Dissolution Kinetics of a Composite Calcium Sulfate, Calcium Phosphate Cement
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Introduction: A composite cement of calcium sulfate (CS) and calcium phosphate (CP) has been developed (PRO-DENSE™, Wright Medical) that is mixed and cures in situ via two reactions; one that produces CS-dihydrate and another that forms brushite. A third, distributed phase of TCP granules is embedded in the biphasic matrix. In vivo studies have demonstrated a marked increase in the amount and strength of new bone formation compared to pure calcium sulfate (CS) materials (Ref 1). It is proposed that the greatly improved in vivo performance may be in part due to differences in the kinetics and physical nature of the resorbing graft. In this study those attributes are compared with pure CS and with simple mixtures of CS and CP in an accelerated dissolution protocol.

Materials and Methods: The dissolution properties of three materials were studied; PRO-DENSE™ (PD), pure calcium sulfate di-hydrate (CS), and a mixture of CS with 20% TCP granules (CS-TCP). Pre-cast pellets 4.8 mm diameter by 3.2 mm tall were placed in fritted glass thimbles to allow removal of pellets at test intervals without damage. The thimbles were submerged in deionized water (changed daily) and the pellets (N=5) were dried and weighed to determine the percent mass remaining. At selected times additional pellets were removed from solution and embedded in PMMA. Cross-sections were subjected to microscopic analysis using backscattered SEM and energy-dispersive X-ray spectroscopy (EDXS) to determine the composition of each region within the pellet.

Results: The mass loss results are shown in Figure 1. The rate of dissolution as determined by the slope of the curves over the first four days shows that PD showed a 50% reduction in weight loss compared to pure CS. After 12 days in vitro the PD curve exhibited a marked change in slope, corresponding to the point at which the CS phase was substantially dissolved. In contrast, the CS-TCP material did not demonstrate a significant reduction in rate until most of the CS had been leached out of the pellets. After that point, the dissolution became very slow as was expected for a pure TCP material.

Discussion: The two composite materials, PD and CS-TCP, contained similar amounts of calcium phosphate (25% and 20% respectively). However, their dissolution behavior was radically different. This is thought to be due to the fact that the CS and brushite in PD are formed simultaneously through chemical reactions and are thus intertwined on a microscopic scale to form the matrix of the set cement. As CS is dissolved, the finely dispersed brushite crystals that are left behind act to slow the diffusion of CS dissolution products. The resulting local increase in concentration of calcium and sulfate ions slows the dissolution rate from the remaining bulk matrix. The TCP granule component of PD is left behind to form a scaffold which is held together in vitro by remnants of brushite.

References: 1. R.M. Urban, CORR, June 2007