Shape Memory and Porosity Characteristics of a Novel Orthopaedic Scaffold

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Statement of Purpose: The ever increasing demand for minimally invasive procedures requires implants that can be delivered through a small incision. Many bone graft substitutes decrease in dimensions quickly after implantation, preventing complete surface area contact at the site of interest. Flowable scaffolds tend to distribute and dissolve in an uncontrolled fashion often leading to increased material loss and incomplete site coverage. A novel bioactive scaffold to meet the challenges of compression and dissolution during and after implantation has been developed. The antimicrobial properties of this scaffold have been previously reported. This study examined the porosity and shape memory characteristics of a chitosan/tri-calcium phosphate anti-microbial scaffold.

Methods: A chitosan polymer (OsteoMEM™, Advanced Biologics, Ladera Ranch, CA) was prepared with the addition of a Tri-Calcium Phosphate (TCP). Briefly, various polymer/calcium phosphate suspensions were frozen then lyophilized to form small, medium, and large cylinders. Each sample consisted of different formulations as shown in Table 1.

n	Cylinder Dimensions (mm)	Formulation (mg/ml)
6	Med Cyl / Ø 12.5 x 1.95	Chi 20 / TCP 60
6	Med Cyl / Ø 12.5 x 2.93	Chi 30 / TCP 60
6	Med Cyl / Ø 12.5 x 3.26	Chi 40 / TCP 80
6	Med Cyl / Ø 12.5 x 3.64	Chi 50 / TCP 100
6	Med Cyl / Ø 12.5 x 4.40	Chi 60 / TCP 120
6	Small Cyl / Ø 2.14 x 18.95	Chi 30 / TCP 60
6	Large Cyl / Ø 4.30 x 18.64	Chi 30 / TCP 60

Table 1: Sample Chart Parameters

All samples were made to the dimensions specified in Table 1. Samples were then individually hydrated with phosphate buffered saline at 37ºC for one minute. The diameter of each small and large cylinder was measured and recorded. The height of each medium cylinder was measured and recorded.

Cylinders (Chi 30/ TCP 60) were also examined under a scanning electron microscope (SEM) and µCT for material porosity. For µCT, one cylinder was frozen quickly (-80ºC) while another was frozen slowly (-25ºC).

Results: Figure 1 illustrates the average expansion of the small, large, and medium cylinders for each Chitosan / TCP formulation after hydration relative to its compressed state.

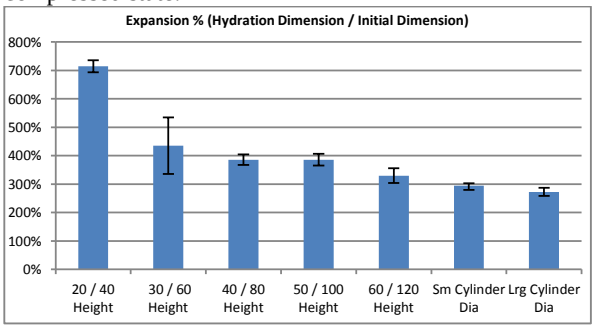

Figure 1: Cylinder Formulations (Compressed vs. Post Hydration)

SEM pictures demonstrate a uniform transverse surface pore structure of around 50µm pore size with embedded TCP (Figure 2).

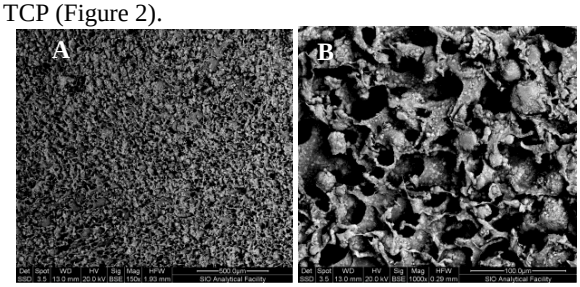

Figure 2: SEM Image a) 150x mag b) 1000x mag

SEM images taken at 150x and 1000x magnification show isotropic pore structure throughout the scaffold.

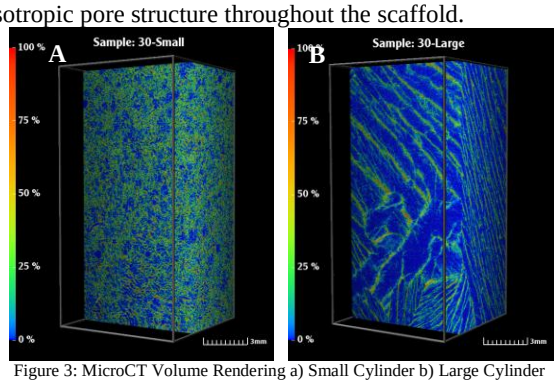

Figure 3: MicroCT Volume Rendering a) Small Cylinder b) Large Cylinder

Freezing rate differences affected the direction of porosity between the two samples. The slowly freezing sample contained larger channels of pores that were not present in the quickly freezing sample. Based on the microCT analysis the small and large samples porosity percentages resulted in 59% and 73%, respectively.

Conclusions: The OsteoMEM™ scaffold exhibited in excellent shape memory characteristics, resulting in significant and controlled expansion across all formulations and sizes. The expansion can be tailored to occur uni-directionally or multi-directionally. The pore structure was greatly affected by freezing rate. The scaffold demonstrated a lower material porosity with an isotropic pore structure for the quicker freezing and a higher material porosity with anisotropic pore structure for the slower freezing scaffolds. The channels that were produced with the anisotropic pore structure may be beneficial for better nutrient transport in vivo and eventual vascularization. With the increase of MIS procedures the controlled expansion of the OsteoMEM™ scaffold makes it an ideal candidate for these type of procedures and warrants further study.

References: