INTRODUCTION: Metal-backed acetabular component designs constitute over 90% of the socket designs used clinically in the U.S. [1]. The widespread adoption of cementless fixation for acetabular components was based on suggestions that using a metal backing would more uniformly distribute stresses to the periprosthetic bone [2]. More recently, researchers have suggested that flexible acetabular cups fabricated from UHMWPE or other polymer composites may provide more physiologic load transfer to the periprosthetic bone [3,4].

Previous analytical and in vitro acetabular cup studies have been restricted to the elderly patient population [4,5,8]. It remains unknown to what extent the quantitative findings from previous biomechanical studies may be generalized to the young patient population. The goal of the current study was to develop finite element models of the natural and surgically reconstructed pelves, based on the geometry and bone density of a relatively young patient (<60 years of age), to study the effects of flexible cups on periprosthetic load transfer during gait. We tested the hypothesis that decreasing the elastic modulus of the acetabular shell would increase the periprosthetic bone strains, and thereby result in more physiological loading of the acetabulum.

METHODS: Two 3-D finite element (FE) models, a natural hip model and a post-total hip replacement (THR) hip model, were developed based on the geometry and material properties from a 45 year-old female donor hip with no known bone disorder (ScienceCare Anatomical, Phoenix, AZ). One mm thick slice images of the hip (523 slices total; 0.781 mm x 0.781 mm resolution), along with a European Spine Phantom were obtained using a computed tomography (CT) scanner. The protocol was approved by an IRB. Linear brick elements were used to model the pelvic, sacral, and femoral trabecular bone, while linear shell elements were used to model a 1 mm thick cortical shell around the shell. The natural hip model consisted of 139,616 brick and 26,776 shell elements (154,533 nodes) (Fig. 1). Non-homogeneous, isotropic, linear elastic material properties were assigned to the trabecular bone based on the QCT data and reported density-modulus relationships [6].

RESULTS: In the natural hip, the strain and stress fields demonstrated bi-centric patterns, with peaks in the anterior and posterior-inferior regions of the acetabulum (Fig. 2). After reconstruction of the pelvis with the CoCr- and UHMWPE-backed cups, the peak minimum principal stresses in the periacetabular trabecular bone increased in magnitude by 36% and 21%. The stresses also appeared to redistribute towards the central portions and superior roof of the acetabulum. Although the stresses in the pelvic trabecular bone were found to be relatively insensitive to the backing material (Fig. 3), the peak bone stresses were greater in the UHMWPE cup compared to the CoCr-backed cup with the stresses distributed over a wider area. The reconstructed hips also had greater strains in the medial wall, adjacent to the acetabular fossa (Fig. 2). As the backing modulus decreased, the bone in the superior and anterior-inferior acetabular regions exhibited greater strains.

DISCUSSION: The implantation of uncemented hemispherical acetabular components resulted in non-physiologic stress and strain fields in the periacetabular bone regions of a young donor. Increasing component compliance by changing the modulus of the backing material from CoCr to UHMWPE led to more evenly distributed periprosthetic stresses, though these changes were modest relative to the material modulus changes. Similar findings in previous analyses based on an elderly patient [8] suggest that age-related effects may not be present. A wider range of patient anatomy and bone quality would have to be examined to confirm these findings The non-physiologic load transfer for all these designs suggest that implant material changes alone may not be sufficient to adjust the periprosthetic stress distribution to physiological levels.


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