Developing Bioactive Glasses and Glass-ceramics for Biomedical Applications

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The initial interest in our group was exploring use of phosphate-based glasses as fully resorbable biomaterials. These glass-based biomaterials offer wide ranging and controlled degradation profiles (from day/s, week/s to many months) by simply manipulating their chemical formulations. Phosphate-based glasses are unique biomaterials, as their chemical composition can be made to resemble the mineral content of natural bone, providing excellent cytocompatibility.
Interest in developing resorbable medical devices has increased over recent years. Initially we explored PLA and PCL polymer matrices to produce implantable medical devices, such as fully resorbable bone fracture fixation plates (see Fig. 1a,b). However, the mechanical properties of polymers alone are insufficient to be used in higher load bearing applications. For example, the modulus of cortical bone in longitudinal direction is ~17.7 GPa [1], whilst those of typical polymeric biomaterials can range between 1 – 5 GPa [2]. Our potential solution to this problem was to reinforce these polymers with high modulus bioactive glass fibres. As such, phosphate-based glass fibres (PGFs) containing calcium were used as the main advantage was that these fibrous materials were also fully biodegradable and possessed sufficient mechanical strength for bone repair (tensile tests demonstrated E≈65+ GPa [3–4]) (see Fig. 1c,d).

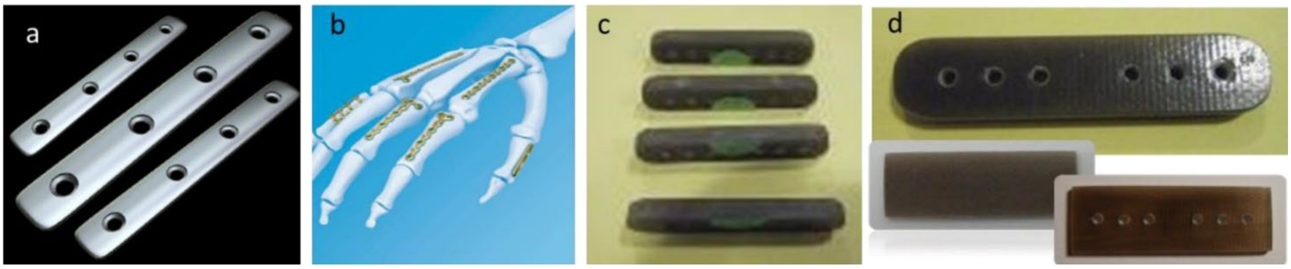

Fig. 1. *(**a**,**b**) Depiction of metal plates used for bone fracture repair; (**c**,**d**) Examples of resorbable composite plates developed in our group [1–3].*

In the last few years, we have also been developing fully resorbable solid/dense (non-porous) and highly porous glass microspheres from phosphate-based glasses for regenerative medicine and other biomedical applications. Manufacturing porous microspheres from glass-based materials with nano- to micron-range porosity has huge potential in bone repair and regeneration applications where larger external pores within the microspheres could accommodate cells and the smaller pores could be utilised to encapsulate other types of biological components such as drugs, small molecules, nucleic acids, proteins, *etc*.
Our group was the first to successfully develop a single-stage manufacturing process for producing solid (non-porous) and highly porous microspheres [5,6] from calcium phosphate-based glasses (see Figs. 2a–d), which has now also been demonstrated for alternate glass systems such as silicates and borates [7,8]. Follow-on studies confirmed that the porous microspheres had both large surface and fully inter-connected porosity (as shown in Figs. 2e,f). Further studies also confirmed that human mesenchymal stem cells not only attached to the microspheres, but also migrated to reside within their pores (see Fig. 2g).
More recently, we have been developing biomaterials for bone cancer and radiotherapy applications which led to manufacture of novel glass ceramic biomaterial. We also managed to incorporate magnetic properties in some biomaterials with potential application for hyperthermia. These will also be briefly highlighted during the presentation.

