BIOACTIVE GLASSES: BENEFITS AND DRAWBACKS FOR USE IN BONE TISSUE ENGINEERING

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Introduction

The first bioactive glass (45S5) was discovered in 1969 by L.L. Hench and since much work has focused on this unique material. Bioactive glass is the first synthetic material that demonstrates not only osteoconductivity but also osteoinductivity. The main advantage of bioactive glass lies in the ability to modify the composition in order to tailor the degradation kinetics, thus matching the rate of tissue regeneration. Unlike other synthetic materials (i.e. polymers, metal, ceramics), ions of therapeutic interest can be incorporated into the glass structure. For example, antimicrobial, angiogenesis or anti-inflammatory properties, just to cite a few, can be imparted to the bone graft by adding specific ions.

However, the use of bioactive glass is facing challenges. It is well known that an optimum bone graft, should be a 3D structure with high porosity (>60%), large pore size (>100µm) and mechanical properties at least similar to the cancellous bone. In order to process such architecture, ceramics and glasses are often sintered at high temperature. However, typical bioactive glasses are prone to crystallization during the sintering process, leading to a decrease, or even suppression of their bioactivity. Furthermore, glasses, per definition, are hard materials, leading to difficulties for surgeons to shape them on site.

Materials and Methods

In this presentation, an introduction to traditional bioactive glass will be provided, focusing on their advantage and disadvantage. Processing and characterization of new borosilicate glasses enabling sintering without adverse crystallization will be presented. The thermal properties of these new glasses were assessed by DTA and XRD. The dissolution mechanism of these glasses was quantified by pH change, ion release (using ICP-OES) and glass structural change (using FTIR). The ability of these glasses to produce a hydroxyapatite reactive layer was confirmed by SEM/EDX. The best glass candidate was 3D printed using a n-Scrypt 3D printer. The architecture (µCT) and dissolution in simulated body fluids were studied.

Human adipose Stem Cells were plated at the surface of glass disc and on 3D printed scaffolds. Cell proliferation was measured. Cell morphology was assessed by immunostaining. Osteogenic commitment was proven by culturing the cells in basic medium as well as osteogenic medium and tracking osteogenic markers.

Finally to facilitate shaping and processing, these new glasses were introduced in composites and hybrids biomaterials. Processing of PLA/bioactive glass and Gelatin/GPTMS/bioactive glass biomaterials as well as their cell/material interaction will be presented.

Results and Discussion

While typical silicate bioactive glasses have found space in clinics for the reconstruction of bone defect, sintering them into scaffolds leads to crystallization, in turns reducing their bioactivity. The new borosilicate glasses developed have shown to not only possess extended hot forming domain but also to promote early cells osteogenic commitment. Indeed, while the cell proliferation was reduced at the surface of the borosilicate glasses, compared to the silicate counterpart, up-regulation of osteogenic and endothelial markers was demonstrated. Borosilicate glasses were shaped into 3D scaffolds with controlled porosity and pore size using the porogen burn-off, 3D prototyping technique or supercritical CO_2 foaming when in composites (FIG. 1).

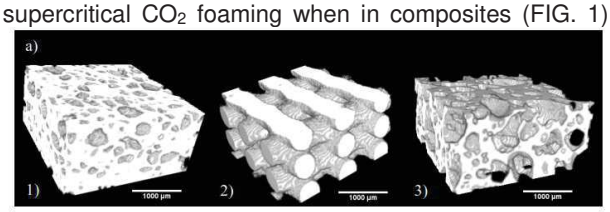

FIG. 1. Borosilicate glass scaffold processed using the porogen burn-off technique (1) 3D prototyping (2) and PLCL/bioactive glass scaffold processed via supercritical CO_2 foaming (3).

The developed scaffolds have mechanical properties superior to the cancellous bone, pore size >100µm and interconnection >50µm.

While these results are promising, the problem of shaping the scaffold on-site remain a drawback. Composites (PLCL/bioactive glasses or PLA/Bioactive glass) have, thus, been developed. PLA/borosilicate glasses composites were processed via twin-screw extrusion, in view of producing screw and/or plates. The presence of bioactive glasses was found to increase the rate of degradation of the PLA, while providing ions, leading to osteoinduction.

Finally, hybrids based on Gelatin / GPTMS / borosilicate glasses or Gelatin / Alginate / bioactive glasses were processed using a one-pot technique. The presence of the bioactive glass was found to stabilize the organic network. The first test of bioprinting (FIG. 2) was successful and cell culture will be continued.

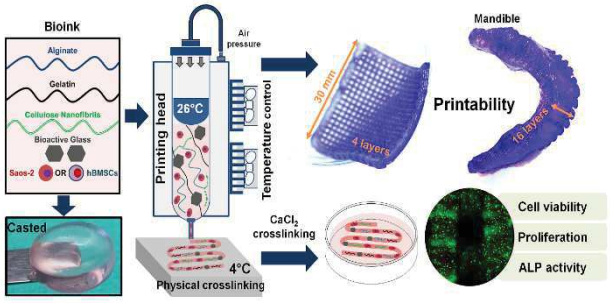

FIG. 2. Schematic of the bioprinting process [1].

Conclusions

In conclusion, bioactive glasses have the unique ability to induce osteoinduction as well as other beneficial therapeutic effects, without the need for costly, and sometimes toxic additional molecules. The composition of the glasses can be tailored in order to allow scaffold production with controlled pore size and structure.

Bioactive glasses can be introduced into polymeric matrix natural or synthetic to benefit from its osteoinductive properties.

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References

[1] M. Ojansivu, A. Rashad, A. Ahlinder, J. Massera, A. Mishra, K. Syverud, A. Finne-Wistrand, S. Miettinen, K. Mustafa, Biofabrication, 11 (2019) 035010