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Periprosthetic Fracture Torque for Short Versus Standard Cemented Hip Stems: An Experimental In Vitro Study

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ABSTRACT

In an attempt to preserve proximal femoral bone stock and achieve a better fit in smaller femora, especially in the Asian population, several new shorter stem designs have become available. We investigated the torque to periprosthetic femoral fracture of the Exeter short stem compared with the conventional length Exeter stem in a Sawbone model. Forty-two stems; 21 shorter and 21 conventional stems both with three different offsets were cemented in a composite Sawbone model and torqued to fracture. Results showed that Sawbone femurs break at a statistically significantly lower torque to failure with a shorter compared to conventional-length Exeter stem of the same offset. Both standard and short-stem designs are safe to use as the torque to failure is 7–10 times that seen in activities of daily living.

In recent years, many new "short" femoral implants for the treatment of degenerative hip joint disease have been introduced to the marketplace [1–4]. The objective of these new designs is to provide an adequate arthroplasty of the hip joint, to preserve proximal bone stock and to allow for a better fit in femurs with narrow canals and or proximally trended isthmus and or femoral bowing when compared with more conventional designs. Shorter uncemented stems require a larger surface of proximal fixation and so require more extensive removal of metaphyseal bone. However, for cemented stems a longer cemented stem would remove a larger volume of bone than is at times necessary. A shorter stem is therefore bone preserving.

In response to this clinical demand, the cemented Exeter hip stem range of polished tapered stems (Stryker Orthopedics, Mahwah, NJ, USA) has been expanded to include a shorter implant for primary surgery. The main design feature of the new "short stem" is that the implant length has been reduced to 125 mm instead of the standard 150 mm, without any changes to the offset or the body size of the implant (Fig. 1). Although this 125-mm stem is shorter than the standard 150-mm Exeter stem in length, it is by no means short. There are already Exeter stems that are 90 and 105 mm being implanted in the revision setting. The 125-mm stem is approximately the same length as the Charnley stem which has been used worldwide for over 40 years.

Recent studies of various shorter implant designs have demonstrated the viability of smaller implants [5–9] and have shown no increased risk for periprosthetic fracture [10]. Others however have shown an increased risk of bone fracture when short implants are used, particularly when used in poor quality bone [11]. Potentially a change in stem design can introduce new complications or failure mechanisms.

Although biomechanical Sawbones studies can never fully replicate a human study, they can reasonably accurately reflect the situation seen in patients, evidenced by a reproducible fracture pattern that is representative of those found clinically. Sawbones also offer a safe model for testing to failure prior to implantation into patients.

The objective of this study is to determine if there is an increased risk for periprosthetic fracture for the 125-mm Exeter stem compared to the 150-mm Exeter stem, and if present, whether this risk was clinically relevant. The primary outcome measure was torque to periprosthetic fracture; the secondary outcome measure was energy to fracture in a Sawbones model.

Materials and Methods

Two different femoral stem lengths were investigated with three different offsets. A 125-mm length stem will be referred to as a short stem and a 150-mm length referred to as a standard stem. Offsets used were 37.5, 44 and 50 mm. All components were Exeter V40 (Stryker Orthopedics, Mahwah, NJ) body size no. 1 stems. Power analysis using figures obtained from a previous Sawbones study with an expected difference of 40 Nm, SD of 20 Nm, power of 80% and a significance level of 5%, indicated that a minimum of 6 femurs were required in

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each group. A total of 42 biomechanical composite Sawbones (medium left femur model 3403; Pacific Research Laboratories, Vashon, WA, USA) were prepared with 14 (2 × 7) Sawbones with each offset for comparison. All implant constructs were prepared by an experienced orthopedic surgeon (G.C., T.M.). A standard femoral neck cut was made approximately 1 cm proximal to the lesser trochanter, using a premade cutting guide to standardize the neck cuts. The bones were then broached using the appropriate Exeter broaching rasp for the stem size (e.g. 37.5-mm no. 1 rasp for a 37.5-mm stem). Broaching was performed to allow the stem to seat with the middle marking at the level of the neck cut (Fig. 2).

A standard rasp was used to prepare for both shorter and standard length stems, as a short rasp was not available. A distal cement plug (Stryker 13–17 mm Artisan plug, Stryker Orthopedics, Mahwah, NJ, USA) was introduced to sit just distal to the tip of the implant. The implant was then cemented with the use of a stem centralizer into the Sawbone using two mixes, or 80 g of Simplex (Stryker Orthopedics, Mahwah, NJ, USA) cement. The distal femoral condyle was resected in the supracondylar region to allow the femur to fit within the testing mechanism (Fig. 3). The purpose of the mounting system was to place the femoral loading axis in the loading axis of the biaxial materials testing device (Instron 8874) (Fig. 4).

The femoral head and intercondylar notch were positioned in the vertical loading axis of the machine to replicate the natural loading axis of the femur. The proximal femur was attached, at the center of rotation of the implant head, by means of a hydraulic clamp. Distally, the femur was fixed with Paladur dental acrylic (Heraeus-Kulzer GmbH, Wertheim, Germany), prepared as per manufacturer's instructions.

The femora were tested in combined compression force with torque. A preload of 2 Nm of internal torque and 2kN of compression was applied, simulating the loading in a single leg stance. The compressive load was then maintained and the implant internally rotated 40° in 1 second. The angle of 40° was chosen to ensure that fracture had occurred fully.

Fracture torque was defined as the maximum torque measured. Fracture energy was calculated by numerically integrating the torque and angle measurements against time. Calculations were made with Matlab 2011b (Mathworks, USA) and statistical analysis performed using IBM SPSS for Windows version 21 (IBM Corp, released 2012, Armonk, NY, USA). Normality testing indicated that the data were non-parametric in nature and so testing was performed using Mann–Whitney *U*-tests and summary statistics are presented as medians and interquartile ranges. Boxplots are presented where the line in the middle is the median. The box encapsulates the interquartile range (IQR) which is the 25th to 75th percentiles. The long lines are the whiskers which are equal to 1.5 times the IQR and reach to the inner fence. The outer fence (not drawn) is 3 times the IQR, or two steps

Fig. 2. Example of how a stem is fitted in the composite sawbone. The three markings on the stem can be used to determine the depth.

Fig. 1. Shorter-length (125-mm) and standard (150-mm) Exeter V40 No 1 37.5-mm offset stems. Photo courtesy of Stryker Orthopedics, Mahwah, NJ, USA.

Fig. 3. The testing mechanism. The composite femur and stem are fitted in the Instron.