Comparison of the Physical Properties of an Innovative Glass Polyalkenoate Cement to Commercial Dental Materials

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Introduction: Conventional glass polyalkenoate cements (GPCs) were introduced by Wilson and Kent (1972) with applications for dental restoratives. GPCs consist of a polyalkenoic acid and a fluoro-alumino-silicate based glass. Upon mixing with water, an acid-base reaction occurs resulting in metal ions from the glass forming a polyacid salt with carboxylate groups resulting in a hard set material. The glass particulate surface subsequently forms a silica hydrogel and any unreacted cores of the glass particles remain in the cements as inorganic fillers[1]. Recently, GPCs have been employed for use in orthopedics including applications in ear, nose and throat surgery. GPCs have also been employed in orthopedics to reinforce osteoporotic femoral heads to improve the stability of hip screws but complications related to aluminum (Al^{3+}) exposure were problematic as Al^{3+} alters the mineralization of skeletal tissue. This study sees the development of an aluminum free GPC designed for orthopedic spinal applications, where this material would be in close contact with mineralized trabecular bone and soft tissues. For this work Zn^{2+} is substituted for Al^{3+} in the glass phase as they both act as network intermediates; however Zn^{2+} is regarded as a more biologically acceptable ion. This study looks at developing a Zn-GPC with physical properties more comparable for use in spinal surgery by altering the starting glass composition[2].

Methods: A glass 0.12Ca-0.04Sr-0.36Zn-0.48Si (BT101) was fired (1500°C, 1h) in a platinum crucible and shock quenched in water. The resulting frit was dried, ground and sieved to <45µm particle size. Cements were formulated using the powder: liquid (P:L) ratio of 2:1.5 with 50wt% additions of PAA where 1g of glass powder was mixed with 0.37g E9 PAA and 0.37ml water. Fuji IX and Ketac Molar were made in accordance with the manufactures instructions. Working times (T_w) setting times (T_s) and setting exotherm determination were undertaken in accordance to the appropriate standards. The mechanical properties of these cements were obtained included compressive strength, biaxial flexural strength, biaxial flexural modulus and hardness over 4 different time points.

Results: T_w and T_s and setting exotherm are presented in figure 1. BT101 has a much shorter Tw than the commercial cements which may be attributed to an accelerated acid base setting reaction. The T_s results were comparable. The maximum strengths for BT101, Fuji Ix and Ketac Molar were 75, 238 and 2116 MPa (compressive strength, figure 2a) and 34,54 and 62MPa (biaxial flexural strength, figure 2b).There was no significant difference in biaxial flexural modulus with respect to maturation (Figure 3a). Hardness values (Figure 3b) for Fuji IX and Ketac Molar showed little deviation, BT101 showed significant decrease over 1-90 days. This may be related to the greater particle size of BT101.

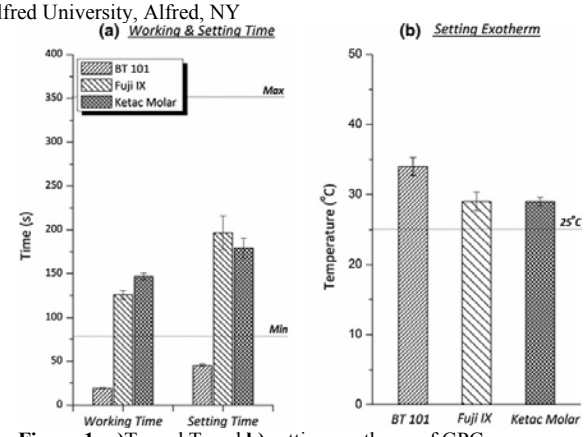

Figure 1: a) T_w and T_s and **b)** setting exotherm of GPCs

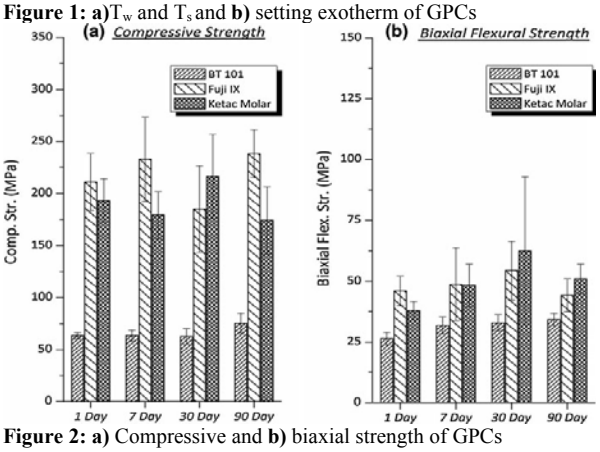

Figure 2: a) Compressive and **b)** biaxial strength of GPCs

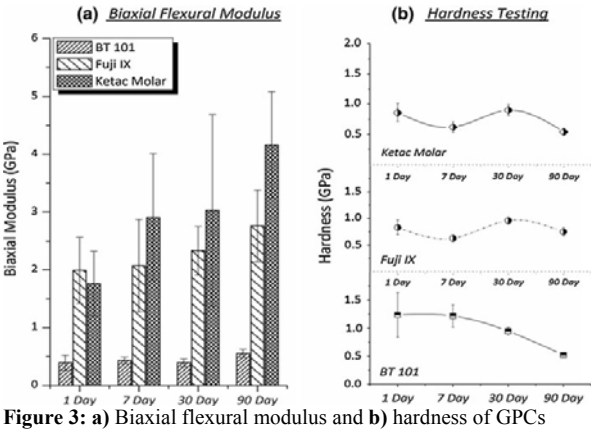

Figure 3: a) Biaxial flexural modulus and **b)** hardness of GPCs

Conclusions: The mechanical properties of BT101 are more closely suited to the surrounding tissue if used in spinal application; further studies will be required to evaluate the bioactivity of this experimental GPC against Fuji IX and Ketac Molar in relation to ion release, antibacterial properties and cytocompatability as a function of time.

References:

[1]Tyas MJ, Burrow MF. Aust Dent J. 2004;49:112-121
[2]Wren AW et al. J Mater Sci: Mater Med, 2013;24:271-280