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Tissue Engineering Applications of Non-mulberry Silk Protein Fibroin Nano Biocomposite Reinforced with Carbon Nanofibers

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Abstract

Natural silk protein fibroin based biomaterials are widely employed in tissue engineering due to their aqueous manufacturing, slow biodegradability, mechanical durability, minimal immunogenicity, dielectric properties, customizable features, sufficient and simple availability. Carbon nanofibers have been investigated for their conductivity, mechanical strength, and potential as a delivery system for tiny molecules. The absence of confirmation of cytocompatibility and limited dispersibility are the main obstacles to their use as successful biomaterials. Throughout the last few decades, many firms have invested substantial quantities of money on biomaterials research in order to create more acceptable, biocompatible items. Biomaterials must be engineered and advanced for use in tissue bioengineering and the healthcare business during this time due to their rapid expansion.

Introduction

Pure materials have been observed to be incapable of solving a given problem on their own. More researchers are being persuaded to pool their resources. The multifunctional composite is made up of several biomaterial components that are as close to the required human tissue as possible. The different features of each of the materials amplify the enticing individual inefficiency. Suture, sponge, film, hydrogel, micro/nanosphere, nanoparticle, membrane, and tubes are some of the silk biomaterials that have been explored in the last few decades in the search for the best artificial tissue support. Silk fibroin is a well-known high-molecular-weight protein polymer derived from silkworms. Superior mechanical strength, ease of fabrication into numerous multifunctional matrices (using aqueous-based processes), high cytocompatibility, and tissue growth are all advantages of natural protein, particularly from nonmulberry sources. Fibroin protein from *Antheraea mylitta* contains its own cell adhesion-promoting tripeptide (-R-G-D-) motif, indicating that it could be used as a scaffold in cell-based tissue engineering and drug delivery [1]. Pure fibroin-based matrices, on the other hand, are insufficiently mechanically strong or electrically conductive to sustain the aforementioned tissue defects/damages when it comes to bone, neuron, and muscle recovery. As a result, numerous doping technologies have been examined to date, including hydroxyapatite, gold nanoparticles, graphene oxide, CNT, and CNF, to improve mechanical modulus, flexibility, and conductivity of fibroin-based matrices for better cell growth, proliferation, and/or differentiation. Carbon Nanofiber (CNF) is a nanoscale carbon fibre made using a catalytic chemical vapour deposition technique at different temperatures. To form a single carbon nanofiber, several curved nanocones made of graphene nanosheets are stacked at a precise angle [2]. The high flexibility, low mass density, and large aspect ratio of CNF have already been discussed. They feature an unusual combination of mechanical, thermal, and electrical properties. Carbon Nanotube (CNT) is a popular cousin of carbon Nanotube (CNF) that is widely used around the world. They are single graphene sheets that have been rolled up and are either Single Wall (SWCNT) or Spiral Multiwall (SWCNT) (MWCNT). CNF is less costly, less poisonous, and easier to functionalize, organochemically modify, and disperse than CNT. Some attempts are attempted to enhance CNT within mulberry silk protein fibroin, as well as their cytocompatibility [3]. Composite materials, gene delivery vehicles, electrodes, atomic force microscopic tips, synthetic membranes, biosensors, hydrogen and charge capacitors, and electron field emitters are all examples of CNF uses. CNF is a powder that is produced and utilised as a filler material. Within the polymer matrix, this offers reinforcement. Some synthetic polymers, such as poly (lacticcoglycolic acid),18 poly (acrylonitrile), and poly-(carbonate)urethane, as well as natural polymers like chitosan, cellulose acetate, and sodium alginate, have already been used as base materials for engineering a variety of artificial extracellular matrices. The reinforcement gives the base matrix more structural stability, electrical conductivity, and mechanical strength. They can also be used as a delivery system for medications and biological molecules that need to be released over time. The biocompatibility of CNT and CNF-based materials is a perennially debated topic. Several scientific groups are investigating the final fate of these compounds on cells in vitro and in vivo systems to address this issue. Furthermore, the CNF has a hydrophobic tendency. For successful composite material engineering, proper functionalization is necessary to make them hydrophilic and compatible with the base matrix. Carbon nanofibers are nanostructures made of graphene. Because of its hydrophobicity and high surface energy, CNF powder does not disperse well in distilled water or dialyzed or undialyzed protein solutions. Because of the significant shear force and molecular repulsion of the CNF, the protein coagulates and aggregates even after adding the CNF powder to the protein solution and sonicating it. Surface functionalization is required at this time. Acid etching, plasma modification, solgel coating, electro-/electro-less plating, wet etching, photochemical functionalization, thermal treatment, and the addition of linker and polymer molecules are all ways that can be used to functionalize CNF. The majority of these procedures are time-consuming and expensive, thus they are not recommended [4]. Furthermore, harsh chemicals and/or harsh treatments are incompatible with the ultimate goal of cytocompatibility. We use ultrasonication (mechanical) and noncovalent surfactant absorption (chemical) approaches to functionalize the CNF, both of which are economical, ecologically benign, and straightforward. The nanorough surface (roughness 100 nm) has a positive influence on attachment, growth, proliferation, and differentiation of smaller cells (human vein endothelial and mammary epithelial cells) as well as larger cells (osteoblast and nerve cells) because it mimics the natural environment of nanodimentional extracellular matrix (ECM). The roughness also helps neurons grow their neurites. As a result, the produced composite matrices have a roughness that is comparable to that of the ECM and may aid in the culture of a variety of cell types.

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