THE EFFECT OF LONG TERM SALINE AGING ON THE FATIGUE PROPERTIES OF CEMENT-IMPLANT INTERFACES

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INTRODUCTION:

Since the introduction of cemented arthroplasty there have been many attempts to improve the bond between the cement mantle and the prosthesis through changes in surface preparation, surface precoating with PMMA, and the cement viscosity during interface formation. A recent development has been to apply PMMA to selected areas of the surface of the prosthesis by injection molding during manufacture of the implant. Although this may produce interfaces of adequate initial fracture resistance, previous studies have suggested that the strength of the cement/metal interface is reduced by up to 80% during saline exposure. This study was conducted to establish the long-term fatigue behavior of injection molded cement-implant interfaces under physiologic conditions.

MATERIALS AND METHODS:

A total of 33 torsion test specimens were machined from forged CoCr rod stock. The specimen test surface (the area where the cement was to be applied) was exposed to a 10 grit blast, then a low pressure bead blast, and finally passivated. The specimens consisted of a 3 mm cement mantle fabricated by injection molding at 250°C under 1500 psi. Each molded specimen was then machined to form a 0.375" gauge section (Figure 1).

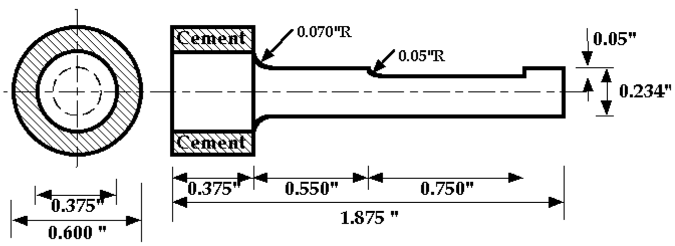

Figure 1. Test Specimen.

Three groups of specimens were tested: i) Injection Molded (Unaged, n=14), ii) Injection Molded (Saline aging: 2 months, n=10), and (iii) Injection Molded (saline aging: 15 months, n=9). All specimens were potted in custom fixtures and loaded in fully reversed torsion (5 Hz) under a constant axial load of 5-lb (compression) in a 37°C continuously circulated saline bath. The amplitude of the applied torque was varied to generate nominal shear stress levels of 4, 6, 8, 10, or 12 MPa at the cement/metal interface. All fatigue data were normalized to 6 MPa using linear regressions obtained from the S-N curves. The normalized data were subjected to further analysis using a two-parameter Weibull regression. The Weibull parameters were used to compute the mean endurance of each group. The tenth percentile of the fatigue life distribution was also calculated as a mathematical estimate of the endurance of the weakest specimens.

RESULTS:

The average fatigue life of the unaged control group was 738,683 ± 311,486 cycles. After two months of 37°C saline aging, the fatigue endurance of the interface dropped by 87% to 102,920 ± 56,018 cycles (p = 0.037). Aging for 15 months reduced the fatigue endurance by 63% compared to Unaged specimens (278,908 ± 212,054). However, the durability of the saline-aged specimens after 15 months of saline aging was approximately two times (170%) the durability of specimens aged for only 2 months (p=0.09).

A similar trend was observed in the endurance of the weakest specimens in each group (10% probability of failure). Following 2 months of saline aging, the fatigue life of these specimens was 20,685 cycles, 87% of the initial control values (162,323 cycles) (2 months) Following 15 months of aging, the fatigue endurance of the weakest specimens was 41,940 cycles, 2 times (202%) greater than the 2 month-aged specimens.

The reliability and data scatter of each specimen type was determined by the magnitude of the Weibull parameter beta (higher beta = less scatter, more predictable behavior). The data indicate that all three groups of specimens performed with similar predictability (14.53 to 10.66) (Figure 2); however, the variability of fatigue resistance increased with prolonged saline aging.

	Weibull Parameters			Fatigue Life (cycles)	
Specimen Type	n	alpha	beta	Mean (p=0.50) ± StdErr	Weakest (p=0.10)
Molded Unaged	14	4.1E-12	14.53	738,683 ± 311,486	162,323
Molded 2 Mo.	10	4.3E-09	11.63	102,920 ± 56,018	20,685
Molded 15 Mo.	9	8.6E-09	10.66	278,908 ± 212,054	41,940

Table 1. Weibull Fatigue Data.

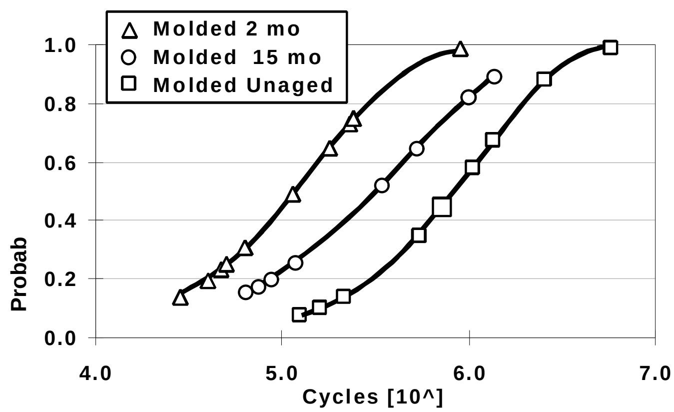

Figure 2. Weibull Fatigue Data.

DISCUSSION:

Our data show that exposure to saline reduced the fatigue life of cement implant interfaces by 87%. However, following longer exposure, some of the initial loss of endurance was recovered, resulting in an overall decrease of 63%. The recovery of endurance at longer exposure times can be attributed to the relaxation of residual stresses generated during modeling. The difference in the rate at which the bond weakens with respect to the rate at which residual stresses are dissipated explains the initial weakening followed by recovery of fatigue strength.

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