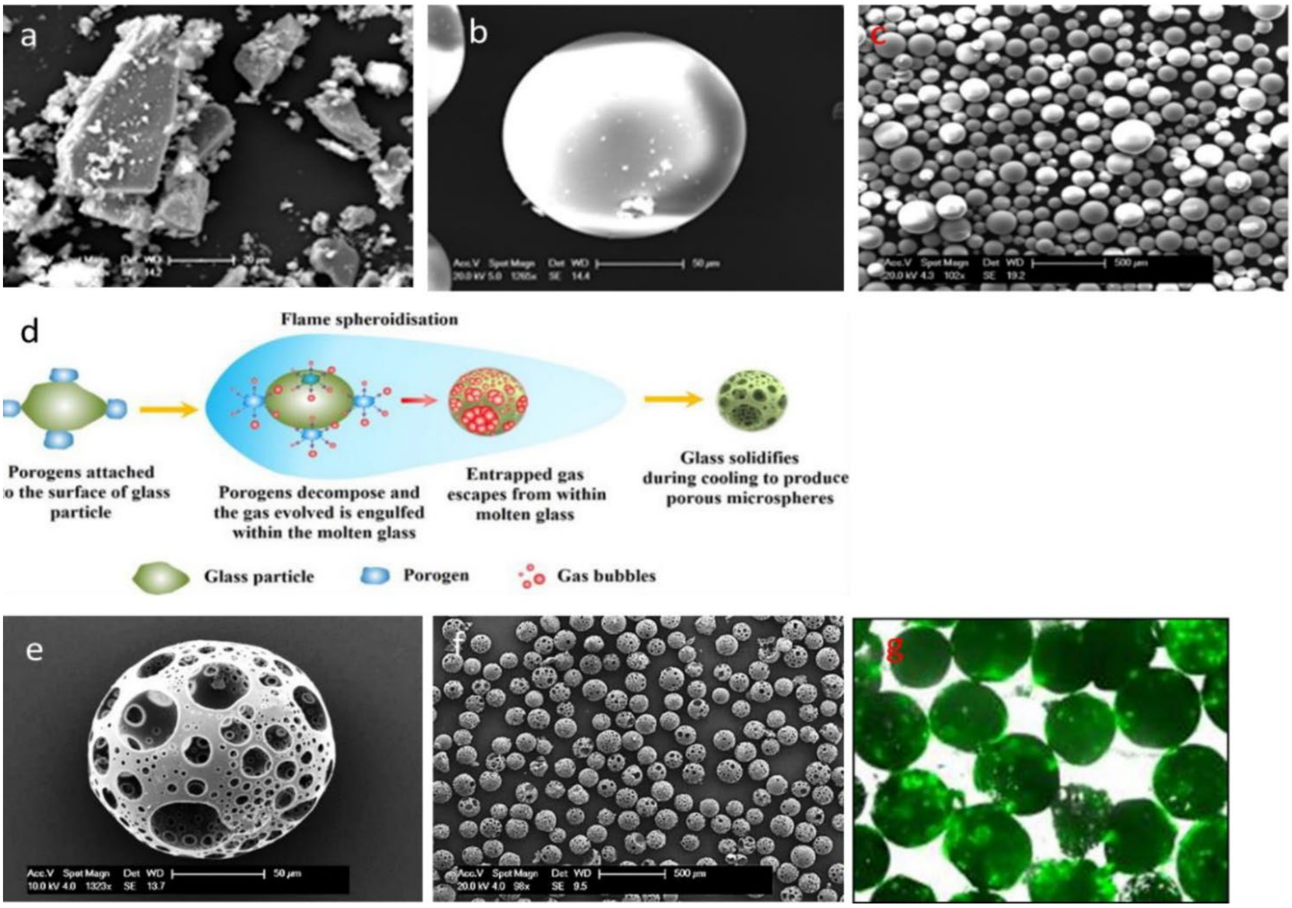

Fig. 2. *(**a**–**c**) Starting particles processed as solid/dense microspheres; (**d**) Scheme of developed manufacturing process;(**e–g**) Highlights of porous glass microspheres produced and stem cell attachment [5,6].*

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