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Potential Nuclear Replacement Materials: Developing a Screening Process

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INTRODUCTION: Currently there is no established criterion for nucleus replacement materials. Initially non-cell-seeded materials are likely candidates for nuclear replacement in the near future. These suitable materials, then, need to restore under long-term nucleus swelling pressure, resist axial compression and must allow for considerable repetitive strain without mechanical failure. In this study a comparative on potential nuclear replacement materials and native nucleus tissue was conducted. The testing framework was derived from native nuclear material testing data, as well as, theoretical assumptions generated from general knowledge of spine biomechanics. The objective was to investigate potentially available biocompatible materials as nucleus replacements and to develop a material screening methodology for future available materials.

METHODS: A total of 100 specimen plugs (15 mm diameter, 15 mm height) were subjected to mechanical testing, with 5 repeated tests for each material. Screened materials include Polyvinylalcohol (PVA), Polyethyl- glycol (PEG), various Chitosan and bovine lumbar nucleus as the control. Two mechanical tests were conducted: confined and unconfined, to generate various mechanical properties of the material. Confined axial compression test (Fig.1a) alternating between 1 hour dynamic loading at 0.1-1.0MPa and 1 hour static loading at 0.1MPa (physiologic swelling pressure[1]) was used to determine creep and recovery rates. The loading, in an environment mimicking physiological conditions, was facilitated by our novel bioreactor developed to incorporate computer controlled dynamic axial loading while collecting mechanical load-displacement data. Permanent strain and time constants were calculated using a Kelvin model[2] curve fit (Fig. 2) on load-displacement data using the least-squares method. Unconfined axial loading tests (Fig.1b) at a 0.1%strain/sec rate was used to determine E-modulus, yield strength, elastic/plastic strain, and elastic recovery of the material.

RESULTS: Preliminary findings showed that native nucleus material behaved significantly different under confined and unconfined tests, and that, in comparison, most materials suffered large permanent strains under minimum physiological loads of 0.1Mpa.

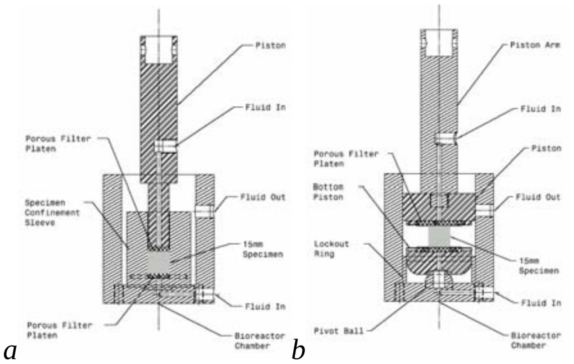

Fig. 1:Cross-sectional view of bioreactor chamber setup (a) for confined compression (b) for unconfined compression

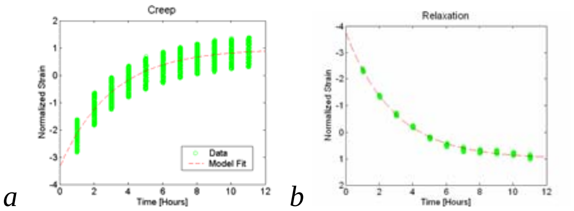

Fig. 2: Sample of normalized strain versus time data fit to the model equation of the (a) creep cycle and (b) relaxation cycle data using a least squares method. The data is shown by the green dots and the model fit is indicated by the dashed red line.

DISCUSSION & CONCLUSIONS: The material testing framework established through this study should be helpful for future material screening, but will also allow for cell-seeded materials, in a real tissue engineering setting, to be tested similarly.

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