Bioactive Glass Scaffolds for Repair and Regeneration of Load-bearing Bone Defects

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Statement of Purpose: In materials science, the ability to develop porous constructs with high mechanical strength is important for a broad range of emerging applications, including filters, catalyst support, and tissue engineering scaffolds. Particularly for orthopedic surgery, the regeneration of large bone defects in load-bearing limbs remains a challenging problem that require scaffolds that combine the strength required for a load bearing application with the large porosities needed to ensure cell survival and tissue regeneration . The aim of this work was to fabricate bioactive 6P53B glass scaffold by direct-ink-write assembly of a hydrogel-based ink, and to evaluate their in vitro degradation and mechanical response.

Methods: Bioactive 6P53B glass with the composition (wt%): 52.7 SiO_2, 10.3 Na_2O, 2.8 K_2O, 10.2 MgO, 18.0 CaO, and 6 P_2O_5 was used in the present study. Glass inks were created by mixing 30 vol% glass particles in 20 wt% Pluronic® F-127 solution. Glass scaffolds were fabricated by printing the inks through a 100 µm nozzle (EFD precision tips, EFD, East Providence, RI) using a robotic deposition device (RoboCAD 3.0, 3-D Inks, Stillwater, OK). After printing, the scaffolds were air-dried and sintered at 700°C for 1 hr. The microstructure of the scaffolds was characterized by Scanning Electron Microscopy, SEM (Hitachi S-4300, Tokyo, Japan). Their *in vitro* degradation was evaluated as a function of immersion time in simulated body fluid, SBF, with a starting pH = 7.2 at 37°C, as described elsewhere [1].

Results: Three-dimensional glass scaffolds with precisely defined rod diameter, spacing, and number of layers were patterned by extruding the glass ink through the 100 µm tip (**Figure 1**). **Figure 1a** shows the sintered scaffold consisting of square pores with the size of 250 µm. The printed rods had a smooth surface and bonded well to the previous layer (**Figure 1b**).

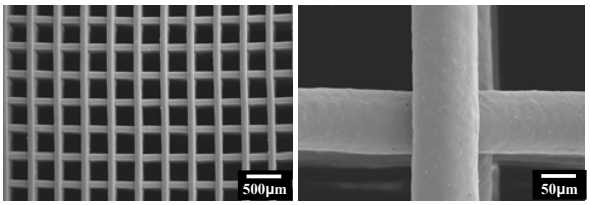

Fig. 1. SEM image of: (a) sintered scaffold; and (b) detailed adhesion of the rods

The porous glass scaffold had a compressive strength of 135 MPa representing specific properties comparable to that of cortical bone but with porosity comparable to trabecular bone (60%). The strength of this porous glass scaffold is ~ 100 times that of polymer scaffolds and 4 - 5 times that of ceramic and glass scaffolds with similar porosity reported elsewhere (**Figure 2**). The scaffolds showed a gradual degradation when immersed in SBF, and the pH of the solution increased with the immersion time (**Figure 3a**). Nano-sized HA crystals formed on the surface of the glass rods after 14 days, an indication of its excellent bioactivity (**Figure 3b**).

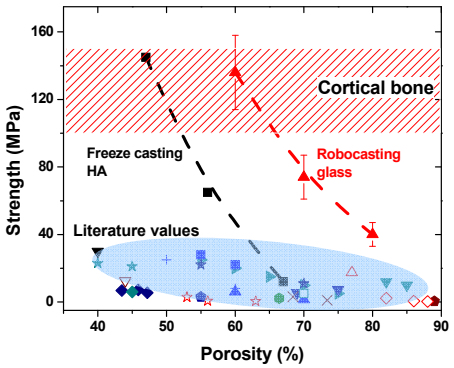

Fig. 2. Compressive strength vs. porosity of the glass scaffolds compared with literature values. As a reference, the compressive strength of cortical bone has been reported to be in the range of 100-150 MPa in the direction parallel to the axis of orientation (long axis) [2]

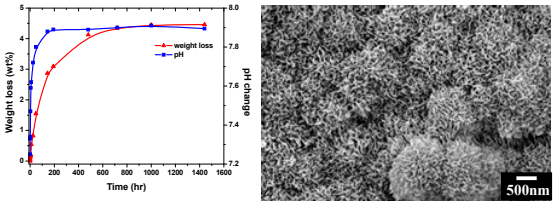

Fig. 3. (a) Weight loss of glass scaffolds and pH change of the solution upon immersion in SBF; (b) microstructure of the rod surface after immersion in SBF for 14 days.

Conclusions: We have developed highly porous and strong glass scaffolds by direct-ink-write assembly of a hydrogel-based glass ink. The sintered glass scaffolds show a compressive strength comparable to human cortical bone, an indication of their excellent potential for the repair and regeneration of load-bearing bone defects. The use of glasses also opens new possibilities, as their composition can be easily tailored to manipulate bioactivity and biodegradation rates as well as the release kinetics of different ions.

References:

1. Fu Q, *et al*. J Biomed Mater Res. 2010;95A :164-71.
2. Rho JY, *et al*. Med Eng Phys, 1995;17:347-55

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