A Comparison of the Pullout Forces of Short and Standard-Length Exeter® Hip Stems Using a Simulated Subsidence Protocol

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INTRODUCTION: Total hip arthroplasty (THA) is often used to treat end-stage osteoarthritis of the hip, or displaced intracapsular hip fractures. Cemented femoral implants are fixed within the femur by means of poly(methyl methacrylate) (PMMA) cement in order to offset instability due to osteopenia or osteoporosis. Taper-slip stems, which are the focus of the present work, are collarless with a highly polished surface finish. Such designs achieve augmented stability via subsidence of the stem within the cement mantle due to the radial forces that are generated, which compress the implant at both the prosthesis-cement and cement-bone interfaces. Aseptic loosening is a common complication associated with cemented THA. The cemented hip stem typically experiences a proximal compression load as a function of the patient's body weight; however, tensile forces could potentially disrupt the cement-prosthesis interface causing the implant to dislodge from the cement. The use of short femoral stems has increased in popularity. They are designed to achieve a more optimal load transfer to the proximal femur, to reduce the rate of periprosthetic fractures, to preserve proximal femoral medullary bone, and to ease stem removal in revision procedures, thus reducing the invasiveness of THA procedures. The literature regarding the biomechanical behaviour of short versus standard hip stems is relatively limited. Therefore, the objective of this study was to compare the pullout forces of two given lengths of a single hip stem design (125mm vs. 150mm; Exeter® V40, Stryker) to assess whether the theoretical advantages of short stems can be observed in primary THA procedures. Pullout forces were biomechanically assessed and compared following simulated, physiological compression loading.

METHODS: Six Exeter® V40 femoral stems were tested in either 125 mm lengths (short) or 150 mm lengths (standard) for a total sample size of 12 (N=12). Each stem was machined to create a flat plane at the proximal end, perpendicular with the femoral axis, with pre-tapped M6 holes in-line with the femoral axis, for the samples to comply with a custom pullout apparatus. Standard surgical guidelines for each implant were followed for femoral canal broaching, preparation, and implantation. Surgical Simplex® P bone cement (Stryker) was used for each sample. Each stem was implanted into its own synthetic femur surrogate (Sawbones, USA), allowed to set, and was then placed under a continuous 1335 N compressive, axial load for 14 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 (Bionix Servohydraulic Test System; MTS Systems Corporation, Eden Prairie, MN, USA) according to a previously developed protocol. The pullout was displacement-controlled; axial force and time were recorded. Testing order was randomized.

RESULTS: The mean maximum pullout forces for the short (125 mm) and standard (150 mm) stems were 3940 ± 1178 N and 4910 ± 1309 N, respectively. Differences between groups and between conditions were analyzed using a one-way analysis of variance (ANOVA); Alpha values of 0.05 ($p<0.05$) were considered statistically significant. The analysis revealed that there was no significant difference between the two groups ($P = 0.21$).

DISCUSSION: As shown in Figure 1, the pullout force did not significantly differ between the short and standard Exeter® stems. Therefore, it may be reasonable to infer that the clinical use of a short stem may provide adequate fixation, while maintaining the expected benefits of the short stem design. Specifically, short stems are meant to achieve a more proximal load transfer, have lower rates of periprosthetic fractures, preserve proximal femoral medullary bone, and ease stem removal during revision surgery [1]. The average pullout force of the standard Exeter® stem (4910 ± 1309 N) closely resembled the results of a pilot study that reported an average force of 5417 ± 959 N for three, standard-length Exeter® stems [2]. Additional study in a clinical population is required to validate these findings.

CLINICAL RELEVANCE: This study validated the effect of stem subsidence due to load on pullout forces for short and standard-length Exeter hip stems. It was concluded that following loading, both stem lengths provided adequate and similar levels of fixation. Short, cemented hip stems may provide a less invasive option for patients undergoing THA while providing fixation that is sufficient to resist aseptic loosening.

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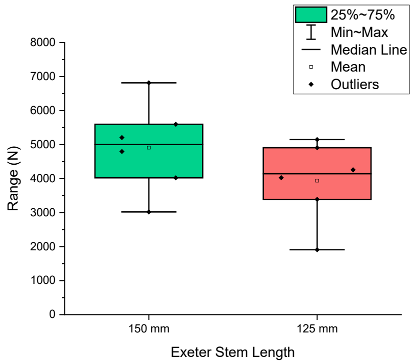

Figure 1. Box plot of maximum pullout forces experienced by each stem length. Standard-length (150 mm) values are shown in green; Short (125 mm) values are shown in red. There was no statistical difference between stem lengths.

Figure 2. The assembled pullout apparatus affixed to a hydraulic test frame.