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LETTER

Influence of two changes in the composition of an acrylic bone cement on some of its properties: the case of Surgical Simplex® P

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Self-curing acrylic bone cements are widely used in orthopaedic surgery for the fixation of joint prostheses [1] and in vertebroplasty and kyphoplasty [2] for the stabilisation and/or augmentation of fractured vertebrae. The cement's curing process is the result of a free-radical polymerisation of a mixture of poly (methy1 methacrylate) [PMMA]-containing powder and a liquid monomer that has methyl methacrylate (MMA) in it, that is initiated by the decomposition of benzoyl peroxide (BPO) in the powder, activated/co-initiated by a tertiary amine (usually, N,N-dimethyl-4-toluidine [DMPT)]) in the monomer, and stabilised by, usually, hydroquinone in the monomer. There are three very important aspects of this polymerisation process. First, only a small amount (typically, 0.1%) of the DMPT is consumed during the polymerisation process, the balance remaining in the cement [3]. Thus, for example, in a cemented arthroplasty, there is the potential that, over the in situ life of the implant, some or all of the residual DMPT may leach out of the cured cement mantle into the peri-prosthetic tissue [4], leading to general systemic effects (such as toxicity of the cardiopulmonary system [5], carcinogenicity [6], damage of chromosomes [7], inhibition of protein synthesis [8], and methemoglobinemia [9]) and/or local effects (specifically, chemical necrosis of the tissue [1]). Second, the process is highly exothermic, with a peak temperature (T_p) as high as 124 °C having been reported in one case [10] (T_p depends on a number of variables, notably the relative amounts of the various constituents in the cement [11].) This high exotherm has been implicated in the thermal necrosis of the peri-prosthetic tissue [1]. Third, although it is believed that the pre-polymerised PMMA beads in the cement powder act as polymerisation sites and influence the rate of the polymerisation process [12], unpublished clinical data (Stryker Howmedica Osteonics, Limerick, Ireland. Personal communication, 2004) indicate that chemical and thermal necroses seen in peri-prosthetic tissues are not influenced by these beads.

These aforementioned points should be borne in mind when formulating an acrylic bone cement; for example, if DMPT is used, its content should be as low as possible (without jeopardising the polymerisation process), an alternative activator agent (that, for example, is nontoxic or less toxic than DMPT) should be considered, and the presence or absence of pre-polymerised PMMA beads should also be considered. The objective of the present work was to determine the extent to which modifying the composition of an acrylic bone cement, using the ideas outlined above, influences the values of the properties of the curing and cured cement. For this purpose, we used a commercially-available acrylic bone cement that is widely used in cemented arthroplasties [Surgical Simplex®P; Stryker Howmedica Osteonics, Limerick, Ireland]; the compositional modifications were reduction of the content of DMPT and elimination of pre-polymerised PMMA beads; and the cement properties determined were peak exotherm temperature (T_{max}), setting time (t_{set}), and ultimate compressive strength (UCS).

The compositions of the cement formulations used are given in Table 1. For each composition, the powder and liquid monomer were hand mixed in a polymer bowl that

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Table 1 Compositions of the cement formulations[a] and values of the properties of the cement determined

Composition of powder (in g)				Composition of liquid monomer (in mL)			Properties		
Co-polymer[b]	PMMA[c]	$BaSO_4$	BPO	MMA	DMPT	HQ	T_{max} (oC)	t_{set} (min)	UCS (MPa)
29.4	6.0	4.0	0.6	19.50	0.50	80[d]	71	11.2	88 ± 2
29.4	6.0	4.0	0.6	19.84	0.16	80[d]	66	17.2	85 ± 3
35.4	0.0	4.0	0.6	19.50	0.50	80[d]	76	9.3	100 ± 8
35.4	0.0	4.0	0.6	19.84	0.16	80[d]	59	12.0	96 ± 2

[a]The first-mentioned formulation is that of the commercially-available cement

[b]PMMA-styrene

[c]Pre-polymerised beads

[d]In ppm

was open to the ambient laboratory atmosphere. T_{max}, t_{set}, and UCS were all determined in accordance with the specifications detailed in ISO 5833 [13].

The results (Table 1) show that (a) with one exception, the values of T_{max}, t_{set}, and UCS for each of the cements are within the limits stipulated in ISO 5833 (that is, $T_{max} < 90$ °C, $t_{set} < 15$ min and UCS > 70 MPa); (b) with a decrease in the DMPT content of a formulation (the amounts of all other constituents remaining the same), there is a moderate reduction in T_{max} (by between 7 and 22%), a significant increase in t_{set} (by between 29 and 54%), but UCS is, essentially, unaffected; (c) with the elimination of pre-polymerised PMMA beads in the powder (but with the amount of DMPT unchanged), there is a significant decrease in t_{set} (by between 17 and 30%) and moderate changes in both T_{max}, and UCS (by between 7 and 14%); and (d) reducing the DMPT content by 68% (relative to that in the commercially-available formulation) and eliminating the pre-polymerised PMMA beads from the powder leads to a cement whose T_{max}, t_{set}, and UCS are 17% lower, 7% higher, and 9% higher, respectively, than the corresponding values for the commercially-available cement.

The main conclusion of this work is that the cement prepared using the formulation that has the combination of 0.8% vol./vol. DMPT content in the liquid monomer and no pre-polymerised PMMA beads in the powder has the optimal mix of the values of the three properties determined; specifically, lowest T_{max}, t_{set} that is neither too low nor too high, and high UCS. Future work will be focused on determining the influence of the compositional changes investigated in the present study on other cement properties, such as curing kinetics, fatigue life, and creep.

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