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Silk Fibroin-PVP-Nanoparticles-Based Barrier Membranes for Tissue Regeneration

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Abstract : Originally, the principles of guided tissue/bone regeneration (GTR/GBR) were followed to restore the architecture and functionality of the periodontal system. In essence, a biocompatible polymer-based occlusive membrane is used as a barrier to prevent migration of epithelial and connective tissue to the regenerating site. In this way, progenitor cells located in the remaining periodontal ligament can recolonize the root area and differentiate into new periodontal tissues, alveolar bone, and new connective attachment. The use of synthetic or collagen-derived membranes with or without calcium phosphate-based bone graft materials has been the treatment used. Ideally, these membranes need to exhibit sufficient initial mechanical strength to allow handling and implantation, withstand the various mechanical stresses suffered during surgery while maintaining their integrity, and support the process of bone tissue regeneration and repair by resisting cellular traction forces and wound contraction forces during tissue healing in vivo. Although different RTG/ROG products are available on the market, they have serious deficiencies in terms of mechanical strength. Aiming to improve the mechanical strength and osteogenic properties of the membrane, this work evaluated the production of membranes that integrate the biocompatibility of the natural polymer (silk fibroin - FS) and the synthetic polymer poly(vinyl pyrrolidone - PVP) with graphene nanoplates (NPG) and gold nanoparticles (AuNPs), using the electrospinning equipment (AeroSpinner L1.0 from Areka) which allows the execution of high voltage spinning and/or solution blowing and with a high production rate, enabling development on an industrial scale. Silk fibroin uniquely solved many of the problems presented by collagen and was used in this work because it has unique combined merits, such as programmable biodegradability, biocompatibility and sustainable large-scale production. Graphene has attracted considerable attention in recent years as a potential biomaterial for mechanical reinforcement because of its unique physicochemical properties and was added to improve the mechanical properties of the membranes associated or not with the presence of AuNPs, which have shown great potential in regulating osteoblast activity. The preparation of FS from silkworm cocoons involved cleaning, degumming, dissolution in lithium bromide, dialysis, lyophilization and dissolution in hexafluoroisopropanol (HFIP) to prepare the solution for electrospinning, and crosslinking tests were performed in methanol. The NPGs were characterized and underwent treatment in nitric acid for functionalization to improve the adhesion of the nanoplates to the PVP fibers. PVP-NPG membranes were produced with 0.5, 1.0 and 1.5 wt% functionalized or not and evaluated by SEM/FEG, FTIR, mechanical strength and cell culture assays. Functionalized GNP particles showed stronger binding, remaining adhered to the fibers. Increasing the graphene content resulted in higher mechanical strength of the membrane and greater biocompatibility. The production of FS-PVP-NPG-AuNPs hybrid membranes was performed by electrospinning in separate syringes and simultaneously the FS solution and the solution containing PVP-NPG 1.5 wt% in the presence or absence of AuNPs. After cross-linking, they were characterized by SEM/FEG, FTIR and behavior in cell culture. The presence of NPG-AuNPs increased the viability and the presence of mineralization nodules.

Keywords : barrier membranes, silk fibroin, nanoparticles, tissue regeneration.
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