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Polymer–Protein Hybrid Network Involving Mucin: A Mineralized Biomimetic Template for Bone Tissue Engineering

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Biomimetic matrices offer a great advantage to understand several biological processes including regeneration. The study involves the development of a hybrid biomimetic scaffold and the uniqueness lies in the use of mucin, as a constituent protein. Through this study, the role of the protein in bone regeneration is deciphered through its development as a 3D model. As a first step towards understanding the protein, the interactions of mucin and collagen are determined by in silico studies considering that collagen is the most abundant protein in the bone microenvironment. Both proteins are reported to be involved in bone biology though the exact role of mucin is a topic of investigation. The in silico studies of collagen–mucin suggest to have a proper affinity toward each other, forming a strong basis for 3D scaffold development. The developed 3D scaffold is a double network system comprising of mucin and collagen and vinyl end functionalized polyethylene glycol. In situ deposition of mineral crystals has been performed enzymatically. Biological evaluation of these mineral deposited scaffolds is done in terms of their bone regeneration potential and a comparison of the two systems with and without mineral deposition is presented.

1. Introduction

Bone disorders caused by illness or trauma significantly compromises patient quality of life. Bones are mostly made of the protein collagen, which forms a soft framework. The mineral calcium phosphate hardens this framework, giving it strength. Although bone is one of the organs that has tremendous self regeneration potential, there are still complications wherein regeneration is delayed or hampered and needs to be stimulated. The existing practices are autologous, allogenic or xenogenic bone grafts which encounter limitations. This is where tissue engineering can play a crucial role in introducing approaches and solutions. One of the approaches of tissue engineering relies on the use of biomaterials to mimic the bone microenvironment and to stimulate bone formation. Further down, tissue engineering strategies work on the triad of scaffolds, cells, and signaling cues. A scaffold serves as a temporary extracellular matrix (ECM) to promote 3D bone tissue formation or regeneration. A temporary scaffold must provide a suitable microenvironment for cells in order to attach, proliferate, and differentiate to form new tissue. In order to obtain scaffolds with the above-mentioned properties, several biomimetic approaches are being studied to introduce design features including material composition, biodegradability, mechanical properties, etc.[1] It is imperative that the scaffold should mimic the ECM as closely as possible. Natural ECM is composed of protein and polysaccharide based networks, which provide mechanical support and signals for essential cell functions.[2] A substantial number of reports have confirmed that natural systems in the form of scaffolds can provide the right microenvironment but lack the appropriate toughness and mechanical suitability. To improve mechanical properties, various polymerization approaches have been introduced. One such type is the use of a double network system. Double network systems with asymmetric structures have excellent mechanical properties and thus show great potential.[3] The double network systems are characterized by the presence of polymer networks originating from covalent as well as noncovalent coordination bonds, which improves their compressive strength.

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