Acidic Degradation of MCPM/TCP Cement

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Introduction

Dicalcium phosphate dihydrate cement (DCPD), based on monocalcium monohydrate and tricalcium phosphate (MCPM/TCP), has been used as bone graft substitute. Many *in vivo* studies demonstrated that the material is well tolerated by tissue and is degradable. However, it is also known that the dissolution of DCPD is acidic. The acidity can be detrimental when DCPD is used as a degradable cell carrier. We hypothesize that the acidity of the MCPM/TCP cement can be modified by MCPM/TCP ratio. The objective of this study is to investigate the effects of MCPM/TCP ratio on pH and other related material properties during *in vitro* degradation.

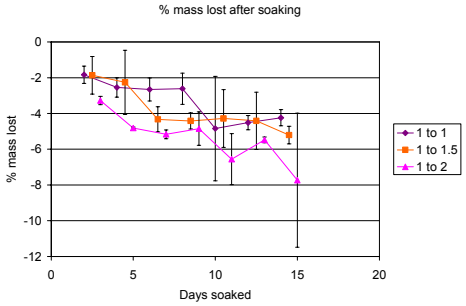
Materials and methods

The phase ratio in cements formed by different MCPM/TCP ratios was first studied. MCPM/TCP powder at 1:1, 1:1.5, and 1:2 molar ratios was mixed with water at powder to liquid ratio of 1.43. The resulting cement was analyzed by XRD (Siemens D5000). DCPD and TCP powders were mixed in 25:75, 50:50, and 75:25 weight ratios and analyzed using XRD to construct a calibration curve. The peak heights at 2θ angles of 11.5° and 31° were used to calibrate the weight ratios of DCPD and TCP in the cement. DCPD cylinders were made from 1:1, 1:1.5, and 1:2 molar ratios of MCPM:TCP, and all cylinders had 1.43 powder to liquid ratio. After mixing the three ingredients together, the slurry was cast into a teflon mold with both a diameter and height of 0.25 inches. The cylinders were vacuum-dried overnight and then weighed. Each cylinder was placed in a glass vial containing 5 mL of PBS at pH 7.4 and incubated at 37°C. It was then removed after a given number of days and vacuum-dried overnight. The cylinders were weighed after soaking to determine the weight loss. The pH of the PBS in the glass vial after removing the cylinder was measured using a pH meter (Denver Instrument, Ultrabasic). The ultimate compressive strength of the DCPD cylinders was determined using an MTS machine (Instron Corp.) at a loading rate of 1.27 mm/minute.

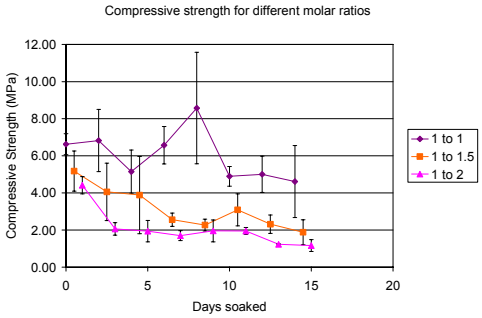
Results and Discussion

In the XRD analysis, the 1:1 MCPM:TCP cement shows excess MCPM, TCP and converted DCPD. This result shows that the stoichiometry of the starting powder does not guarantee the complete conversion. With the low solubility of TCP, a higher amount of TCP will be needed to react with the more soluble MCPM. This can be seen in the XRD of the 1:1.5 and 1:2 ratios samples where MCPM was consumed and no remaining MCPM peak is detected. The peaks height ratios in the XRD of 1:1.5 and 1:2 MCPM:TCP correspond to 28% TCP and 46% TCP, respectively.

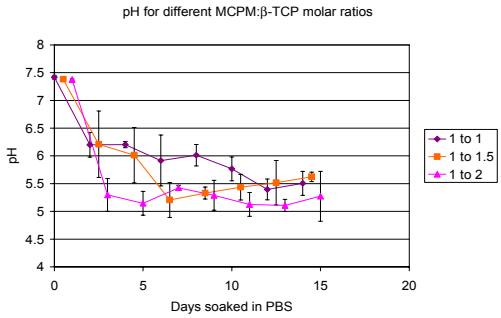
In the weight loss study, the 1:2 group shows a trend of faster degradation, though not statistically significant. The large standard deviation came from large piece of cement breaking away from one of the specimens during retrieval.



In the strength study, the 1:1 ratio shows the highest strength. The data suggests the excess TCP powder reduces the overall strength of the samples.



With excessive MCPM, we would expect 1:1 group to be the most acidic. To our surprise, the 1:1 and 1:1.5 showed a higher pH value than 1:2 group at day 2 and day 4. The 1:1 group remains higher pH value till day 10. The structural instability of 1:2 as seen in the weight loss data may have contributed to the faster decrease of pH.



Conclusion

A stoichiometric mixture of MCPM/TCP leads to a highest pH value and strength in the resulting cement. Excessive TCP in the MCPM/TCP mixture does not lead to a lowered pH nor a higher strength. The cellular response to this material will be studied next.