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Probing the structure of electrochemically aggregated collagen

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The internal structure of porous materials and membranes plays a critical role in their mechanical and biochemical properties, especially if they are targeted for cell growth in tissue healing and regeneration applications. Collagenous membranes are a class of proteinaceous materials that has been targeted for cell scaffolding studies because collagen is a structural protein found in many tissues. Collagen's aggregation in a hierarchical fibrillar structure can be stimulated and controlled in vitro to create products that function similarly to those produced in vivo. This can be accomplished merely by changing pH and temperature, even in the absence of growth factors and enzymes that are present during in vivo growth.

Scaffolds can interact with cells by serving as a structure for their attachment, or as a matrix for introducing nutrients, antibiotics, and other molecules to the cells. In this way, the 3D structure and mechanical properties of a scaffold can influence how cells move within and interact with it. In earlier work, we showed that electrochemically produced type I collagenous membranes can control cell proliferation to mimic their behaviour in vivo, unlike collagen fibrilized by standard thermal methods.[1,2] Furthermore, the electrochemically assembled collagen has proven to be a better matrix for osteoblast differentiation relative to other types of common scaffold materials. Since these findings show that matrix composition alone does not explain cell response, we continue to study the 3D structure of the electrochemically produced collagen scaffold prepared under different conditions.

It is challenging to assess the internal structure of a membrane, such as the sizes and connectivity of its pores, since traditional optical or scanning probe imaging methods do not allow access to internal voids within the material. SPT is a passive microrheological technique [3] that we used to follow the diffusion of individual fluorescent particles that were suspended in the collagen membrane during its electrochemical formation. Each sphere samples its local rheological environment, which makes SPT well-suited for assessing the degree of heterogeneity in a system. While there have been bulk rheological studies of collagen-based matrices and at least one diffusion study within individual collagen fibrils, there is a surprising absence of microrheological studies of collagen-based scaffolds.

Earlier work from our group showed that preparing these membranes in the presence of different cations led to different degrees of collagen fibrillation and aggregation as well as differences in membrane stiffness.[4] Our preliminary SPT results show that all of these electrochemically produced collagen membranes have a very compartmentalized structure, regardless of their stiffness. Our findings suggest that electrochemically induced aggregation can independently affect the structure, stiffness, and fluid viscosity of collagen membranes, which offers interesting future opportunities in cell scaffold design.

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