THE STABILITY OF STRAIGHT CEMENTED FEMORAL STEMS AS A FUNCTION OF SURFACE FINISH, PROXIMAL STEM GEOMETRY, AND INTERFACE BONDING CONDITIONS

Introduction

Currently, many authors advocate the polishing of all cemented femoral stems regardless of stem taper and proximal geometry; however, the most successful cemented femoral stems in the literature vary widely in surface finish and shape, ranging from highly polished double-tapered to matte or rough-finished straight stems. Since the mechanisms by which straight stems achieve fixation differs from that of double-tapered stems, findings for one stem type should not be universally applied to other stems. Recent clinical studies which have compared straight stems of various surface finishes have differed in their findings. While some have concluded that polishing the surface finish is advantageous, (Della Valle, 2005, Collis, 2002, Vaughn 2003) others have concluded that there is no clinical difference between polished and matte or rough surface finishes. (Rasquinha 2004, Vail, 2003)

Collectively, the results of these studies indicate that the relative influence of surface finish depends on stem type, or more specifically, proximal stem geometry, necessitating further investigation.

Therefore, the goal of the present study was to measure the stability of four versions of an otherwise identical straight stem, varying only in surface finish and proximal stem geometry, under both initially bonded and initially debonded stem-cement interface conditions, and under physiological loading representative of today’s heavier, more active THR population.

Materials and Methods

Four specimens each of four otherwise identical straight stems, varying only in surface finish and presence or lack of collars were tested under two conditions: (1) initially intact interfaces, simulating immediate post-operative conditions, (2) initially debonded stem-cement interface conditions, simulating conditions several months post-op when fibrous tissue has formed. Stems were implanted in composite model femurs, and then a dynamic joint reaction force, torque, and abductor muscle force simulating walking and stair-climbing activities were applied for 20,000 cycles at a rate of 1.0 Hz. The peak joint reaction force was 3500 N, the peak torque about the femoral shaft was 24 Nm, and the peak abductor muscle force was 1500 N. Per-cycle micromotion and total displacement over time were measured in all three directions at the stem-cement and bone-cement interfaces throughout loading. Mean per-cycle motions were calculated during walking and stair-climbing cycles during the initial cycles of loading and the final cycles of loading. Additionally, the total unrecovered displacement, or migration, of the stem and the cement mantle in all three planes was calculated.

For each output variable (i.e., motion amplitude and location) a separate GLM was constructed. The input variables were surface finish (polished or rough), proximal stem geometry (collared or non-collared), and initial bonding conditions (bonded or debonded). Least squares regression was used to calculate the output variable as a linear function of the input variables, with the coefficients for each input variable representing its relative effect on the output variable, all input variables were considered equal. The corresponding P value represents the probability that such a calculated relative effect would be obtained by chance alone.

Results

Overall, the presence or lack of a collar had very little influence on per-cycle motion in the axial direction. Specifically, all relative effects were less than three microns, and none had P values lower than 0.33. However, in the medial-lateral direction, the presence of a collar increased per-cycle motion at the stem-cement interface by 5-6 µm (P<0.07). In contrast, in the anterior-posterior direction, the presence of a collar decreased per-cycle motion at the stem-cement interface by 3-4 µm (P=0.05). In terms of migration, the trends were stronger at the bone-cement interface than the stem-cement interface, and the presence of a collar increased axial cement mantle migration by 15 µm (P=0.03) and increased medial/lateral migration by 10 µm (P=0.03).

Whether or not the stem-cement interface was initially bonded or debonded had very little effect on axial per-cycle motion or migration. In contrast, in the medial-lateral direction, initially debonded stems experienced greater per-cycle motions at the bone-cement interface by 3 µm (P=0.05), and in the anterior-posterior direction by 2-4 µm (P=0.02). In contrast, in terms of migration, bonded stems moved more than debonded stems. Specifically, in the lateral direction, there was greater motion of the stems by 24 µm (P <0.01) and of the cement mantle by 18 µm (P<0.01). Similarly, in the anterior direction, the cement mantles of bonded stems moved more by 10 µm (P<0.01) than those with initially debonded interfaces. Although the trends varied for the three planes and for per-cycle versus total migration, a typical box-plot of the raw data is presented below to show some of the differences due to surface finish, proximal stem geometry, and initial bonding conditions.

Discussion

These results indicated that for straight stems, surface finish had a greater influence on stability than proximal stem geometry or initial bonding conditions. Specifically, rougher surfaces provided more stability than polished, regardless of the proximal stem geometry or bonding conditions, at the stem-cement interface, but less stability at the bone-cement interface. These results are consistent with previous push-out studies of surface finish. (Crownshield, 1998)

Previously, studies have suggested that collars reduce distal migration. In this study, collars did not reduce per-cycle motions, although, perhaps had the study been conducted for a longer period, there would have been a difference in axial migration. Instead, the collar was found to act as a fulcrum in the coronal plane, increasing per-cycle motion in the medial-lateral direction.

Unlike double-tapered stems which are believed to achieve tighter fixation at the stem-cement interface in the debonded conditions, the straight stems in this study moved more at the stem-cement interface under initially debonded conditions. This demonstrates that the mechanisms by which straight and double-tapered stems both loosen and achieve stability differs, hence emphasizing the need to consider them independently, and not apply findings for one stem-type to the other.