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S. Sahmani, S. Saber-Samandari, A. Khandan, M.M. Aghdam

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Nonlinear resonance investigation of nanoclay based bio-nanocomposite scaffolds with enhanced properties for bone substitute applications

S. Sahmani[a*], S. Saber-Samandari[b], A. Khandan[b*], M.M. Aghdam[c]

[a] *Mechanical Rotating Equipment Department, Niroo Research Institute (NRI), Tehran 14665-517, Iran*
[b] *New Technologies Research Center, Amirkabir University of Technology, Tehran 15875-4413, Iran*
[c] *Mechanical Engineering Department, Amirkabir University of Technology, Tehran 15875-4413, Iran*

Abstract

Various types of ceramic, polymer and bio-nanocomposite scaffolds have been used in laboratory and animal studies for bone tissue engineering. Pore size, chemical composition, and cell proliferation assay of biomaterials play an important role in the bone formation in in vitro and in vivo tests. In the current work, the titanium oxide (TiO_2) nanoparticles are added to nanoclay (NC) and composed with NaCl microparticles to build a porous scaffold using space holder technique. Then, the biomechanical, surface properties, and biological response of the samples are monitored to check the morphological, thermal, cell behavior and biological behavior of the manufactured bio-nanocomposite scaffolds using scanning electron microscopy (SEM), fourier transform infrared (FTIR), atomic force microscopy (AFM), X-ray diffraction (XRD), differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA) techniques. The obtained results show that the minimum requirement for the pore size is considered less than ∼100 nm due to the cell size, migration requirements and transport of the alive cell. However, pore sizes higher than ∼65-100 nm are supported in order to enhance the formation of the tissue in the biological environment such as simulated body fluid (SBF) and physiological saline (PS) as well as excellent capillaries formation. The resulting porosity is obtained without using porosity agents, and it is found that the holes are related to dimensions within the range of 60-82% and 55-75% for the samples soaked in the SBF and PS after 21 days, respectively. Also, it is revealed that the fracture toughness and compressive strength values of the samples are within the range of 0.66-0.89 $MPa.m^{1/2}$ and 4.5-5.7 MPa, respectively. Additionally, based on the extracted mechanical properties of the bio-nanocomposite scaffold, the nonlinear resonance response of a beam-type bone implant under soft and hard excitations is predicted analytically corresponding to the both subharmonic and superharmonic ranges. The bio-nanocomposite scaffold containing 15wt% TiO_2 represents proper cell viability and cultured cell which prove the cytocompatibility of the fabricated NC-TiO_2-NaCl scaffolds.

*Corresponding author. Tel.: +98 21 66405844, Fax: +98 21 66419736.
E-mail addresses: sahmani@aut.ac.ir; ssahmani@nri.ac.ir (S. Sahmani), sas.khandan@aut.ac.ir (A. Khandan)