. DVRTs were implanted in mid-anterior and proximal-anterior MCL fibres. Corresponding optical markers were tracked with two calibrated 50 Hz cameras and SIMI software was used to reconstruct the 3D coordinates using DLT methodology.

RESULTS AND DISCUSSION

There was no significant difference in Δε detected using OPT or DVRT during cyclic uniaxial tension testing (p=0.184) (Fig.1). The DVRT did report significantly mean higher absolute strain (p=0.001).

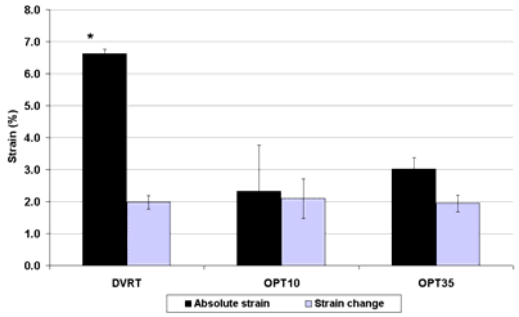

Figure 1: Isolated test results

The DVRT results for quasi-static tests may have been influenced by the motion of deep MCL fibres around the device. OPT can measure only surface strains (Fig2), which may account for the difference in results.

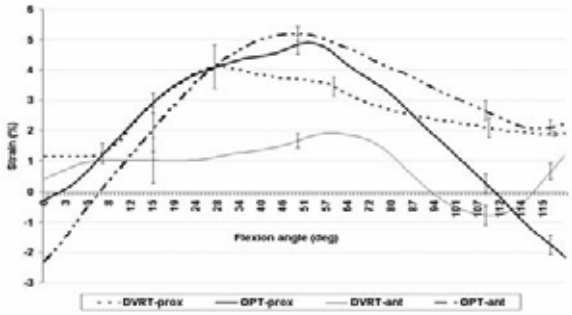

Figure 2: *In vitro* test results

CONCLUSIONS

While no significant difference for measurements of Δε= using DVRT or OPT was shown, practical issues with each method were identified. Ideally for strain measurement in soft tissues, a non-invasive method will be utilized to preserve the ligament structure. However this is unsuitable for intra-articular or multi-layered ligaments. The sensitivity of OPT is dependent on the chosen gage length. Implantable devices should be small and compliant enough to avoid abnormal tissue deformation, and caution used in interpretation of results from multi-layered ligaments.