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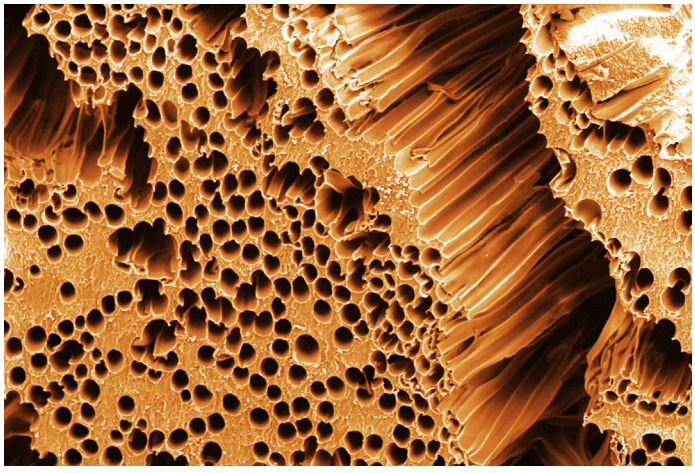
Mimicking dentin structure

Bio-inspired scaffolds for dental tissue engineering

Morteza Haeri and A. Jon Goldberg*

Center for Biomaterials, School of Dental Medicine, University of Connecticut Health Center, Farmington, CT, USACenter for Biomaterials, School of Dental Medicine, University of Connecticut Health CenterFarmingtonCTUSA

* *Corresponding author*: Goldberg, A.J. (goldberg@uchc.edu)



The fabrication and use of natural or synthetic scaffolds has become an integral part of regenerative medicine. Since the seminal work of Robert Langer in 1993 [1], the design, synthesis and modification of scaffolds to induce specific cell responses and regeneration of different tissues has become a field of study. Essentially, the scaffolds must reproduce the complex physicochemical features of the host tissue they intend to help regenerate. Accordingly, the architecture of a scaffold is among a myriad of parameters that may affect cell response and ultimately determine cell fate. It has been shown that architecture alone in the absence of morphogenic factors can dictate stem cell fate. In the case of tubular porous scaffolds, the diameter and density of tubules can be the determining factors influencing differentiation and adhesion of progenitor cells [2–5].

At the Center for Biomaterials, University of Connecticut, School of Dental Medicine, we are involved in the development of innovative bio-inspired scaffolds for tooth regeneration. Dental caries (tooth decay) remains the most prevalent infectious disease and treatments using restorative dental materials suffer from problems including leakage at interfaces, deterioration, and recurrent lesions. Our ultimate clinical vision is to regenerate dentin in diseased or traumatized teeth in order to reduce or even eliminate the need for synthetic filling materials.

Teeth are comprised of the enamel, dentin and cementum surrounding the dental pulp. Dentin, a mineralized connective tissue, comprises the bulk of the tooth, and has a tubular structure. The tubules span the entire thickness of the dentin and form as a result of the mineralization mechanism of the odontoblast cells. The diameter and density of the tubules vary within dentin from the pulp to the enamel, with larger diameter tubules near the pulp. Odontoblasts residing at the perimeter of the pulp extend processes into the tubules. The tubular nature of dentin allows for fluid movement within the tubule when a stimulus is applied, which can stimulate pulpal free nerve endings close to dentin. We have developed acrylate based microtubular scaffolds with structures resembling that of natural dentin. We are studying how mimicking the tubular architecture of natural dentin influences differentiation of pulp progenitor/stem cells into odontoblasts and subsequent formation of dentin. Tubular scaffolds are also used in regeneration of bone, heart and neural tissue [6].

There are several fabrication methods to create oriented microtubular scaffolds including sacrificial fiber templating, phase separation, and three-dimensional rapid prototyping techniques [7,8]. Each of these methods has their advantages as well as disadvantages. Rapid prototyping, for instance, provides more precise control over the three-dimensional architecture of the scaffolds while suffering from limited material selection and resolution. High resolutions in the range of a few micrometers may be achievable using more advanced laser-based systems, but they are

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costly and lack speed. The sacrificial fiber templating method is an inexpensive, scalable method to create long aspect ratio microtubular scaffolds mimicking the structure of dentin. In this method, a polymer is formed around an oriented array of fibers, which will be leached using a solvent leaving a tubular structure behind. Fiber size determines the size of the tubules formed after leaching process, and tubule density can be controlled by changing the packing density of the fiber array. Using this technique, microtubule size can be controlled to be small enough to only allow cell processes and not the cell bodies from entering the tubules.

This issue's cover image shows a microtubular scaffold made from an acrylate copolymer, and was captured using a tabletop scanning electron microscope. The scaffold was made via the sacrificial fiber templating method by packing poly vinyl alcohol fibers inside a mold and polymerization of acrylate monomers around it. The fibers were subsequently washed away leaving the tubular structure behind. The cut on the right side of the image reveals the orientation of the tubules and their long aspect ratio.

Further reading

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