THE EFFECT OF CEMENT THICKNESS AND SURFACE ROUGHNESS ON THE STRENGTH OF THE METAL-CEMENT INTERFACE

INTRODUCTION

Hip arthroplasty using a metallic, stem-type femoral component with self-curing acrylic bone cement is one of the most successful surgical procedures worldwide. However, failures of the cemented stem sometimes occur and leads to symptomatic implant loosening and often requires another operation. Failure mechanisms have been attributed to early debonding at the metal-cement interface, suboptimal cementing technique, stem surface roughness or stem geometry. Even though the procedure has a highly predictable outcome, questions still persist concerning optimal cement technique as “the optimum cement-metal interface has yet to be identified” (1). Many previous studies have demonstrated effects on interface shear strength associated with surface roughness, type of metal, cement type, cement preparation, interface formation time, simulated operative contamination and fluid sorption. Recently, in a detailed long-term radiographic study of the cement mantle, it was concluded that the worst results were “those that filled half or less than half of the medullary canal”, i.e. a stem-cement fill ratio of 50% or less (2). All previous published metal-cement interface studies have involved rod specimens less than half of the simulated cement encasement, i.e. stem-cement ratio less than 50% (3). Moreover, the effect of cement thickness on the interface strength has apparently not been studied with experimental mechanical testing. The purpose of this study was to assess the effect of cement thickness, a surgeon-controlled variable, on the interface shear strength of a metal-cement interface, suboptimal cementing technique, stem surface roughness, and low interface shear strength as a function of cement thickness.

METHODS

Cylindrical rods were manufactured from Co-Cr-Mo alloy (ASTM F-799, ASTM F-86), all with 50.8 mm in length and a diameter of 7.95 mm or 15.8 mm. The metallic implants had either a mirror-polished surface (Ra=5.8) or a grit-blasted surface (Ra=210-298). Each implant was cleaned, passivated, packaged and gamma sterilized prior to testing. The cement (Palacos-R) was prepared by hand-mixing for two minutes and inserted into a cylindrical PVC mold (I.D.=20.6 mm, length=25.4 mm) followed by insertion of the metallic implant. The cement mantle thickness was taken as the maximum load recorded during the test. Applied interfacial shear strength (ISS) was calculated by dividing the measured loads by the nominal interface area. Parametric analysis of the relative mechanical performance of the metal-cement interface was measured with the push-out method using an MTS test machine operated in the displacement control mode (with a ramp function) at a displacement rate of 2 mm/min until failure. The load at failure was taken as the maximum load recorded during the test. A Student’s t-test with a significance level of 0.05 was performed to determine if any significant differences existed between the groups.

RESULTS

For all rough (grit-blasted) metallic specimens with either a thin or thick cement mantle, the ISS was significantly lower, by an order of magnitude, than for the rough specimens. Sorption was observed to deteriorate the ISS of the cemented polished specimens with the thick cement mantle with a statistically significant decrease noted between the 24-hr dry-tested specimens and the 3-month specimens immersed in 37°C water (Figure 1). For all rough (grit-blasted) metallic specimens with either a thin or thick cement mantle, the ISS was observed to be insensitive to cement mantle thickness as well as sorption. For the polished specimens with the thick cement mantle, the ISS was significantly lower, by an order of magnitude, than for the rough specimens. Sorption was observed to deteriorate the ISS of the cemented polished specimens with the thick cement mantle with a statistically significant decrease noted between the 24-hr dry-tested specimens and the 3-month specimens immersed in 37°C water (Figure 1).

DISCUSSION

The dilemma of the optimal cement-metal interface is exemplified by the dichotomy between those who believe that it is important to obtain a firm and lasting bond between the metallic stem and cement (4, 5) and others who have indicated that “there is no need to roughen the surface of the stem in the hope of enhancing a mechanical bond between the metal and the cement” (6, 7). Based on the results from these static tests it would appear that the ISS of the cemented grit-blasted surface with a thin or thick cement mantle would provide a sufficient bond, which is insensitive to cement mantle thickness or sorption. On the other hand, sorption following immersion easily reduced the low ISS of the cemented polished specimens rendering them with an easily “debonded” interface.

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REFERENCES