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Hybrid, Bio functionalized, Commercially Available Heart Valve

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Introduction

Heart valve replacements that are currently available either fail due to leaflet thickening, lack of growth or remodeling potential, or have limited long-term performance. Imitating the architecture, mechanical behavior, and biochemical signals of the native valvular extracellular matrix (ECM) is necessary to address these issues. An electrospun PEGdma–PLA scaffold that was tailored to the structure and mechanical properties of native valve leaflets was created successfully here. When seeded on the scaffold, valvular interstitial cells (VICs) and valvular endothelial cells (VECs) performed similarly to native leaflets when cultured in a bioreactor under physiological conditions. The first layer-specific measurement of the Young's modulus was made possible by employing atomic force microscopy (AFM) to obtain in-depth mechanical data from the leaflets. Spongiosa stiffness was noticeably lower than that of the fibrosa and ventricularis. In addition, research into the development of human fetal heart valves found that versican and collagen type I are crucial structural proteins. These proteins were added to the scaffold as a proof of concept, demonstrating that the hybrid valve could be biofunctionalized using nature's blueprint.

Description

The inability of the replacement heart valves that are currently on the market to grow or change after implantation is a major drawback. The complex fibrous network known as the valvular extracellular matrix (ECM) is made up of signaling molecules like growth factors and water-storing proteoglycans (PGs), as well as structural proteins like collagens, elastic fibers, and microfibrils. Electro spinning is a good way to make fibrous scaffolds that look like the ECM. A droplet of polymer fluid is subjected to a powerful electric field. A fiber is formed when the force from the electric field overcomes the surface tension of the polymer droplet solution. This fiber travels to the counter electrode in spinning motions while the solvent evaporates. The scaffold's mechanical properties and fiber size can be altered by adjusting parameters like solvent, voltage, electrode distance, or polymer. In addition, components of ECM can be electrospun to biochemically functionalize the material. Defining signaling molecules, three-dimensionality, and appropriate mechanical properties have all been shown to have a significant impact on cell survival, adhesion, migration, proliferation, and differentiation. The Young's modulus significantly varies with organ in natural ECM. Bone tissue for instance has a solidness of 106-107 kPa, in the interim skin is significantly more flexible with a modulus of 10-100 kPa. The stiffness of a matrix, as well as its density, can be used as a clue to determine the fate of stem cells. As a result, mesenchymal stem cells differentiated into neural tissue when cultured on hydrogels with a stiffness of 0.1 kPa, into myogenic tissue when exposed to hydrogels with a stiffness of 11 kPa, and into osteogenic tissue when cultured on matrices with a stiffness of 34 kPa. Exposing neonatal rat cardiomyocytes to 10 kPa, the stiffness of native rat myocardium, resulted in their maturation. A crucial parameter for tissue growth and remodeling is the Young's modulus. In this way, it is vital to distinguish the mechanical properties of the flawless tissue and make an interpretation of these discoveries to organ-and tissue-customized biomaterials plan [1-5].

Conclusion

Due to blood flow, the leaflets of the heart valve are permanently exposed to a high pressure of 120/80 mmHg and laminar and oscillatory shear stress. Therefore, an engineered heart valve material should not only mimic the native ECM's mechanical properties but also withstand vivo mechanical forces. We measured the Young's modulus in each layer of native heart valve leaflets using atomic force microscopy (AFM) in addition to comprehensive analyses of the materials and cell–matrix interaction. Our goal was to create a hybrid bio-functionalized heart valve that resembles the natural aortic valve and could potentially be produced as a ready-to-use medical device.

The scaffold surfaces' atomic composition was determined using ESCA. A pressure of 109 mbar was applied to the analysis chamber of the Axis Ultra device (Kratos Analytical, New York, USA), which contained electrospun scaffolds. The kinetic energy of the emitted auger and photoelectrons was measured after all samples were activated with X-rays. The obtained results were compared to known values for the individual components from the literature to confirm the presence of both polymers (PEGdma and PLA) on the fiber surface.

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