Antibiotic additives alter the static and viscoelastic properties of bone cements

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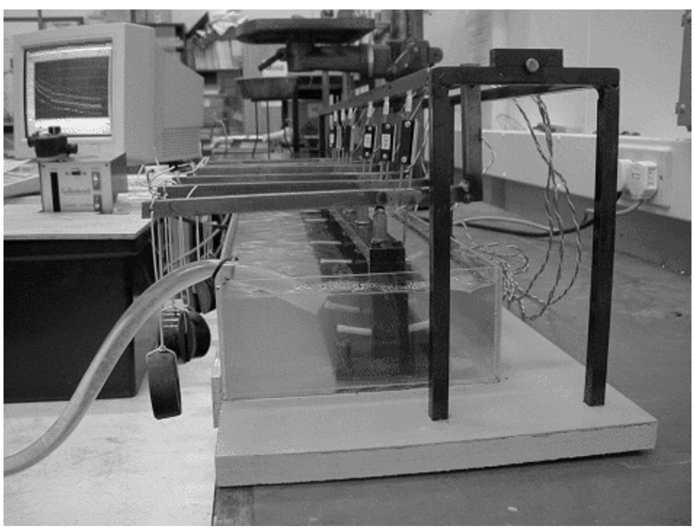
Introduction: In arthroplasty antibiotics are added to bone cements to prevent deep infection. The static properties of plain and antibiotic laden cements have been extensively described in the literature [1]. Commercially available cements must perform above the minimum values set by ISO 5833:2002 [2]. However, no upper or lower limits are set for the viscoelastic properties of the cements, despite this being a recognised factor affecting the cement-implant performance [3]. The ability of acrylic bone cement to creep and stress relax in conjunction with force-closed stems in hip arthroplasty affords protection of the vital bone-cement interface. With this design subsidence of the stem within the cement mantle over time does not lead to clinical failure [4]. Conversely, the clinical performance of shape-closed stem designs can be negatively affected by cements demonstrating excessive creep.

This study investigated the effect of antibiotic additives on the static and viscoelastic properties of PMMA cement.

Materials and Methods: The mechanical and viscoelastic properties of Simplex P, Simplex Antibiotic and Simplex Tobramycin (Stryker, Limerick, IE) were investigated. This family of cements was chosen as they are characterised by the same polymeric base, that of Simplex P, the plain formulation, but contain different antibiotic additives. In particular Simplex Antibiotic contains 0.5g Erythromycin and 3 million I.U. Colistin, while in Simplex Tobramycin the only additive is 0.5g of Tobramycin.

The static properties of the cements (compressive strength, bending strength and bending modulus) were assessed following ISO 5833:2002 [2], while stress relaxation and creep were assessed under quasi static conditions in a four point-bending configuration.

The creep experiments were carried out using a custom made apparatus with the specimens positioned in a distilled water bath at 37°C



Creep rig

. Six rectangular test specimens of 75±0.1 mm length, 10±0.1 mm width and 3.3±0.1 mm depth were produced for each cement type and conditioned in saline at 37±1°C for 48±2 hours prior to testing. The specimens were mounted in the creep rig and their deformation under a constant load, producing a maximum nominal stress of 8MPa in the centre of the beam, was recorded over a period of three days. Differences in the deflections of the cements were evaluated at six time points, namely one, three, six, twelve, twenty-four and seventy-two hours from the start of the experiment.

Stress relaxation experiments were carried out in air at room temperature, using a material testing machine equipped with a four point bending rig. Additionally, cement porosity was measured, for each batch of cement, from 5X magnification digital images of the centre of the mid cross-section of the creep samples using a custom developed algorithm (Matlab + Image Processing Toolbox, MathWorks, MA).

All data were analysed using ANOVA with Bonferroni post-hoc test (SPSS, SPSS Inc, IL, USA). Differences between the means were considered statistically significant when $p<0.05$.

Results: Bending strength measurements were the least sensitive to differences in the cements. Plain Simplex displayed lower bending and compressive strength but higher bending modulus than the antibiotic laden options. The bending modulus could only discriminate between Simplex P and Simplex Antibiotic ($p=0.02$). Differences in the compressive strength of the three cements were significant, with the plain option being the weakest. Stress relaxation only discriminated between plain and Tobramycin loaded cement ($p=0.028$), while creep was more sensitive to differences and allowed distinction between plain and antibiotic loaded bone cements. The creep behaviour correlated with the cross sectional porosity measurements.

Discussion: The success of cemented THA depends on surgical technique, host factors, prosthesis design and type of bone cement [5]. This study has demonstrated that additives can have a significant effect on the mechanical and viscoelastic properties of PMMA cements. In particular, the static tests specified by the current international standard are not as sensitive to subtle changes in the composition of the material as creep.

The ultimate clinical performance of collarless tapered polished stem designs is dependent on the visco-elastic behaviour of the cement, therefore knowledge of the viscoelastic behaviour of individual cement formulations is necessary to aid the matching of optimal cement properties with a given stem design.

References: [[1] Lewis 1997 J Mat Res [2] ISO 5833:2002 [3] Lee 2002 J Mater Sci [4] Fowler 1988 Clin North Am [5] Malchau 1998 AAOS

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