THE EFFECT OF SURFACE FINISH ON THE BEHAVIOR OF TAPERED CEMENTED TOTAL HIP STEMS

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INTRODUCTION
Aseptic loosening has been identified as a major threat to the long term success of cemented total hip stems (Schulte et al., 1993). Several studies have implicated debonding at the stem-cement interface as the cause of aseptic loosening (Harrigan et al., 1992; Jasty et al., 1991). Many prosthesis designs try to improve the strength of the stem-cement interface by using stems with a rough surface. Another approach is to incorporate stem-cement interface debonding into prosthesis design by using stems with a highly polished surface. The goal of this study is to compare the pull-out loads and axial displacements of stems that differ only in surface roughness to determine the effects of surface finish on total hip stem behavior.

PROCEDURES
Tapered, collarless total hip stems were inserted into nine embalmed cadaveric femora using Palacos R PMMA bone cement (Merck; Darmstadt, Germany). A plug inserted into the femoral canal prevented cement from encapsulating the distal 10 mm of the stem. Seven specimens had a polished surface finish ($R_s = 0.14 \mu m$) and two had a matte surface finish ($R_s = 3.3 \mu m$). After curing, the specimens were potted and mounted in a load frame on a servohydraulic testing machine. Each stem was subjected to a static load corresponding to single-legged stance (12° Adduction, 0° Flexion, Joint Load = 1400 N, Abductor Muscle Force = 880 N) for 24 hours. Axial displacement of the stems was measured using a miniature differential voltage displacement transducer. After loading, a tensile axial force was applied to the stems via a pull-out fixture (Hustosky et al., 1998).

RESULTS AND DISCUSSION
The mean pull-out load of the seven polished stems was 1238 N (±400 N). The polished stems were extracted from the cement mantle without damaging the cement, bone or fixture. The matte finish stems did not pull free of the cement; in both cases the femur fractured within the mounting fixture before the stem could be removed from the cement mantle. The mean failure load of these two specimens was 6743 (±654 N) (Figure 1). The mean distal displacement of the matte finish specimen after 24 hours was 0.04 mm (±0.014 mm) and the mean displacement of the polished finish stems after 24 hours was 0.33 mm (±0.064 mm).

![Figure 1: Mean failure loads of polished and matte finish stems.](image)

A finite element model of the implanted stem was generated (Saligrama et al., 1996). The model includes viscoelastic behavior of PMMA cement and load conditions identical to those applied in this study. The model also includes interface elements which are used to analyze three stem-cement interface conditions: perfect bond, debonded with a friction coefficient of 0.22 and completely debonded (friction coefficient = 0.0). The measured and calculated displacement data...
may include displacement due to elastic deformation, viscoelastic behavior of the cement and slip of the prosthesis within the cement mantle. Comparison of experimental displacement data to finite element results (Figure 2) suggest that the matte finish specimens achieved a well-bonded stem-cement interface while the polished specimens had debonded at the stem-cement interface with a friction coefficient less than 0.22.

**Figure 2:** Comparison of experimentally measured distal displacement of matte and polished surface stems to finite element model results.

Based on the comparison of stem displacements and the mode of stem pull-out, one can deduce that the pull-out load of the polished stems is a measure of the taper-lock effect brought about by creep induced subsidence of the tapered stem within the cement mantle. Theoretically, the pull-out load of matte finish stems measures the static shear strength of the stem-cement or cement-bone interfaces. In this study, failure of the bone occurred before failure of the interfaces. Therefore, a direct comparison of pull-out strengths, while useful for investigating mechanical behavior of total hip stems, should not be the sole means of evaluating total hip stems with different surface finishes. The relatively low pull-out loads of the polished stems do not necessarily indicate poor fixation. The high radial compressive loads generated by the taper-lock effect of the stem within the cement mantle are considered beneficial to maintaining interface integrity (Miles, 1990) and act to provide implant stability (Hustosky et al., 1998; Lee, 1990). On the other hand, the high failure loads of the matte finish stems mean that the stem-cement and bone-cement interfaces are subjected to high shear loads. Ling (1992) identified this as destructive loading and clinical evidence (Gardiner and Hozack, 1994) has suggested that this may put the implant at risk for early clinical failure. The cyclic nature of in vivo loading would most likely be more detrimental to the interfaces of the matte surface stem and may cause more subsequent debris generation compared to the polished stem.

**SUMMARY**

Results of this study illustrate the relationship between surface finish and interface strength using polished and matte finish stems. The polished stems debonded at the stem-cement interface and achieved fixation through a mechanical taper-lock of the stem within the cement mantle. The matte surfaced stems achieved fixation through a mechanical interlock between the stem and cement mantle. While both surface finishes seem to allow for a means of stable fixation, the long term effects of the high shear loads at the stem-cement and cement-bone interfaces of the matte surface specimens may prove detrimental to the long term success of THA.

**REFERENCES**


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