Multi-functional Sr-Phosphate (Sr-P) Nanocomposites for Caries Treatment

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Statement of Purpose: This paper reports the development of multi-functional Sr-Phosphate (Sr-P) filled nanocomposites for the treatment of dental caries, a common chronic infectious transmissible disease. The work is a further improvement of caries infiltration therapy aiming towards the early carious lesions. The treatment uses Icon, a low viscosity, light curable resin comprising of crosslinking monomers and a photoinitator. The tretment consists of penetration of Icon into the porosities of an enamel lesion situated several hundred micro meters underneath the surface layer [1]. However, there is no clinical or radiographic evidence to demonstrate whether the Icon infiltrant completely filled the carious lesions. We chose strontium hydroxyapatite ($Sr_{10}(PO_4)_6(OH)_2$), SrP) to provide radio-opacity as well as a source of phosphate ions for remineralization. We have recently developed the synthesis of SrP nanoparticulates using a novel microwave assisted processing [2]. It is hypothesized that these nano-fillers will not alter the low viscosity of the resin, and yet provide the required radio-opacity and the phosphate ions for remineralization. Hence, these nanocomposites are termed multi-functional.

Methods: Appropriate analytical grade water-soluble reagents were dissolved in DI water and treated in a household 700 W microwave (Kenmore) oven for 5 min maximum power heating. The precipitates were collected via filtering and dried in 37˚C oven overnight. The as-synthesized nanoparticles (SrP) were characterized by X-ray diffraction (XRD, Rigaku), Fourier transform infrared spectroscopy (FTIR, UMA-600 Microscope, Varian Excalibur Series, Digilab), scanning electron microscope (SEM, Hitachi) coupled with energy dispersive x-ray spectroscopy (EDS), and transmission electron microscope (TEM, Hitachi). Its zeta potential was measured using zeta potential/particle sizer (380 ZLS, Nicomp).

One vial of Icon infiltrant (DMG American) with a volume of 0.45 ml (0.5g after curing) and 0.001 g of SrP were added to a 2 ml centrifuge tube. Ultrasolication was used to disperse the nanoparticles.Subsequently, the mixture was light cured for 40 seconds to solidify the Icon infiltrant. The radiopacity of the mixture was determined using an X-Ray machine at 0.10 kVp. The dispersion of SrP nanoparticles in cured Icon matrix was characterized using SEM. The penetration ability of Icon infiltrant before and after nanoparticles addition was compared by adding 0.1 ml solution to porous ceramic stick surface (Buelher). The extent of infiltration was checked in a SEM. The preliminary ion release study was carried out by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES, Fisher Scientific) to measure the concentration of Sr^{2+} change in PBS.

Results:

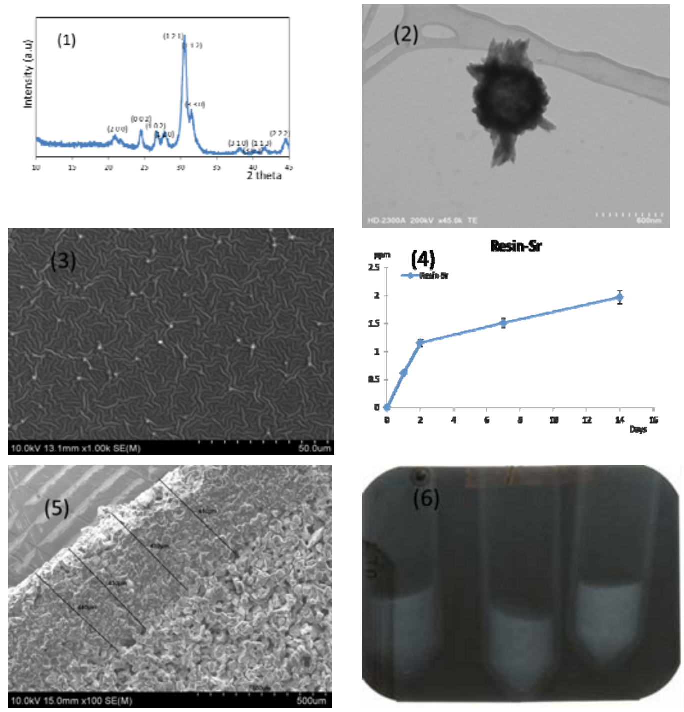

Figure (1) XRD pattern of as-synthesized Sr-P: (2) TEM of an individual Sr-P nanoparticle; (3) SEM of the nanocomposite with bright spots of Sr dispersed in the Icon film; (4) Release of Sr ion from the composite over 15 days; (5) Penetration of the filled resin is approximately 400μm into a porous ceramic; (6) X-ray opacity shown by the filled resin.

Figures (1) to (6) show that: 1) our microwave process is able to synthesize nanocrystalline Sr-P nanoparticles; 2) these particles can be uniformly dispersed in the Icon resin without agglomeration. 3) the nanocomposites can release Sr ions for 15 days, which means that the phophates ions are also being released at the same time; 4) The filled resin maintains its rheological property for penetration inside a simulated porous surface like the ones encountered in the caries site; 5) the filled resin provides adequate radio-opacity.

References:

1. Soviero VM, Sellos MC, dos Santos MG. Micro-invasive treatment of caries - expanding the therapy spectrum in modern pediatirc dentistry. Intenerational Dentistry SA 2010;12:34-42.
2. Zhou H, Nedley M, Bhaduri SB. Microwave assisted solution combustion synthesis of strontium phosphate (SrP) whiskers. Materials Letters (accepted for publication, 2013).