FINITE ELEMENT ANALYSIS OF THE MECHANICAL PROPERTIES OF BIOACTIVE GLASS-CERAMIC SCAFFOLD DESIGNED FOR OSTEOCHONDRAL TISSUE

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ABSTRACT

Osteochondral tissue defects involve cartilage and underlying subchondral bone caused by trauma, aging and joint disease[1]. Tissue engineering has provided a promising alternative for repairing these defects by developing three-dimensional interconnected porous scaffolds of biocompatible materials such as biphasic or tri/multiphasic structures. These structures aim to mimic characteristics of the osteochondral tissue, formed by regions with different biochemical composition, structural, and mechanical properties[2,3]. The design of scaffolds involves parameters such as pore size, porosity, interconnectivity between pores to imitate tissue architecture and assist in nutrient delivery and tissue regeneration [4]. Moreover, the material must have mechanical properties compatible with native osteochondral tissue to achieve structural integrity properly[4]. One way to evaluate the design of scaffolds is using computational simulation by finite element method, which brings approximate solutions for different types of analysis[5]. In this study, ceramic scaffold architecture with lattice-based rectangular unit cells was designed to analyze the effective elastic modulus and compressive strength as a function of porosity. Biosilicate®

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glass-ceramic was chosen to simulate a subchondral bone scaffold substitute to tissue engineering[3,6]. The scaffolds consisted of a 600 µm diameter cylinders series stacked in a cubic structure with a distance between each cylinder in the same layer. Three levels of pore size (300, 500, and 700 µm) were assigned to the scaffold architectures. The lay-down angle formed by two orientations of cylinders between adjacent layers was 90º. Biosilicate® scaffolds were statically simulated under uniaxial compression and simplified boundary conditions[4,7,8], in order to evaluate the component in a load-bearing environment as occurs in native tissue[1,2]. Biosilicate® elastic modulus (75 GPa[9]), Poisson's ratio (0.2[10]), and a strain rate of 0.01% due to fragile material characteristics were used to determine effective elastic modulus and compressive strength of the scaffolds by finite element analysis. The results indicated that the effective modulus increased 30% with the decrease pore size and porosity from 700 µm (50%) to 300 µm (33%), respectively, while the strength increased 8% with the decrease pore size and porosity. This behavior suggests that the scaffold with a smaller pore size and porosity is more capable of supporting load; thus, there is an increase in the structure's stiffness and mechanical strength. Furthermore, the effective modulus and strength are in agreement with subchondral bone mechanical properties[3,6]. On the basis of the results on elastic modulus and strength, Biosilicate® scaffolds will support the compressive loads imposed on the subchondral tissue.

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