Povidone-Iodine Does not Affect the Polymerization of PMMA Under Clinical Conditions

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Statement of Purpose: Total joint arthroplasty is a common orthopaedic procedure prone to infections[1]. In an attempt to reduce the risk of surgical site infection dilute Povidone-iodine(PVP-1) solution has been used to lavage the surgical site after implantation of orthopaedic prosthetics[2,3]. PVP-1 also known as betadine, is a stable iodophor chemical complex. The active agent, triiodide, is an oxidizing agent that acts as a bactericidal agent through iodination of lipids and oxidation of cytoplasmic and phospholipids membranes. Poly(methylmethacrylate) (PMMA) known commonly as bone cement is used in many total joint arthroplasty procedures to fix the prosthetic bone interface. Commercially available bone cement consists of preformed PMMA microspheres and methacrylate monomer, which undergoes free radical polymerization[1]. Oxidizing agents are known to inhibit free radical polymerization. PVP-1 is a strong oxidizing agent. This study was conducted to investigate whether the presence of a powerful oxidizing agent such as PVP-1 during polymerization can affect the resulting compressive strength of bone cement.

METHODS: Four groups with one batch each totaling 200 test cylinders of PMMA were hand mixed in a standard fashion according to ASTM F451-08 standard[4]. Each group was made from 40g powder and 20mL monomer plus 4 mL of one of the following: no additive, 10% PVP-1, De-ionized H20 (DI), or 4% chlorhexidine. Each batch was hand mixed without vacuum, and once in dough phase, loaded into a Teflon mold forming 12x6mm cylinders[4]. In an attempt to more closely replicate the clinical environment, two subsequent groups of bone cement similar to the control group were hand mixed (40g powder and 20ml monomer) and then submerged in either 10% or 0.35% PVP-1 for five minutes before being irrigated with saline and placed in the Teflon molds. Set times were determined by probing and measured for each group. After allowing the PMMA to set for 48 hours, the cylinders were machined flat for mechanical testing. All cylinders were transilluminated under 5x magnification, and cylinders with visible defects (surface irregularities, voids >0.5mm) were excluded from testing. Ten cylinders (n=10) from each group were then randomly chosen. A Test Resources AT830 axial torsion machine was used for axial load compression testing. Load rate was set at 24.0mm per minute in accordance with ASTM F451-08[5]. The load displacement data was exported to excel and converted to stress/strain. The yield point was identified in accordance with F451-08. An analysis of variance (ANOVA) statistical model was used to analyze the difference between the four groups.

RESULTS: The set times for the control, DI, chlorhexidine, 10% PVP-1 submersion, and 0.35% submersion group were 13.75, 8.75, 10.25, 14.75, and 13.5 minutes. The PVP-1 group did not set. The average compressive strength for the control, PVP-1, DI, chlorhexidine, 10% PVP-1 submersion, and 0.35% PVP-1 submersion group was 114.4 MPa, 24.1 MPa, 90.9 MPa, 89.9 MPa, 107.6 MPa, and 110.8 MPa respectively. The average failure of the PVP-1 group was significantly less ($P<0.001$, t-test) than the other five groups. The DI and chlorhexidine groups were also significantly less than the control group, but not significantly different from each other. The PVP-1 submersion groups were not statistically different from the control group.

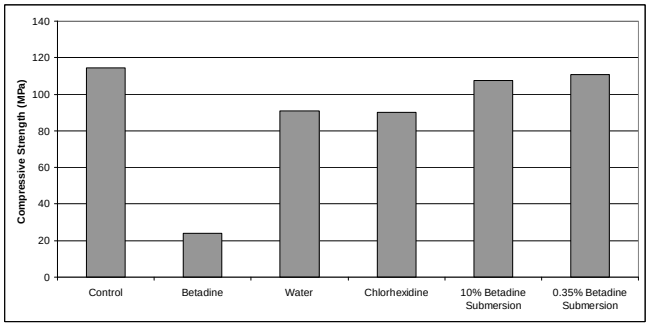

Table 1: Average Compressive Strength. Strength is reported in MPa. There is a significant decrease in compressive strength in the PVP-1 group compared to the other five groups.

Conclusion: Normal cement becomes exothermic during polymerization and sets in roughly 12 to 18 minutes depending on conditions. The PVP-1 group never became exothermic, and did not set. In fact it did not become hard enough to machine and test until 48 hours after mixing. The DI and chlorhexidine groups did fail at a lower compression force than did the control group, but some decreased structural integrity was expected due to the addition of water and chlorhexidine to the monomer. We would have expected to see a similar decrease in compressive strength at yield point in the PVP-1 group if the PVP-1 did not affect free radical polymerization. The PVP-1 average failure was at 24 MPa, which was significantly less ($p<0.001$, t-test) than the other five groups, and significantly below the accepted minimum standard for PMMA in total arthroplasty (70 MPa, ISO 5833). These observations suggested that PVP-1 acts as a free radical scavenger, significantly inhibiting free radical polymerization of methacrylate monomer if exposed during mixing. However the PVP-1 submersion groups were not statistically different than the control group. This suggests that while PVP-1 can inhibit free radical polymerization of PMMA, under clinical conditions it does not have a significant affect on the final compressive strength. In conclusion PVP-1 can adversely affect the setting of acrylic bone cement under optimal conditions, but, under clinical conditions it does not have a significant affect. To minimize this potential affect of PVP-1 on PMMA polymerization, PMMA should not be exposed to PVP-1 until after mixing.

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