Can a Dual-tapered Press-fit Stem be used in Cases with Severe Proximal Femoral Defects

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Introduction: Non-cemented total hip arthroplasty femoral components are widely accepted within the orthopedic community for primary arthroplasty, particularly in cases with good bone quality. However, revision or post traumatic cases typically involve substantial amounts of proximal bone loss, which may result in an increase in micromotion and decrease in osseointegration, leading to higher failure rates. Success of non-cemented femoral implants is marked by their ability to achieve stable initial fixation. The purpose of this study was to measure initial stability of three different femoral stem designs in intact femurs and after simulation of severe, progressive proximal bone defects to determine how much bone loss could be withstood before the implant became unstable.

Methods: The three non-cemented stem types included were designed to achieve clinical stability by one of the following: 1) fully coated, for complete bone ingrowth, 2) proximal ingrowth, or 3) dual-tapered, diaphyseal press-fit.

Nine composite specimens were used, three for each stem design. Each femur was cut and prepared using surgical instrumentation specific to each implant design. They were then potted and mounted into a custom fixture built into an MTS 858 biaxial servo-hydraulic load frame with the proximal head of the implant inserted in a custom made holder, which allowed for motion in the coronal plane, equipped with a load cell used to measure direct force on the implant.

Five displacement transducers were used to measure anteroposterior, mediolateral, and axial motions at the bone-stem interface throughout testing. A combined dynamic axial and torsional load was applied cyclically at rate of 1 Hz beginning at 200 N and 1 Nm external rotation and increasing in amplitude to 2000 N and -5/+20 Nm internal/external rotation. After intact testing, a transverse cut was made distal to the proximal stem shoulder, without removing the implant, and the specimen was retested. This was repeated until failure or a maximum of 6 cuts and a total of 105 mm of proximal bone loss. Loading after the sixth cut was applied to 3000 N and -10/+25 Nm internal/external rotation. Gross failure was defined as unstable migration. Failure or a maximum of 6 cuts and a total of 105 mm of proximal bone loss. Testing was stopped if axial migration exceeded 10 mm, rotation exceeded 10°, or periprosthetic fracture occurred.

Force, torque, displacement, rotation, and motion were continuously recorded at a rate of 20 Hz. Average peak per cycle micromotion was determined for each specimen during each of the loading steps. Migration was also calculated during each step and combined to determine total migration.

Results: Of the three different femoral stem designs, only one made it through all six cuts without failure. Specifically, the dual-tapered, diaphyseal press-fit stem design, perhaps due to the rectangular cross-section, remained well-fixed when as much as 105 mm of proximal bone was resected, with average cyclic micromotions remaining below 30 µm in the mediolateral direction and below 10 µm in the anteroposterior direction. In contrast, both the proximally coated and fully coated stems failed by torsional instability no later than the third cut, or 60 mm of bone loss. In addition, both stems experienced average micromotions more than 100 µm per-cycle in the mediolateral and anteroposterior directions, prior to failure. All six proximally coated or fully coated stems rotated 45° or more, such that the experiment had to be terminated before the loading protocol was completed. Total axial migration was lower than 5 mm for all three stem designs.

Discussion: Apart from the obvious limitations of a biomechanical model, the lack of soft tissue and muscles as well as the inability for the coated stems to achieve any initial bony ingrowth may bias the results in favor of the dual-tapered stem. Nevertheless, ingrowth takes time and sufficient initial stability for fibrous tissue formation to occur.

Under the scenario of simulated severe proximal bone loss, the dual-tapered press-fit stem with a rectangular cross-section was far more stable than the proximally coated and fully coated stem designs with circular or oval cross-sections, where any lower than 10-12 cm of diaphyseal contact length resulted in gross instability. Therefore, the results provide strong support for the use of a dual-tapered stem in revision cases as an alternative to longer, fully-coated cylindrical stems.

Significance: Dual-tapered, diaphyseal press-fit stems with rectangular cross-sections provide more stability than coated cylindrical stems in cases of severe bone loss. Therefore, the use of dual-tapered stems in revision cases may be preferred.