

BioDynamic Test Instrument for Characterization of Tissues and Biomaterials

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INTRODUCTION: The objective of this work was to employ the novel design of the BioDynamic testing platform to evaluate the mechanical properties of hydrogels and other composite biomaterials. The testing platform allows for continuous test and stimulation in a fully integrated and instrumented configuration by providing material characterization (viscoelastic properties, strength, creep and stress relaxation) within a physiological environment (nutrient flow, pressure loading, pH, dissolved oxygen, and temperature).

METHODS: An advanced BioDynamic testing platform has been designed that can be used to evaluate the mechanical properties of tissue-engineered constructs for both cardiovascular and musculoskeletal applications.

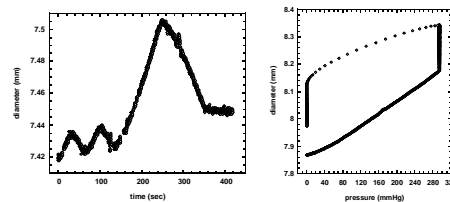
The BioDynamic instrument was used to test a variety of specimens to demonstrate its versatility and advanced features with two examples described here. The dynamic mechanical properties of polyvinyl alcohol hydrogels (Cambridge Polymer Group, Boston, MA) were evaluated with our unique computer-controlled moving magnet linear motor that provides load, displacement, strain or pressure profiles. The hydrogel samples were 3-4 mm in diameter and 3-4 mm in height, and testing was performed in compression with a 5 mm displacement transducer and a 250 gram force transducer.

Vascular graft distension with increasing pressure was also evaluated in a BioDynamic instrument using a laser micrometer. The graft material used (Gel-Del Technologies, Inc., St. Paul, MN) is composed of proteins and polymers fabricated to mimic the viscoelastic properties of native blood vessels. The inner diameter of the grafts used was 3 mm and total length was approximately 30 mm. A laser micrometer was placed over the chamber with the laser beam penetrating the transparent chamber doors and measuring outer diameter (OD) changes with pressure and time.

RESULTS: The ability to perform very low force applications was tested using hydrogel specimens. The peak-to-peak loading on the

hydrogel was approximately 2 mN with a corresponding peak-to-peak displacement of 28 μm . A distinct linear region was not observed with a displacement ramp as the specimen made a very gradual change in stiffness as a function of % strain. Upon completion of data acquisition, the software calculated the modulus and tan delta for the specimen, which appeared to exhibit resonance between 20 and 100 Hz.

When two cycles of a sinusoidal pressure waveform from 0 to 25 mmHg were followed by a cycle of pressure increase to 250 mmHg, the diameter response of the composite vascular graft biomaterial followed the pressure changes very closely throughout the test. After each cycle, OD did not return to its initial value within the test's time frame, indicating potential creep behavior. A cycle of pressure increase from 0 to 295 mmHg is also shown. The specimen is again exhibiting creep by not returning to its initial diameter over the time frame studied.



CONCLUSIONS: The development goal was to create a fully integrated computer-controlled data acquisition and analysis testing system to characterize biomaterials, scaffolds and tissues in a biological environment.

The data obtained with the hydrogels show that the BioDynamic instrument is suitable for evaluating the dynamic properties of soft biomaterials. The results obtained with the vascular graft biomaterial confirmed the biphasic composition of the specimen that is composed of a protein-rich material and synthetic polymers and can serve as an indicator of vascular wall elasticity and compliance. Preliminary results with hydrogel disks for orthopaedic applications and vascular grafts show that the BioDynamic test instrument is a powerful tool for the integration of biochemical and mechanical stimulation and properties characterization in one system.