Addition of Antibiotic Increases Fracture Toughness of PMMA Bone Cement

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Introduction: Additives to polymethylmethacrylate bone cement have been shown to cause crack propagation in the interbead matrix resulting in increased fracture toughness [1-3]. Antibiotics added to bone cement are incorporated into the interbead matrix. The purpose of this study was to determine if addition of antibiotic, at the time of surgery or at manufacture, results in a similar toughening phenomenon for bone cement.

Methods: Three variations of Simplex® P Bone Cement (Stryker Orthopedics, Inc., Mahwah, NJ) were tested: plain Simplex® P ("PLAIN"); plain Simplex P with 1.2 gm equivalent tobramycin (Pharma-Tek, Inc., Huntington, NY) added at the time of cement mixing ("PLAIN-ANTIBIOTIC"); and Simplex® P With Tobramycin ("ANTIBIOTIC") with the antibiotic added at manufacture. The cements were mixed under vacuum (500 mm Hg) for 180 seconds and then poured into closed-coffin moulds to create rectangular compact tensile (RCT) specimens. After 1 hr in the moulds, the specimens were placed in distilled water at 37°C for 48 hours before testing.

Fracture toughness testing was conducted according to ASTM Standard D5045. The specimens were cyclically loaded at 10 Hz to create a fatigue crack and then were ramp loaded to failure at 100 N/s while load and crack opening displacement data were obtained. The specimen geometry, the fatigue crack length, and scanning electron microscopy (SEM) images of the fracture surfaces were obtained after each specimen fracture.

Results:

Table 1: **Fracture Toughness (MPa $m^{1/2}$)**

PLAIN	1.22 ± 0.22 (n=9)
PLAIN-ANTIBIOTIC	1.45 ± 0.08* (n=9)
ANTIBIOTIC	1.27 ± 0.12 (n=9)

* $p < 0.05$

Discussion: Tobramycin added at the time of cement mixing significantly increased the fracture toughness of the tested bone cement ($p<0.05$). This elevated fracture toughness was similar to that found previously, 1.41 ± 0.08 MPa $m^{1/2}$, when tobramycin in a different dosage and powder particle conformation (2.4 gm Nebcin®: Eli Lilly & Co, Indianapolis, IN) was added to this same bone cement [4]. Thus, the toughening effect appeared to depend on the presence of the antibiotic and not on the tested dosage levels or antibiotic powder particle size. When the antibiotic had been added at manufacture, the fracture toughness did not statistically differ from that of the plain bone cement.

The crack propagation pathway, as seen on SEM, was changed by the addition of the antibiotic. The fracture surface of the plain bone cement specimens showed a smooth surface where the PMMA beads and the interbead matrix were easily discerned, Figure 1. The surface was more complex for the specimens in which the antibiotic had been added at manufacture, but the beads and the interbead matrix could still be readily seen. Addition of the antibiotic at cement mixing resulted in a complex fracture surface that passed almost entirely through the interbead matrix, Figure 2. These SEM observations qualitatively support the fracture toughness results. Further research is needed to understand this toughening phenomenon and its possible occurrence with other bone cements and antibiotics, and to assess its clinical significance in combination with other mechanical properties of antibiotic impregnated bone cement.

Figure 1: PLAIN (200x)

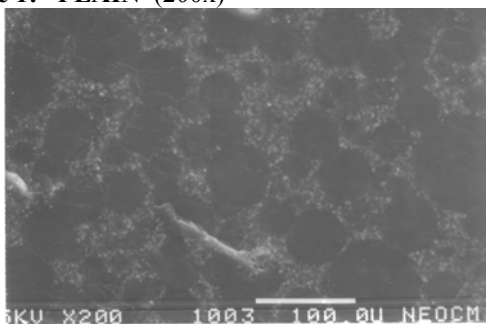
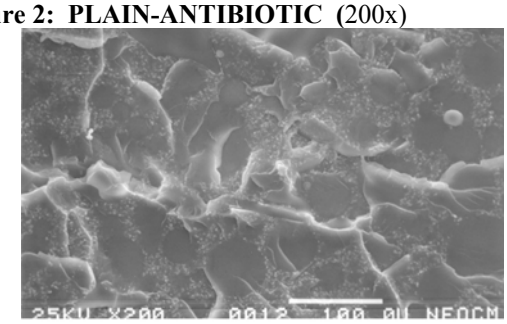


Figure 2: PLAIN-ANTIBIOTIC (200x)



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