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Optimization of an acidic calcium phosphate cement with enhanced radiopacity

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INTRODUCTION: Calcium phosphate cements (CPCs) are commonly used in biomedical applications due to their resemblance to the mineral phase of bone. However, due to this resemblance the radiopacity of CPC is very similar to that of bone. The inorganic radiopacifiers (e.g. ZrO₂ and BaSO₄) commonly used in non-degradable bone cements are not water-soluble and cements utilizing these radiopacifiers have shown an increased bone resorption [1]. To overcome this problem, other radio opaque agents need to be investigated. Studies have shown that strontium can enhance the osteoblasts activity, which could lead to increased bone formation [2]. Hence, soluble strontium salts could be an alternative for enhanced radiopacity. However, additives that do not (or only partially) take part in the setting reaction may have a negative effect on the cement’s mechanical properties. In this study the influence of additions of strontium chloride (SrCl₂) on various properties of a CPC is evaluated. The objective is to find an optimal composition with regards to radiopacity, compressive strength (CS), and setting time.

METHODS: A screening study was first performed with three factors included; wt% sodium pyrophosphate (SPP), wt% SrCl₂ and liquid phase (phosphoric acid, citric acid, or water). The maximum amounts of SPP and SrCl₂ were fixed at 5 wt%, and 30 wt% respectively; and the concentration of the acids were kept at 2 M and 0.5 M for phosphoric acid and citric acid respectively. From the results of the screening study further testing was performed using 10 wt% SrCl₂ and varying the amount of SPP from 0.25 to 1 wt%.

The CPC consisted of equimolar amounts of β-tricalcium phosphate and monocalcium phosphate monohydrate. The cement powders were mixed with the liquid in a powder to liquid ratio of 3.3 g/mL.

RESULTS: The CS measurements showed that the incorporation of 30 wt% SrCl₂ decreased the strength drastically (Fig 1). However, as the amount of SrCl₂ decreased, the effect on CS was not as pronounced. It was also seen that the incorporation of all additives increased the setting time remarkably. Most distinct was the increase to approximately 400 minutes for cements containing 30 wt% SrCl₂ together with 5 wt% SPP. Furthermore, the setting of cements without any SPP or SrCl₂ is very short and moldering was almost impossible. The radiopacity of the cements showed logarithmic relations, and 15 wt% and 30 wt% had a similar radiopacity of 1.4 and 1.5 mmAl/mm, respectively. To increase CS and decrease setting time it was desirable to have as low amounts of SrCl₂ as possible, which still showed radiopacity, and 10 wt% was hence chosen for further studies.

DISCUSSION & CONCLUSIONS: This study has shown that compositions containing 1 wt% SPP and 10 wt% SrCl₂ could be a feasible alternative for cements requiring enhanced radiopacity. These cements have a setting time of approximately 35 minutes and show CS of around 20 MPa, this can be compared to cement without any SrCl₂ or SPP, but with 0.5M citric acid to make moulding possible, which had CS of around 12 MPa and a setting time of approximately 10 minutes.


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