Control of Single Odontoblast Polarization in a Bio-inspired 3D Platform

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The polarization of odontoblasts is a prerequisite for the formation of tubular dentin that is crucial for maintaining the normal biological functions of a tooth. It is well accepted that the odontoblast polarization is initiated and modulated by a variety of biophysical and biochemical signals. However, the details of the signals are largely unknown because they are interweaved to form a complex signaling network in vivo. Due to this barrier, the mechanism of odontoblast polarization remains ambiguous.

In this work, we report the development of a unique bio-inspired three-dimensional (3D) in vitro platform that controls single odontoblast polarization and is capable of dissecting the signals that initiate and regulate odontoblast polarization. We first developed an extracellular matrix (ECM)-like nanofibrous micropatterned 3D matrix using an approach that combined electrospinning, chemical crosslinking, and a polyethylene glycol (PEG)-based photolithography and a laser-guided ablation process. The bio-inspired 3D platform successfully initiated single DPSC to polarize in vitro. We identified the tubular architecture of the matrix is a crucial biophysical factor to initiate DPSC polarization. The polarized DPSC exhibited a functional long process of more than 20 μm within the 3D platform, and the Golgi apparatus of the DPSC moved to a position that is similar to a polarized odontoblast in vivo. Our bio-inspired 3D platform provides a powerful tool for in-depth understanding of cell-matrix interactions in 3D environment, which not only helps elucidate fundamental biological processes, but also guides the design of next-generation biomaterials for tissue repair and regeneration.