ABSTRACT INTRODUCTION:

Poly(methyl methacrylate) (PMMA) bone cement is widely used in arthroplastic procedures of the hip, knee, and other joints for the fixation of the polymer or metallic prosthetic implants to living bone. However, there are several problems associated with the use of it, such as high maximum exothermic temperature, lack of bioactivity, and volumetric shrinkage upon curing etc. Its non-adhesive to bone with the formation of a fibrous layer between the bone surface and the cement is one of the major causes to loosening of cemented femoral components. Strontium-containing hydroxyapatite (Sr-HA) bioactive bone cement was developed to overcome the problems of PMMA bone cement.

The first formulation of Sr-HA bone cement (Sr-HA Spine) was designed for the use of percutaneous vertebroplasty and have shown good results in clinical trial. This formulation was modified and optimized for use in arthroplastic procedures in this study (Sr-HA Joint). Not only is the mechanical strength of the bone cement enhanced, but also the bioactivity. The Sr-HA Joint cement provides a good option as an alternative to be used in arthroplastic procedures of implant fixation.

METHODS:

1. Materials:

Strontium-containing hydroxyapatite (Sr-HA) powder was synthesized and characterized as previously reported. The new formulation of Sr-HA Joint cement is achieved by altering the ratio or removal of one or more components in the original formulation of Sr-HA Spine cement.

PMMA cement used in this study was the SMARTSET MV Endurance PMMA cement.

2. Determination of maximum temperature and setting time:

The evaluations of the setting profile (maximum temperature and setting time) followed the ISO 5833 (1992) standard.

3. Mechanical properties of cement:

The mechanical properties of the cement were measured according to ISO 5833 standard. All the specimens were sent to certified laboratory (EndoLab, GmBH, Germany) for testing.

4. Pull-out test

The adhesive force between the bone cement and the metallic implant was evaluated through a specially designed pull-out experiment (Fig. 1). The stem (Charnley roundback 40 femoral component, Thackray, U.K.) was inserted into the cylinder filled with 100 g of bone cement. In addition, it was precisely aligned such that the center of the drilled hole on the stem coincided with the centre of the circular opening of the cylinder. The depth of insertion was kept constant at 90 mm ± 0.5 mm for each test. The symmetric axis of the stem was kept absolute vertical with respect to the long axis of the cylinder until completion of setting. The pull-out force of the stem from the Sr-HA Joint cement and PMMA cement lining were found and compared. The pull-out tests were performed with material testing machine (MTS 858 Mini Bionix).

5. Osteoblast response on cement

MG-63 osteoblast-like cells were used in this study. Five 14 mm ± 0.1 mm diameter discs of bone cement were prepared for each time point. 2 × 10^4 cells/ml/well were seeded on the cement disc in a 24-well plate for 3, 7, 14 and 21 days, with the supplement of DMEM containing β-glycerophosphate (3 mM) and ascorbic acid (0.25 mM). The number of cells was assessed using MTT assay. Mineralization was observed by stereomicroscope (Leica MZFLIII) after staining with 2 % Alizarin Red S.

RESULTS SECTION:

The optimized new Sr-HA Joint cement was composited of a powder blend of strontium-containing hydroxyapatite (90 %), barium sulfate (10 %wt) and benzoyl peroxide (0.75 %wt), and a liquid blend of bisphenol A diglycidylether dimethacrylate (50 %wt) and triethylene glycol dimethacrylate (50 %wt) and N,N-dimethyl-p-toluidine (0.26 %wt).

The setting and mechanical properties of the Sr-HA Joint cement were summarized in Table 1.

Table 1. Properties of the Sr-HA Joint cement and the requirements of ISO 5833.

<table>
<thead>
<tr>
<th>Property</th>
<th>Sr-HA Joint</th>
<th>Requirement of ISO 5833</th>
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<tbody>
<tr>
<td>Peak temperature / °C</td>
<td>74.0 ± 1.4</td>
<td>&lt; 90</td>
</tr>
<tr>
<td>Setting time / min</td>
<td>7.5 ± 0.4</td>
<td>6.5 – 15</td>
</tr>
<tr>
<td>Bending strength / MPa</td>
<td>53.7 ± 6.6</td>
<td>&gt; 50</td>
</tr>
<tr>
<td>Bending modulus / MPa</td>
<td>4587.4 ± 341.2</td>
<td>&gt; 1800</td>
</tr>
<tr>
<td>Compressive strength / MPa</td>
<td>146.4 ± 3.1</td>
<td>&gt; 70</td>
</tr>
</tbody>
</table>

The pull-out force of the Sr-HA Joint cement was found to be 2748.33 N ± 618.95 N and the result for the PMMA cement was 2779.33 N ± 214.92 N.

The Sr-HA Joint cement allowed osteoblast attachment and proliferation. Similar attachment and proliferation rate of the cement was observed when compared with the Sr-HA Spine cement previously reported in the literature. Decrease in the cell number was observed from day 14 to day 21, with increase in bone-like nodules formation.

DISCUSSION:

The new formation of the Sr-HA Joint cement was optimized based on the setting and mechanical performance. The testing results of the Sr-HA Joint cement fulfilled all the requirements of ISO 5833 standard. The pull-out force of the Sr-HA Joint cement was similar to the PMMA cement, which indicates that the bonding force between the Sr-HA Joint cement and the implant is sufficient. From the in vitro study, it demonstrates that the Sr-HA Joint cement is bioactive, which allows osteoblast attachment, proliferation and mineralization.

The new Sr-HA Joint bioactive bone cement provides a good option as an alternative to be used in arthroplastic procedures of implant fixation. Clinical trial will be performed using this cement in the future.

REFERENCES:


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