A Fracture Mechanics-Based Approach to the Structural Integrity of Fibrous Scaffolds

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Abstract

Biodegradable polymeric scaffolds are increasingly used in tissue engineering due to their ability to replicate the intricate architecture of the extracellular environment in human soft tissues. Specifically, electrospinning is an established technique for producing micron-scale non-woven fibrous meshes, characterized by structural anisotropy, porosity, and biocompatibility, all crucial properties for successful *in vivo* integration and tissue repair (1).
From a mechanical perspective, electrospun synthetic polymers exhibit complex behavior combining inelastic and rate-dependent phenomena typical of native collagenous tissues, albeit with notable qualitative differences (2). When applied to engineered cardiovascular tissues such as blood vessels or heart valves, it is also essential that polymeric scaffolds maintain their structural integrity and durability under cyclic hemodynamic loading.

This study proposes a fracture mechanics-based approach to assess the resistance to crack propagation of fibrous polymeric materials designed for regeneration of aortic valves. On the experimental side, we adopted classical fracture tests developed for soft polymers, such as pure-shear tests (3), combined with digital image correlation (DIC) to map strain fields under load, and a crack-tip algorithm to determine the crack propagation speed. Due to the material's remarkable anisotropy, cracks perpendicular to the mean fiber direction do not propagate in a self-similar manner, preventing direct computation of fracture toughness from the material's strain energy. We propose an alternative approach based on generalized energy balance integrals (4), integrated with DIC and a constitutive model developed by our group (2). The combined experimental and computational approach provides a robust framework for assessing the fracture and fatigue properties of non-woven fibrous materials.

References

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