Bioactive pore-graded glass-ceramic scaffolds for bone tissue regeneration

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1. Introduction

Bone is a connective tissue characterized by high hardness and excellent mechanical properties. Since 1970s, biocompatible ceramics, e.g. hydroxyapatite, calcium-phosphate salts and bioactive glasses and glass-ceramics, have been widely investigated as materials for bone repair [1], and they have been often used to fabricate three-dimensional (3-D) scaffolds able to mimic the trabecular architecture of cancellous bone. Bioceramic scaffolds proposed in literature, although being similar to spongy bone from a topological viewpoint, exhibit a mechanical strength that is one order of magnitude lower than that of natural bone tissue [2]. The aim of the present work is to fabricate scaffolds able to effectively mimic the natural bone from a structural and mechanical viewpoint and to promote new tissue in-growth inside the implant.

2. Materials and Methods

The basic material used for scaffolds fabrication was a silicate glass (CEL2) in the SiO_2-P_2O_5-CaO-MgO-Na_2O-K_2O system [3]. The scaffolds were produced by using different methods, i.e. polyethylene burn-out, sponge replication, glazing techniques and some combinations of these methods [4]. A thermal treatment allowed to remove the organic phase and to sinter the glass particles. The scaffolds were characterized by scanning electron microscopy and density measurements to determine their pores content. Their mechanical strength was assessed via compressive tests and their *in vitro* bioactivity was analyzed by soaking the samples in acellular simulated body fluid (SBF).

3. Results and Discussion

The methods used for scaffolds fabrication are efficient and reproducible. Scaffolds able to mimic the porosity gradients of cancellous bone (Fig. 1a) and to reproduce the trabecular-cortical bone system (Fig. 1b) were successfully produced. As regards scaffolds mechanical strength, in comparison with the results reported in literature [2] the presence of a compact layer (porosity < 5%vol.), mimicking the cortical bone, coupled with a porous one (porosity ~65 %vol.) enhances the scaffold strength up to 10 MPa.

The scaffolds also exhibited an excellent bioactive behaviour: after soaking for 1 week in SBF, scaffold struts were completely coated by a continuous and homogeneous layer of hydroxyapatite, that is known to have compositional and crystallographic similarity with bone mineral.

Many potential biomedical applications could be developed by using graded glass-ceramic scaffolds, such as grafts for the substitution of both small and extensive bone portions, also in load-bearing bone segment. The ease of processing will make it possible to fabricate a wide range of complex shapes according to specific aims of bone surgery. The presence of an outer compact layer could be useful for fixing a synthetic grafts with screws avoiding the damage of its trabecular structure.

4. Conclusion

3-D glass-ceramic scaffolds mimicking the cancellous-cortical bone system were successfully obtained by using a bioactive glass (CEL2) and different fabrication methods. Specifically, wholly porous scaffolds were fabricated by PE-burn-out or sponge replication techniques, and afterwards a compact layer was joined to the porous one for obtaining double-structure scaffolds. The prepared CEL2-derived scaffolds were highly bioactive and exhibited architecture, porosity and mechanical strength comparable to the analogous features of natural bone.

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References

[1] Hench LL. Bioactive materials: the potential for tissue regeneration. J Biomed Mater Res 1998; 41: 511-8.

[2] Chen QZ, Thompson ID, Boccaccini AR. 45S5 Bioglass®-derived glass-ceramic scaffolds for bone tissue engineering. Biomaterials 2006; 27: 2414-25.

[3] Vitale-Brovarone C, Verné E, Robiglio L, Martinasso G, Canuto RA, Muzio G. Biocompatible glass-ceramic materials for bone sustitution. J Mater Sci: Mater Med 2008; 19: 471-8.

[4] Vitale-Brovarone C, Baino F, Verné E. High strength bioactive glass-ceramic scaffolds for bone regeneration. J Mater Sci: Mater Med 2009; 20: 643-53.

Figures

Fig. 1. CEL2-derived graded scaffolds: (a) scaffold with gradient of porosity (scaffold top: porosity ~25%vol.; scaffold bottom: porosity ~50%vol.); (b) scaffold mimicking the cancellous-cortical bone system.