A Comparison of the Setting, Exotherm and Antibacterial Properties of a Zinc based Glass Polyalkenoate Cement with a Commercial Bone Cement

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Introduction: Vertebral compression fractures are a considerable concern in orthopaedics today as they are costly to treat and result in significant pain and morbidity, particularly in osteoporotic patients. Treatment of these fractures can be achieved through the use of acrylic bone cements which are injected into the vertebrae in procedures such as Vertebroplasty and Kyphoplasty. The most frequently used bone cement is Simplex P which is an acrylic based cement with applications in both spinal and joint replacement surgery.

This work sees the formulation of a novel bone cement based on a traditionally dental material, glass polyalkenoate cements (GPCs). GPCs are prepared by the reaction of an ion-leachable glass with an aqueous solution of a polyalkenoic acid, typically polyacrylic acid (PAA)[1]. Conventional GPCs are based on calcium alumino-silicate glasses, however aluminium (Al) has been implicated in the pathogenesis of neurological disorders and decreased bone metabolism. This work replaces the Al content of the commercial GPCs with Zinc (Zn) in order to produce a bioactive bone cement based on GPC chemistry[1]. Strontium is also included in this cement to increases its bone forming abilities [2].

Materials & Methods: A glass composition was produced $0.48SiO_2$ - 0.36ZnO - 0.16CaO - 0.04SrO. Reagents were ball milled and fired in a platinum crucible (1480°C, 1Hr). The melt was quenched in water and the resulting frit was dried, ground and sieved (<45µm). GPCs were produced by mixing the glass in a 2:1.5 (powder: liquid) ratio, with 50wt% E9 PAA. Trisodium citrate (TSC) was added to improve the handling properties of the cement at concentrations of 10wt%. The commercial material used was Simplex P (Stryker Howmedica, Limerick, Ireland). Setting times were determined according to ISO9917[3]. Cement exotherm was determined by filling plastic moulds (12.6 mm height, 12.5 mm Ø) with cements ($n = 3$). A thermocouple attached to an Accumet portable AP6 multimeter (Reagecon, Shannon, Ireland) was placed into the cement 30 s after mixing and the peak exotherm was recorded. Antibacterial testing was performed on BT 101 and Simplex P ($n=3$) using the agar diffusion test with *E. coli*.

Results & Discussion: From figure 1a it can be seen that it took far longer for Simplex P (378±2.9s) to set as compared to BT 101 (180±3.2s). Figure 1b shows the exotherm results where Simplex P reached a peak temperature of 60±4.4°C during setting where BT 101 reached a peak temperature of 34±1.3°C. The setting time and the temperature reached during the setting reaction of a bone cement can affect the properties and success of the implanted material.

Antibacterial testing (figure 2) in *E. coli* revealed that BT 101 exhibited inhibition zones of 10mm while Simplex P did not exhibit any antibacterial properties. The antibacterial properties of the Zn-GPC is attributed to Zn ion release.

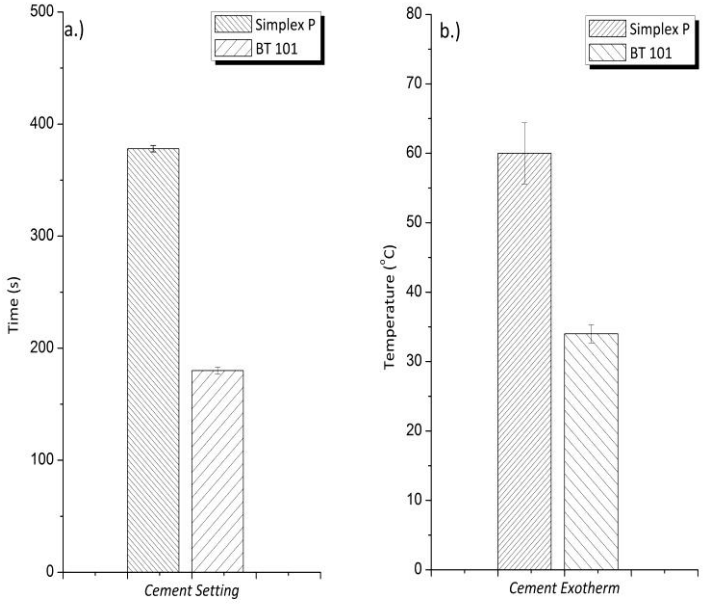

Figure 1. Results of cement a.) Setting and b.) Exotherm, considering Simplex P and BT 101.

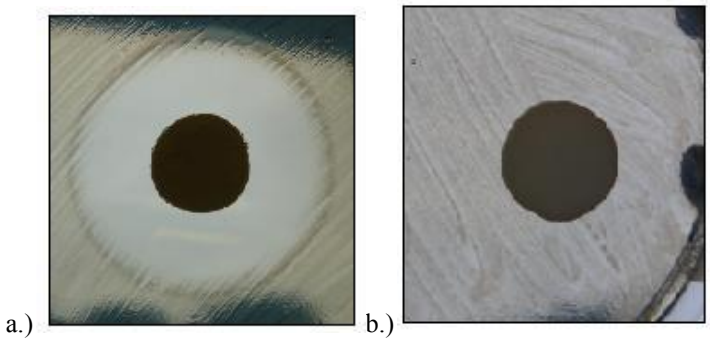

Figure 2. Inhibition zones of a.) BT 101 and b.) Simplex P in *E. coli*.

Conclusion: The setting time and exotherm were determined for BT 101 and Simplex P and it was found that BT 101 had a shorter setting time while also having a significantly lower setting temperature, an exotherm close to that of body temperature. It was also found that BT 101hibited antibacterial properties when tested in *E.coli*. However, Simplex P did not exhibit any antibacterial effects.

References:

1. Boyd, D., and Towler, M.R. Journal of Material Science: Materials in Medicine, 16, 843, 2005.
2. Marie, P.J. Osteoporosis International, 16, S7, 2005.
3. ISO9917, Specification for dental water-based cements. 1991.