Collars on Cementless Femoral Stems Make More of a Contribution to Primary Stability When Subjected to Adverse Mechanical Environments

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Disclosures:
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Introduction: The short and long term success of cementless femoral stems is dependent on achieving good primary stability (PS), which allows bone ongrowth and successful osseointegration to occur. In the weeks following surgery the stem is at risk of subsidence, due to the applied axial and rotational forces. Excessive micromotion at the bone implant interface and migration may result in the failure of osseointegration and the formation of a fibrous tissue layer, jeopardizing the long term success of the hip. There are examples of collarless femoral stems (e.g. Accolade, Stryker), collared stems (e.g. Furlong, JRI Orthopaedics) or designs with options for both (e.g Corail, DePuy). The use of a collared or collarless stem largely appears to due to surgeon preference. There is considerable debate regarding the benefits of a collar. The potential benefits are prevention of migration in the early post-operative period and improved load transfer to the calcar. Clinical studies have reported no difference in the revision rate of collared and collarless versions of the same stem [1]. In contrast, in vitro studies have reported improved PS when using a collared stem. In particular, Demey et al [2] reported that a collar increased the force required to initiate subsidence from 3129N to 6283N, however these forces are high in comparison to those experienced during activities of daily living and might only be experienced in heavy subjects or during stumbling. Assessment of PS under a range of patient characteristics and loads could help to better understand the conditions when a relevant difference in PS of collarless and collard designs exists. Our hypothesis is that for typical patient characteristics there is little or no difference in PS of both designs, but under more severe conditions (high body mass or poor bone properties) a collar can improve primary stability.

Methods: A combined musculoskeletal and finite element modelling approach was used, based on the CT scan of a male femur of unknown age. Muscle attachment points were morphed to the femur from a standardised atlas. An individual estimate of the loads acting on the femur during level gait was obtained by querying an indexed database of joint and muscle loads. Joint contact and muscle forces were obtained using a previously validated musculoskeletal model [3] of the lower extremities using inverse dynamic and static optimization techniques with gait data from 20 THA subjects. Based on the implantation conditions observed across this cohort, proximal femoral anatomy was systematically varied for each subject’s musculoskeletal model to obtain force estimates for a range of femoral anteversion (FAV) angles (5 retroversion to 35° anteversion), CCD angles (105 to 145°) and femoral neck lengths (FNL) (25 to 70mm). This resulted in a total of 810 different parameter combinations for which the musculoskeletal loads (expressed in multiples of body weight) were calculated for walking and then stored in the database. The specific FAV, CCD and FNL for the femur was used to query the loading database to provide an estimate of the musculoskeletal loads which were then applied to the FE model discretised into 21 sequential load steps. Body mass was estimated using standard relationships between femur length, height and BMI. Three body masses were used (633, 731 and 829N) representing an average BMI (28.3), plus one standard deviation (BMI = 32.7) and plus two standard deviations (BMI = 37.1). The femur was rigidly constrained at the femoral condyles. FE models were generated of the femur implanted with an idealized cementless femoral stem (based on the geometry of the Corail stem, Depuy Inc.) with and without a collar. The titanium stem (Young’s modulus of 110,000 GPa and poisons ratio of 0.3), was placed in a neutral orientation by an experienced surgeon. Heterogeneous bone material properties were applied to the model using established apparent density-modulus relationships [4]. The influence of bone properties was explored, using the originally defined properties and by decreasing the moduli by 10 and 20 percent. The bone-implant interface was assumed to be debonded (coefficient of friction = 0.6), with no interference, simulating the immediate post-operative period. The resultant micromotion was calculated, as the measure of primary stability, using custom written scripts to interrogate the models. Composite peak micromotion (CPM) plots was calculated, which reported the peak micromotion at each point of the bone-implant contact surface that occur during the entire activity. The CPM data were then interrogated to measure the mean, median and peak CPM, as well as the percentage area experiencing micromotions less than 50 microns, between 50 and 150 microns and in excess of 150 microns.

Results: There was only a minor difference in the primary stability of the collared and collarless stems under average conditions, BW=633N and normal (100%) bone properties (figure 1 and 2). The mean CPM was 14.6 and 26.5 microns for the collared and collarless stem respectively and both had in excess of 95% of bone-implant interface with micromotions less than 50 microns. As
the body mass increased and the bone properties decreased, the rate of change in the predicted micromotions was significantly lower for the collared stem as compared to the collarless stem. For the range of the mean CPM was 14.6 to 23.9 for the collared stem, but was much higher, from 26.5 to 40.1, for the collarless stem. A similar trend was observed for all metrics examined (mean, median and peak CPM and percentage area experiencing micromotions less than 50 microns, between 50 and 150 microns and greater than 150 microns).

**Discussion:** The mechanical environment experienced by a cementless femoral stem is dependent on a number of factors including body mass and bone quality. For typical patient characteristics with an average body mass and normal bone properties there is little difference in primary stability of a collared and collarless stem under physiological loading. Only when the mechanical environment becomes more severe, either through increasing body mass or decreasing bone properties does it become apparent that a collar can enhance the PS of a stem. This may explain, in part, the lack of difference in revision rate seen in clinical studies as the majority of hips will experience a normal or near normal mechanical environment. However, in patients with high BMI, poor bone quality or both, the addition of a collar can significantly improve PS.

**Significance:** On the basis of this study, surgeons should consider the use a collared prosthesis if they are in any doubt about achieving good quality PS of a cementless femoral stem.

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**References:**
Figure 1: Response of the collared stem as a function of body mass (633, 731, and 829N) and bone properties (100, 90, and 80%).

Figure 2: Response of the collarless stem as a function of body mass (633, 731, and 829N) and bone properties (100, 90, and 80%).