Comparison of Stress Relaxation Properties of Synthetic Composite with Small Intestinal Submucosa

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Introduction

The search for novel biomaterials that can mimic body tissues in their functions has been an ongoing quest in tissue regeneration. Many synthetic and xenogenic natural matrices have been explored, however, they lack either mechanical strength or cell colonization characteristics found in natural tissues. Moreover the natural matrices such as small intestinal submucosa (SIS), lack sample to sample homogeneity, leading to unpredictable clinical outcomes. This work explored a novel fabrication technique of blending synthetic (50:50 PLGA) and natural polymers (gelatin-chitosan) to form a composite structure by the use of an etching technique that produces nano scale surface features. The viscoelastic property, an area of mechanical analysis which remains largely unexplored in tissue regeneration, of the material was assessed. For this purpose, stress relaxation behavior of the composite scaffold was also compared to the SIS by performing stress relaxation tests.

Materials and Methods

The composite scaffold was formed by sandwiching a thin layer of 50:50 PLGA between porous layers of gelatin-chitosan using a previously described procedure with minor modifications[1] . PLGA surface was etched at the nanoscale using NaOH to reduce the scaffold thickness thereby allowing easy spreading of the hydrophilic gelatin-chitosan solution on its hydrophobic surface.

Uniaxial tensile tests were done on the composite in hydrated medium at 37°C at a controlled cross head speed of 10 mm per minute and a fixed load of 100 N. Stress relaxation experiments of the "ramp and hold" type performed at variable ranges of temperature (25°C and 37°C), loading rates (3.125% s^{-1} and 12.5% s^{-1}) and relaxation times (60s, 100s and 200s) found stress relaxation to be sensitive to temperature and the loading rate. Similar experiments are performed on the SIS and the output stress relaxation behavior was compared. A lower range of the strain rate had to be used for the SIS because it fails at the higher ranges (Break strain < 90%)[2].

To quantify the relaxation behavior of the matrices, the very poplular Quasi Linear Viscoelastic (QLV) model is used and the data obtained from the model is compared to the experimentally obtained stress values for both the loading as well as the relaxation part of the stress relaxation curve. The QLV model is modified to incorporate the fact that the loading was done in a finite amount of time and not instantaneously as assumed by Fung YC.

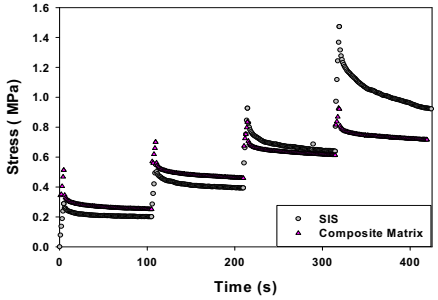

Figure 1: Comparison of stress relaxation behavior of SIS with the composite scaffold at 3.125%/s loading rate, 25°C and 100 s relaxation time.

Results and Discussion Composite scaffolds consisting of a thin layer (<1 mm) of PLGA sandwiched between chitosan-gelatin porous structures were formed using an etching process that produced nanoscale surface features. Etching reduced the thickness of the scaffold by nearly 50% than otherwise via increasing the surface roughness of PLGA membrane. Etching time of 10 min showed optimum effect on roughness without affecting the tensile properties and composites generated were not toxic to cellular attachment.

Tensile testing showed that it can be elongated up to nearly 400 % of its initial length, nearly 8 times more than SIS.

"Ramp and hold" experiments performed on PLGA membranes showed significant effect of temperature and loading time on the maximum stress accumulated per cycle. Comparison of stress relaxation behavior between SIS and the composite matrix as seen from Figure 1 showed opposite behavior; SIS showed strain hardening where as the composite matrix showed strain softening. QLV modeling indicated that etching process affects the viscous component of PLGA membrane and the process of making the porous structures did not alter the viscoelastic properties.

References

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