INTRODUCTION

Hip resurfacing arthroplasty has changed the treatment of end stage arthritis without severe deformity for young, active adults. Presently, there are varying clinical approaches to hip resurfacing implant design selection and cementation techniques, and cement penetration into the femoral head has been identified as one of the critical factors in the longevity of the resurfaced joint [1]. Enough cement penetration is needed to adequately secure the implant to the bone, while too much penetration may lead to thermal necrosis, possibly resulting in loss of normal bone remodeling and increased risk of failure. Current implant designs for hip resurfacing arthroplasties offer various offsets between the femoral component and reamer, representing differing theories as to the optimal offset and resulted cement mantle thickness for effective adherence of the implant to bone. The purpose of this study was to explore the effect of a range of reamer-femoral component offsets on cement penetration into the femoral head.

METHODS

Three sets of 6 plastic hip resurfacing femoral component models were designed using CAD and cast (Huntsman Pro-cast, Hong Kong) from silicone molds created by rapid prototyping. Models were designed with reamer-femoral component offsets of 0.0 mm (50 mm diameter, n=6), 0.5 mm (51 mm diameter, n=6), and 1.0 mm (52 mm diameter, n=6) relative to the outer diameter of the reamer.

The femoral components were implanted onto models of reamed femoral heads made from high-density open-cell reticulated carbon foam (Pacific Research Laboratories, Vashon, WA) that simulated the density, porosity, and pore connectivity of trabecular bone [2]. For implantation, the femoral components were filled to 50% of their depth with PMMA bone cement. To ensure consistency in seating the implant on the foam, an Instron 8511 materials testing machine (Instron, Norwood, MA) and custom fixtures were utilized to insert the femoral component on the bone and maintain an approximately 20 N load on the construct while the cement cured. Following implantation, the components were cut longitudinally and cement penetration was assessed on four unique surfaces per foam-implant unit. Digital images were processed in ImageJ (NIH) to determine actual component offset and cement penetration depth, height, and area (Figures 1 and 2). An analysis of variance (ANOVA) was performed on the set of data to determine statistical significance between offsets for each of the measured values.

RESULTS

The cement penetration depth from the dome (measurement #1) was found to be significantly greater for the 50 mm implant (0.0 mm offset, 13.5±1.6 mm) compared to both the 51 mm (0.5 mm offset, 11.8±1.8 mm, p=0.0006) and 52 mm (1.0 mm offset, 10.2±1.0 mm, p=0.0001) implants. In addition, the cement penetration depth from the dome for the 51 mm implant was significantly greater than that for the 52 mm implant (p=0.002). Similar results between the offsets were found for the penetration depth of measurement #2.

At the chamfer, the penetration of the cement (measurement #3) was also found to be significantly greater for the 50 mm implant (9.3±0.9 mm) compared to both the 51 mm (8.3±0.7 mm, p=0.0001) and 52 mm (6.9±0.5 mm, p=0.0000) implants. Also, the cement penetration depth at the chamfer was significantly greater for the 51 mm implant than the 52 mm implant (p=0.0000). Similar results were observed for measurement #4.

Cement penetration from the wall at measurement #5 was found to be statistically similar for each of the offsets examined (p=0.75 to 0.98). The cement penetration depth at the wall for measurement #6 was found to be significantly less for the 50 mm implant (4.4±0.7 mm) compared to both the 51 mm (1.4±1.3 mm, p=0.002) and 52 mm (2.9±0.6 mm, p=0.0000) implants. In addition, the 51 mm implant was found to have significantly less penetration at the wall (measurement #6) than the 52 mm implant (p=0.0000).

Cement penetration height (measurement #8) was found to be significantly greater for the 50 mm implant (22.5±2.1 mm) than either the 50 mm implant (18.4±2.4 mm, p=0.004) or the 51 mm implant (19.5±3.1 mm, p=0.0004). The cement penetration height was statistically similar between the 50 and 51 mm implants (p=0.28).

The area of relevant cement penetration (measurement #10) was significantly larger for the 50 mm implant (191.0±8.9 sq. mm) compared to both the 51 mm implant (182.5±13.6 sq. mm, p=0.04) and the 52 mm implant (179.0±12.8 sq. mm, p=0.002). However, the 51 mm implant did not have a significantly different area of penetration than the 52 mm implant (p=0.57).

DISCUSSION

Results from this study suggest that the reamer-femoral component offset significantly affects not only the cement mantle, but also the extent of cement penetration. Increasing the offset decreased the depth and area of cement penetration, while increasing the penetration height. Our study results indicate that, for the situation where cement is applied by filling the cup to 50% of its depth without applying cement directly to the head of the femur, the 1.0 mm offset provides the most cement coverage to the femoral head while reducing the amount penetrating into the bone, possibly reducing the risk of thermal necrosis and ultimately, implant failure.

REFERENCES


Figure 1. Cross-sectional view of an implant model implanted onto foam. Cement penetration was measured from the dome (#1 and 2), chamfer (#3 and 4), and wall (#5 and 6). In addition, the cement mantle (#7), cement penetration height (vertical distance from inner proximal surface of the dome to the most distal region of cement penetration into foam, #8), and height from the inner proximal surface of the dome to the distal edge of the dome (#9) were measured.

Figure 2. Cement penetration area measurement (red outline, #10).