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Title: **A Biomechanical Assessment of Pullout Forces for Three Cemented Femoral Stems**

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Background: A total hip arthroplasty (THA) is often used to treat end-stage osteoarthritis of the hip, or displaced intracapsular fractures. Taper-slip, cemented femoral stems are collarless, have a highly polished surface finish, and are designed with either a double or triple taper. This stem design benefits from micromotion at the prosthesis-cement interface, achieving stability through subsidence of the stem within a cement mantle. Radial forces allow for compression of the implant at both the prosthesis-cement and cement-bone interfaces. There are some caveats to using bone cement, such as the risk of aseptic loosening. Under normal circumstances the hip stem experiences a compressive load, but tensile forces can disrupt the cement-prosthesis interface causing it to dislodge.

Objective: This study sought to determine which common, cemented taper-slip prostheses (C-Stem® [DePuy Synthes], CPT® [Zimmer Biomet], and Exeter® [Stryker]) could be removed with a moderate amount of force to facilitate reoperation in cases of revision, without compromising the prosthesis-cement interface. Pullout forces were biomechanically assessed and compared following weight-loading.

Methods: Three femoral prostheses were obtained from each company. Standard surgical guidelines were followed for femoral canal broaching, preparation, and implantation. Surgical Simplex® P bone cement (Stryker) was used for all samples. The femoral stems were implanted into nine synthetic femur surrogates (Sawbones, USA), allowed to set, and were then placed under a continuous 330 N load for 7 days to encourage stem subsidence. Loading occurred in an incubator at 37°C with 100% humidity to simulate a physiological environment. The samples were removed individually at the end of the loading phase and pullout forces were assessed with a materials testing system according to a previously developed protocol. The pullout was displacement-controlled; axial force and time were recorded. Testing order was randomized.

Results: Maximum pullout forces immediately prior to failure varied for each stem-type. C-Stem samples required the highest force to displace from the cement mantle, while CPT required the least amount of force. The mean maximum pullout forces for C-Stem, Exeter, and CPT were 8381 N (SD ±268.9), 5417 N (SD ±958.6), and 1738 N (SD ±551.2), respectively. Differences between groups were analyzed using a one-way analysis of variance (ANOVA) and a Tukey honestly significant difference (HSD) post hoc test; Alpha values of $P<0.05$ were considered statistically significant. The analysis confirmed that the difference between groups was statistically significant ($P=0.0001$) and the Tukey post hoc test revealed a significant difference between all comparisons ($P<0.004$).

Conclusions: The triple-tapered stem under investigation (C-Stem) had a significantly higher pullout force compared to the double-tapered stems (CPT and Exeter). Future pullout studies would benefit from using higher compression loads that are closer to that experienced by the hip during dynamic motion. This study concluded that Exeter offers a medium pullout force that maintains secure fixation to the cement mantle, yet may allow for a relatively uncomplicated revision that improves both functional outcomes and patient quality of life. It is reasonable to infer that the C-Stem may be accompanied by a more arduous revision compared to both CPT and Exeter.

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