# ACRYLIC BONE CEMENTS MODIFIED WITH PEG/ALGINIC ACID SHAPE STABILIZED PHASE CHANGE MATERIALS

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## Introduction

Acrylic bone cement, based on poly(methyl methacrylate) (PMMA), is widely used for the fixation of artificial joints to the bone tissue but also in remodelling osteoporotic and vertebral fractures repair (1). It is usually supplied as a two component system: polymer powder and liquid monomer. Bone cement is prepared by mixing these two components and the liquid monomer polymerizes around the polymer powder microparticles to form hardened cement. In this free radical, exothermic polymerization process, huge amount of heat is generated to the environment. The temperature of bone cement during the curing process is in range from 40°C to 110°C (2). One of the method to reduce too high maximum polymerization temperature is using phase-change materials (PCM) e.g. based on poly(ethylene glycol) (PEG). PEG is very effective, biocompatible heat accumulator, but it needs to be stabilized to prevent the PEG leakage out of the system in the higher temperature. PEG can be easily stabilized with polysaccharides. In our preliminary study, we investigated the influence of pristine PEG of on the polymerization temperature of PMMA cement (3). The maximum temperature was reduced by 13°C, but the mechanical properties of cement decreased below requirements. Then, we decided to use potato starch as a shape stabilizer for PEG (4). The results confirmed that 15% of potato starch slightly reduced the thermal capacity of PEG but the mechanical strength of PMMA modified with PEG/potato starch systems was kept. In this study, PEG will be stabilized with different amount of alginic acid (AA) in order to investigate the influence of amount of polysaccharide on efficiency of PEG-based heat accumulators intended to PMMA cements.

## Materials and Methods

Duracryl®Plus, an acrylic bone cement was purchased from Spofa Dental. PEG (Sigma - Aldrich) with average molecular weights of 4000, 8000 and 12,000 g/mol was used as a cement modifier. Alginic acid (AA) (Sigma - Aldrich) was added to the PEG as a shape stabilizer.

*Preparation of PEG/AA systems*

In the first stage, different amount of alginic acid (1g, 2g, 3g) was dissolved in 90 ml of 2% NaOH. Next, PEG of given molar mass was dissolved in the alginic acid solution in accordance with TABLE 1.

TABLE 1. PEG/AA systems composition.

| AA / PEG: | 10% | 20% | 30% |
|---|---|---|---|
| **4000** | 9:1 | 8:2 | 7:3 |
| **8000** | 9:1 | 8:2 | 7:3 |
| **12000** | 9:1 | 8:2 | 7:3 |

The mixture was placed in a water bath at 72°C and stirred for 7 min. When the mixture was gelatinized, the solutions were poured into a Petri dishes and dried at room temperature for 7 days. Then, the blends were grinded finely in the mortar.

Acrylic bone cement was modified with 15% of PEG/AA systems. The liquid to powder ratio was 0.37ml/g. The curing temperature of cements was measured using an electronic thermometer in accordance with the ISO 5833 standard. Ultrasonic measurements and compression test, to estimate the mechanical properties of bone cement, were used. SEM analysis was used for the observation of surface morphology.

## Results and Discussion

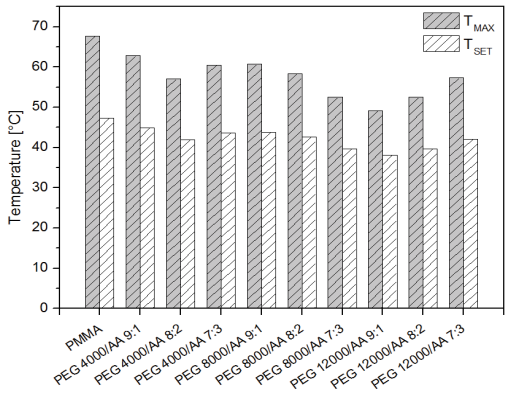


FIG. 1. The maximum temperature ($T_{MAX}$) and the setting temperature ($T_{SET}$) of PMMA/PEG/AA bone cements.

Temperature measurements (FIG. 1.) confirmed that all heat accumulators work effectively. The maximum temperature was decreased up to 17°C (PEG 12000/AA 9:1). The mechanical tests proved that the addition of stabilized PEG to the PMMA cement does not affect the mechanical strength significantly. SEM micrographs (FIG. 2) showed that the additive of PEG/AA system was evenly distributed on the PMMA surface.

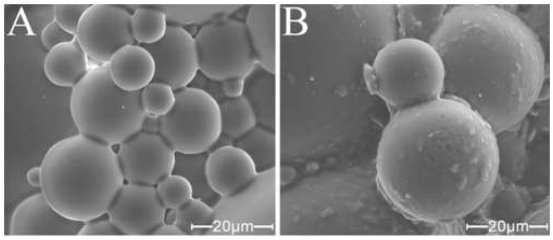


FIG. 2. SEM micrographs of PMMA (A) and PMMA/ PEG/AA system 9:1 (B).

## Conclusions

In this work, acrylic bone cement was modified with 15% of PEG/AA shape stabilized PCM in order to reduce too high polymerization temperature of PMMA. Different molar mass of PEG and various AA content in heat accumulators were tested. It was proved that 20% of AA and PEG of 12000 are the most effective combination that allowed to decrease maximum temperature of cement and keep the mechanical properties of PMMA bone cement.

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