Novel Microwave Assisted Route for Preparing Monetite Bone Cement with No Heat Generation

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Statement of Purpose: Monetite (DCPA, $CaHPO_4$) bone cement can be considered as an alternative to brushite (DCPD, $CaHPO_4.2H_2O$) cement as it exhibits chemical composition and solubility close to DCPD [1]. Additionally it was observed that DCPA does not reprecipitate into apatite in vivo like DCPD, thus providing greater degradatbility for bone regeneration [2]. The reactants for DCPA cements are mainly $Ca(OH)_2$, H_3PO_4 and $NaHCO_3$, providing advantages in industrial manufacturing. However, similar to DCPD cements, DCPA cement can also generate heat during reaction. This work addresses a novel route to prepare DCPA bone cement based on microwave irradiation, which can significantly decrease released heat during setting and improve the compressive strength of the final products.

Methods: The powder component of DCPA cement is $Ca(OH)_2$ (purity >95%) without any further treatments. Setting solution was prepared by mixing sodium bicarbonate ($NaHCO_3$, >99.7%), H_3PO_4 (85% v/v) solution and deionized (DI) water. Cement pastes were prepared by manually mixing $Ca(OH)_2$ with setting solution and extra DI water in an agate mortar by using an agate pestle. Initially, 0.6175g of $Ca(OH)_2$ mixed for two minutes with 0.8ml of DI water to form a paste with $Ca(OH)_2$ uniformly dispersed in the water. Subsequently 0.75ml of setting solution was added to the materials with 1 min mixing to form a paste. This paste was placed in a mold and pressed by finger to make it a disk sample for compression test and cell culture after its complete set. For comparison, the freshly mixed paste was placed into a household 800W microwave oven heated at the maximum power for 5 min. After microwave treatment, the paste converted into dried materials, which was very brittle and can be easily crushed into fine powders. The as-prepared powders were mixed with DI water for 1 min following a 2:1 g/ml ratio in an agate mortar. The paste was also placed in the mold to make samples for further testing. The novel DCPA cement was referred as MW-DCPA. Both DCPA and MW-DCPA were characterized using XRD, FTIR, SEM. Their surface temperature during heating, setting time and compressive strength were measured. The osteoblast proliferation on these samples was also evaluated.

Results: Both cements can set, but microwave treatments can change the setting time (20 min) as compared to regular DCPA cement (36 min). On the other hand, as compared to regular DCPA cement, the MW-DCPA cement generated no heat during setting (Fig. 1). Additionally, the compressive strength measurement showed MW-DCPA higher values (approximately 18 MPa) as compared to regular DCPA cement attributed to the removal of porosity during setting. The XRD results confirmed both samples formed DCPA as their final phase (Fig.2). The SEM characterization showed the fine powders after microwave treating are composed of both needle-like and plate-like crystals, and the final set MW-DCPA showed less porosity than regular DCPA cement (Fig. 3). MC3T3 preosteoblast cells can proliferate on the surface of MW-DCPA cement (Fig. 4).

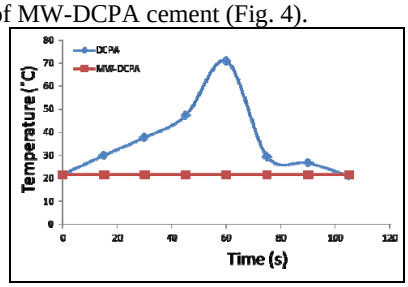

Figure 1. Temperature change during setting of DCPA and MW-DCPA

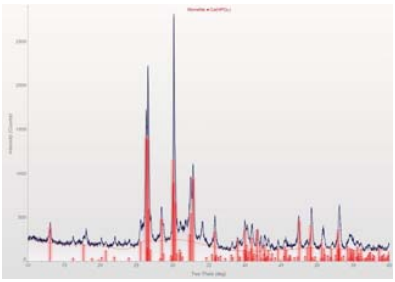

Figure 2. XRD pattern of MW-DCPA

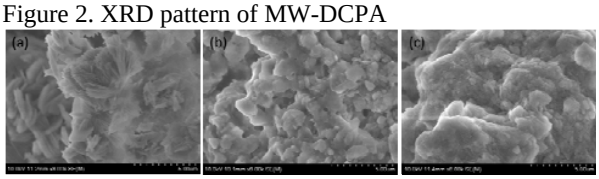

Figure 3. SEM images of (a) fine powders after microwave heating; (b) regular DCPA cement; (c) MW-DCPA cement

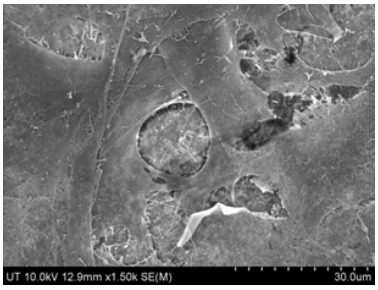

Figure 4. Morphology of MC3T3 cells proliferated on MW-DCPA after 7 days.

Conclusions: A novel method to produce DCPA cement based on microwave irradiation was developed. It can solve some problems found in regular DCPA cements including heat release and low pH during setting reaction, poor compressive strength, and long setting time. It is believed this technique can also be applied to other CPCs based on acid-base reactions.

References:

1. Dorozhkin, S. J Mater Sci. 2007;42:1061-1095.
2. Tamimi F. Biomater. 2010;31:2762-2769.