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Influence of Cobalt Incorporation on the Structure and Properties of SOL-Gel Derived Mesoporous Bioglass Nanoparticles

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Abstract : Incorporation of therapeutic elements such as Sr, Cu and Co into bioglass structure and their release as ions is considered as one of the promising approaches to enhance cellular responses, e.g., osteogenesis and angiogenesis. Here, cobalt as angiogenesis promoter has been incorporated (at 0, 1 and 4 mol%) into sol-gel derived calcium silicate mesoporous bioglass nanoparticles. The composition and structure of cobalt-free (CFN) and cobalt-doped (CDN) mesoporous bioglass nanoparticles have been analyzed by X-ray fluorescence (XRF), X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS) and Fourier-Transform Infra-red spectroscopy (FT-IR). The physicochemical properties of CFN and CDN have been investigated using high-resolution transmission electron microscopy (HR-TEM), Selected area electron diffraction (SAED), and Energy-dispersive X-ray (EDX). Furthermore, the textural properties, including specific surface area, pore-volume, and pore size, have been analyzed from N^{2-}sorption analyses. Surface charges of CFN and CDN were also determined from surface zeta potential measurements. The release of ions, including Co^{2+}, Ca^{2+}, and SiO_4^{4-} has been analyzed using inductively coupled plasma atomic emission spectrometry (ICP-AES). Loading and release of diclofenac as an anti-inflammatory drug model were explored in vitro using Ultraviolet-visible spectroscopy (UV-Vis). XRD results ensured the amorphous state of CFN and CDN whereas, XRF further confirmed that their chemical compositions are very close to the designed compositions. HR-TEM analyses unveiled nanoparticles with spherical morphologies, highly mesoporous textures, and sizes in the range of 90 - 100 nm. Moreover, N^{2-} sorption analyses revealed that the nanoparticles have pores with sizes of 3.2 - 2.6 nm, pore volumes of 0.41 - 0.35 cc/g and highly surface areas in the range of 716 - 830 m^2/g. High-resolution XPS analysis of Co 2p core level provided structural information about Co atomic environment and it confirmed the electronic state of Co in the glass matrix. ICP-AES analysis showed the release of therapeutic doses of Co^{2+} ions from 4% CDN up to 100 ppm within 14 days. Finally, diclofenac loading and release have ensured the drug/ion co-delivery capability of 4% CDN.

Keywords : mesoporous bioactive glass, nanoparticles, cobalt ions, release
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