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A. Coughlan

S. M. Breed

C. Ashraf

J. A. Cardinale

et. al. For a complete list of authors, see https://scholarsmine.mst.edu/che_bioeng_facwork/1159

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Increasing the Quantity of Silver in Zinc-Based Glass Polyalkenoate Cement: Is there an Improvement in Antibacterial Efficacy?

A. Coughlan, S.M. Breed, C. Ashraf, J.A. Cardinale, M.M. Hall and M.R. Towler
Alfred University
1 Saxon Drive
Alfred, NY 14802

I. INTRODUCTION

Bone cements should have the ability to chemically bond to both bone and surgical metals, exhibit no chemical or thermal necrosis, and have no significant shrinkage or exotherm upon setting. Taking these properties into consideration, glass polyalkenoate cements (GPCs) have potential as bone cements. GPCs are formed by the reaction between an ion-leachable glass and an aqueous solution of polyacrylic acid (PAA) [1] and have proven antibacterial and cariostatic properties [2], which are related to their ability to release beneficial amounts of ions over time [3, 4]. The GPCs can be formulated to release ions that can have a therapeutic benefit in a chosen application such as fluoride release in dental applications [5], which assists in the prevention of secondary caries [6]. Recently, GPCs have been formulated with zinc (Zn) replacing Al; a more biologically acceptable ion [7]. The authors have previously shown that GPCs based on a glass phase containing both Zn and silver (Ag) have the ability to release ions which are antibacterial against both Staphylococcus aureus (Oxford strain) [8] and Pseudomonas aeruginosa (a clinical isolate) [9, 10] in vitro and methicillin-resistant S. aureus (MRSA) both in vitro and in vivo [11]. The authors have also shown that their cements have the ability to inhibit proliferation of a biofilm of P. aeruginosa (PA01) [9]. The objective of the study reported herein is to build on the authors previous publications in order to determine if increases in Ag content of the glass phase of these cements will result in a concomitant increase in antibacterial efficacy of the resultant Ag–Zn GPCs formulated from them.

II. EXPERIMENTAL METHODS

Four Glasses (0.5g) were synthesized (Table 1) to sub <90μm and mixed with 0.3g polyacrylic acid (PAA-Mw:81,800) and 0.4ml of deionized water to form GPC discs (8mmØ, 2mm th).

Table 1: Glass Composition (mol. Fraction)

Glass	SiO2	ZnO	Na2O	Ag2O
Control	56.04	33.09	10.87	0.00
A	56.04	32.79	10.87	0.33
B	56.04	32.43	10.87	0.66
C	56.04	32.10	10.87	0.99

The Ag release of the GPCs were measured at 1, 7 and 14 days using Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) using a Ag standard reference, and sample size, n=3. Ion release testing was conducted using deionized water. The surface area of each disc was calculated. The constructs were matured in analytical water; with up to 65mL of water immersing the samples. Two strains of bacteria; S. aureus (ATCC 12600) and P. aeruginosa (ATCC 10145) were tested. Plates were prepared using Brain Heart Infusion (BHI) agar with the bacteria swabbed on top. Three discs were placed on each with three plates were produced for each glass. Zone of inhibitions were measure at 1, 7 and 14 days.

III. RESULTS

This antibacterial efficacy is independent of pH, given that a pH of 7 was recorded for all solutions at all time frames, inferring that the metal ion release, and not H^+ release from the polyacrylic acid, is responsible for the coatings' antibacterial efficacy. The ion release profiles of Ag can be observed in Figure 1, where the dotted lines indicate the Ag concentrations in the three cements (excluding the control).

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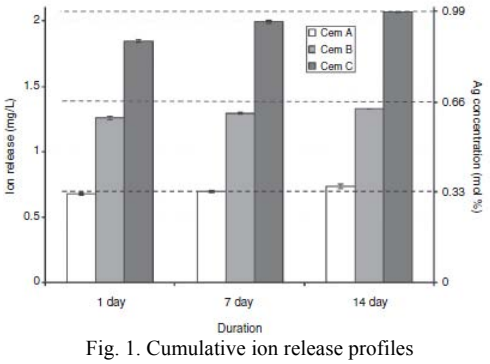

Fig. 1. Cumulative ion release profiles

The antibacterial efficacy of each GPC was evaluated. The Ag-containing GPCs did not show notably increased inhibition of growth of S. aureus compared to the control cement (Figure 2), while there appeared to be a dose dependent inhibition of growth of P. aeruginosa (Figures 3).

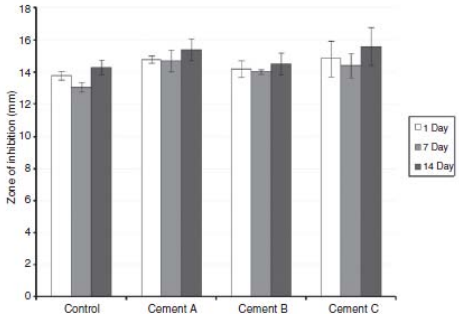

Fig. 2. Antibacterial profiles against S. aureus

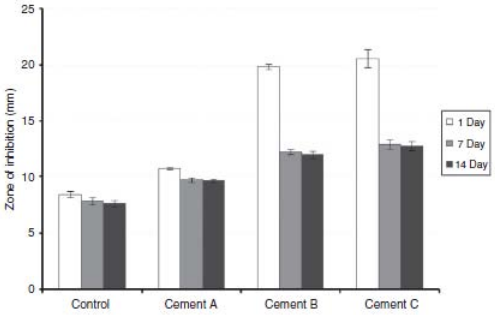

Fig. 3. Antibacterial profiles against P. aeruginosa

IV. CONCLUSION

GPCs can be formulated to release antibacterial ions. The objective of this work was to determine the feasibility of adding increasing amounts of Ag into a series of novel GPCs and testing the resultant antibacterial efficacy using an accepted in vitro methodology for the potential of developing an Ag–GPC bone cement. This research has shown that adding more Ag to the glass phase of a GPC allows more Ag^{+} to be released. However, increasing the Ag content in the GPCs does not automatically increase antibacterial efficacy. This indicates the possibility of a MIC. Further research is required to identify the exact MIC of Ag in a GPC.

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