ABSTRACT INTRODUCTION:

Hip resurfacing arthroplasty (HRA) is a conservative alternative to conventional hip replacement surgery which helps to preserve proximal bone stock. Currently, femoral components of most HRA are secured to the femur with bone cement. Recently, however, uncemented femoral components became commercially available to alleviate the drawbacks of using bone cement [1]. These femoral components rely on press fit and bone ingrowth for fixation. Early failures of femoral components through loosening or femoral neck fracture are often attributed to bone resorption within the femoral head and femoral neck narrowing. These types of failures have been observed in recent clinical trials of both cemented and cementless resurfacing implants, but are not fully understood [2, 3]. The purpose of this investigation was to examine bone remodeling around cementless HRA implants and analyze the effect of different ingrowth regions using an adaptive finite element model.

METHOD:

3D finite element models of an intact femur and a femur with an implanted femoral HRA component were developed from segmentation of qCT scans of a fresh frozen cadaveric specimen, resulting in a mesh of 28424 and 24049 linear elastic tetrahedral 10 node elements for the intact and implanted femur, respectively. Femur elements were assigned material properties based on bone density at the element’s location [4], while the implant was assigned material properties of Co-Cr. Remodeling was simulated based on the strain energy density differences between the implanted and intact femur model [5], implemented as a subroutine within a finite element solver [6]. Bone density, and therefore modulus, was updated after each analysis step. The femoral head was loaded to peak forces expected during walking [7] for an 80 kg patient, and was rigidly constrained across its entire cross-section below the lesser trochanter.

Four contact cases, shown in Figure 1, were analyzed in order to investigate the effects of ingrowth at different regions of the implant: (I) tied contact at both the implant cap and stem, (II) frictional contact at both the cap and stem, (III) tied at cap and frictional at stem, and (IV) a hypothetical model where the distal end of the stem was ignored and the remaining regions were fixed selectively in order to improve simulation results. The fixed surface was used to model perfect bone ingrowth and the friction surface simulated a press fit.

RESULTS:

Figure 3 shows the percent change in bone density of the four contact cases, relative to the intact femur. All four cases showed significant bone density decreases, particularly in regions 7 and 8. This effect was most significant in cases I and III, where the implant cap was bonded to the femur. In all cases, localized bone density decreases were observed along the cortex, which may represent thinning of the cortical bone. Again, the effect was more severe in cases I and III.

DISCUSSION:

These simulations show significant decreases in bone density for all four cases, particularly at the femoral head. The stiff implant shields the head of the femur from stresses experienced by the native femoral head. The most severe bone loss underneath the cap (region 8) was observed for case III which represents the commercially available implants. The best scenario was the hypothetical contact case (IV), where more stress is transferred from implant to bone compared with the other cases, reducing the severity of bone loss. The results showed that bone absorption depends on location of bone ingrowth into the implant, which can be optimized to reduce absorption. In addition, the results of case IV, where the distal end of the stem was ignored, suggest that there may be a benefit of using a smaller peg.

SIGNIFICANCE:

This investigation provides insight into the stress shielding effect, and resultant bone loss, caused by cementless HRA implants. These effects may cause failure due femoral fracture or loosening of the implant. The methods and results of this investigation can be used to optimize cementless femoral HRA components, reducing bone loss and lowering susceptibility to these failures, all without the drawbacks of using bone cement for fixation.

REFERENCES: