An Osteoconductive, Load Bearing and Resorbable Scaffold

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Statement of Purpose: Highly porous scaffolds fabricated using a proprietary Cross-Linked Microstructure (CLM^{TM}) process in a resorbable (bioactive) glass composition were subjected to an *in vivo* animal study to evaluate the feasibility for use as a weight-bearing tissue engineering scaffold. The CLM scaffolds were manufactured by sintering resorbable glass fibers in an interconnected open pore network defined by pore-formers distributed in the fiber structure. The porosity can be controlled from 20 to 75% with a pore size range from 50 to 750 µm.

The CLM structure in a resorbable composition with open and interconnected porosity exhibits potential for adequate mechanical properties and bioactivity at the same time. *In vivo* results of CLM implants demonstrate new bone formed in pores and around the fibers. Evidence of bone formation directly on the surface of the CLM implants with continuity of the mineral phase between the bone and implant demonstrate direct bonding to the scaffold.

An optimized porous CLM resorbable glass scaffold with a bonded fiber structure and interconnected porosity is promising for applications in orthopedic tissue engineering as it combines high strength and bioactive properties. The potential applications of this high strength, resorbable glass fiber-based scaffold include load-bearing implants for treating problems of the spine and extremities.

Methods: In the CLM process glass fibers (5-9wt% Na_2O; 10-14% K_2O; 2.5-6.5% MgO; 18-22% CaO; 3-5% P_2O_5; and 50-54% SiO_2) are mixed with a binder, poreformer and a liquid into a plastically moldable material and sintered to form the bioactive implant. Different amounts of poreformer and sintering time were used to create 30-40% porous (LP) and 50-60% porous (MP) 6 x 12mm cylindrical implants.

Five (5) sections of LP and MP implants were polished and evaluated using SEM and ImageJ (National Institutes of Health, http://imagej.nih.gov/ij/) to evaluate pore size distribution. Static compressive testing was performed on each group of implants.

6 mm round vertebral defects were created in skeletally mature ewes (Ovis Aries) in the vertebral bodies of L3 (caudal aspect) and L4 (cranial aspect) to a depth of 12 mm +/- 1 mm using a 6.0 mm cannulated drill bit under an IACUC approved protocol. The implant was impacted into the defect hole. Animals were sacrificed at 6 and 12 weeks post-implantation. Lumbar vertebrae were harvested and specimens were trimmed. Ground sections were taken through the approximate center of the implant. Back-scattered Electrons Scanning Electron Microscopy (BSE-SEM) and Wavelength-dispersive X-ray spectroscopy (WDS) were performed.

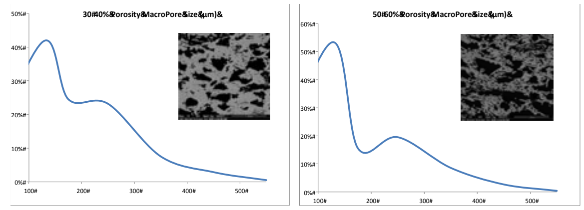


Figure 1: Macropore size A) LP and B) MP implants

Results: Micro (25-100µm) and macro (100-600µm) pores were present in all implants (Figure 1). The LP implants had a compressive strength >35 MPa, while the MP implants strength was >10 MPa.

The BSE-SEM images (Figure 2) show not only bone ingrowth into the pores of the implant but also formation directly on the CLM surface by 6 weeks. EDX was used to interrogate the mineral distribution and implant make up. Figure 3 shows locations of three elements (calcium, silicon and phosphate) found in bone mineral as well as in the CLM bioactive glass implant, giving insight into the scaffold behaviour. The outer surfaces are calcium and phosphorous rich, with the center of the struts demonstrating minimal CaP. It is possible that these ions are leaching out and participating in the bone forming/deposition processes.

Figure 2: Backscatter of LP at A) 6 and B) 12 weeks

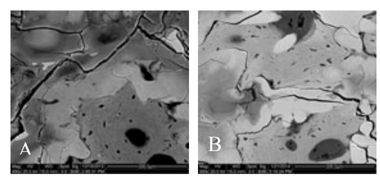
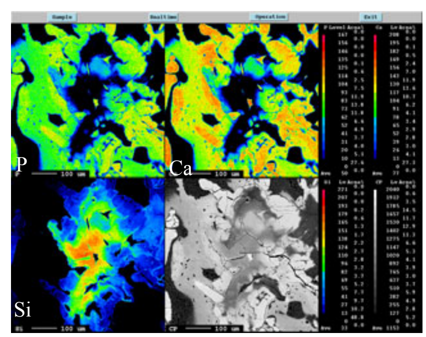


Figure 3: Wavelength Dispersive X-ray Spectroscopy of LP at 6 weeks



Conclusions: There is a demand for the development of improved biomaterials to be used as load bearing, osteoconductive implants. Porous three-dimensional bioactive glass implants employing the CLM process may meet this demand. The porosity not only increases the total reacting surface of the glass, but also serves as a framework for tissue ingrowth. Bioactive glass CLM in the 30-40% may be applicable in load bearing applications.

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