THE MECHANICAL PROPERTIES OF A COLLAGEN-GLYCOSAMINOGLYCAN SCAFFOLD FOR TISSUE ENGINEERING

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Scaffolds are used for a variety of tissue engineering applications such as to induce regeneration of damaged tissue *in vivo* and as constructs allowing *in vitro* cell behavior studies. The mechanical properties of 2D substrates and 3D scaffolds have been observed to affect cell migration and contractile behavior; to perform quantitative cell behavior studies in a scaffold, detailed mechanical and structural analysis is required to understand the local cell environment. Here we have measured the microstructural, mechanical, and permeability properties of a series of collagen-glycosaminoglycan (CG) scaffolds fabricated via freeze-drying: uniform scaffolds with homogeneous pore structure and equiaxed pores, constant composition and relative density (R_d, 0.6%), but with distinct pore sizes (151, 121, 110, 96 μm) have been produced [1,2]. The scaffold microstructure is characteristic of an open-cell foam [1]; cellular solids theory suggests that the scaffold Young's modulus (E*) and compressive strength depend on scaffold R_d and the Young's modulus of the scaffold material [3]. After fabrication, all scaffolds were crosslinked via dehydrothermal (DHT) crosslinking (105^{o}C, 24hrs, <50mTorr) [1]; two intensities of carbodiimide (EDAC) crosslinking were also used to increase scaffold stiffness relative to DHT independent of pore microstructure [4]. Mechanical characterization was performed on dry and hydrated CG scaffolds with pore sizes ranging between 96 and 151 μm and a constant R_d of 0.6% [2]; mechanical tests were also performed on a series of scaffolds with a range of R_d (0.6, 0.9, 1.2, 1.8%). The bending stiffness of individual scaffold struts was measured via AFM, allowing calculation of the scaffold $E^*_{theoretical}$ using cellular solids modeling for comparison with $E^*_{experimental}$.

The CG scaffolds were found to be mechanically isotropic. $E^*_{experimental}$ and compressive strength of the dry scaffolds (DHT, R_d 0.6%) was 32,300 ± 5700 Pa, and 5400 ± 680 Pa, respectively. $E^*_{experimental}$ and compressive strength of the hydrated scaffolds (DHT, R_d 0.6%) was 208 ± 41 Pa and 21 ± 8 Pa, respectively. $E^*_{experimental}$ and compressive strength of the CG scaffolds were found to be independent of mean pore size, but dependent on scaffold relative density ($E \alpha R_d^1$, R_d: 0.6 – 1.8%). Both the $E^*_{experimental}$ and the compressive strength increased with the degree of crosslinking (2.0 and 7.2x stiffness of DHT using two distinct EDAC intensities).

The Young's modulus of the dry individual scaffold strut (DHT crosslinked, R_d 0.6%) was measured experimentally to be 1.2 ± 0.9 GPa; an open-cell foam cellular solids model [5] predicted a scaffold modulus of 44.1 ± 30.9 kPa ($E^*_{theoretical}$), comparing favorably with experimental results ($E^*_{experimental}$: 32.3 ± 5.7 kPa). Note that cellular solids models for open cell foams indicate a modulus dependence on the square of R_d; the observed best-fit linear dependence is likely related to the small range of densities tested. Cellular solids modeling has also been utilized successfully to model the permeability characteristics of these CG scaffolds under a variety of compressive strains (0 – 40%), *K*: 0.2E-10 – 1.4E-10 m^4/Ns [5].

References

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