INTRODUCTION

In cementless hip arthroplasty fixation of acetabular cups is often achieved using a press-fit between the cup and the bone, where the acetabulum is typically under-reamed by 1-4mm [1-4] with respect to the size of the cup. Deformation of the cups during insertion remains a concern as it could lead to changes in the clearance and sphericity of the bearing, which can adversely affect fluid film lubrication and lead to increased wear in hard-on-hard bearings. In extreme cases equatorial or edge contact may occur, which may cause the joint to seize [5,6].

Jin et al [5] and Yew et al [6] together showed that cup deformation increased as (1) cup wall thickness decreased, (2) the amount of oversizing increased, and (3) the size of the cup increased. These results suggest that many current hip implant designs, which have adopted a large diameter femoral head and thin walled acetabular cup, may experience significant deformation. Jin et al reported deformations of a modular hip implant into the deformed elliptically shaped shell with a 1mm under-reaming of the acetabulum. The deformed shape of the cup equator was roughly elliptical or “fish-eyed”, caused by squeezing between the ischial and ilial columns of the pelvis.

In modular cups with shell-liner taper junctions, deformation of the shell caused by the insertion process may compromise the effectiveness of the taper. Squire et al [3] intraperatively observed “toggling” of the liner following impaction of the shell before the liner was firmly implanted. They reported in vivo diametral deformations of the shell from a modular cup (Pinnacle 100, DePuy) to be in the range from 0.0 to 0.57mm with an average of 0.16 ± 0.16mm. Although this deformation of the shell was corrected to a large extent following impaction of the liner into the shell [5], the residual effects of deformation on the shell-liner taper junction are unknown. It is proposed that impaction of the undeformed liner into the deformed elliptically shaped shell may compromise the taper because contact at the taper occurs predominantly along the minor axis of the shell, not evenly all the way around the taper. Consequences of a compromised taper may include an increased risk of liner dislocation and increased wear between the shell and liner.

Additionally, Walter et al [7] suggested that uncoupling of the shell and liner may lower the natural frequency of the assembled cup to within the audible range such that squeaking noises may be emitted under a driving frictional force. As uncoupling may be increased due to a compromised taper, this suggests that cup deformation may play a role in causing hip squeaking.

This study is part of a long term project to investigate press-fit fixation and its effects. This part of the project used a dynamic finite element model to simulate the impaction of a modular hip implant into a under-reamed acetabulum. A “typical” implant geometry was used to investigate the effects of varying the amount of cup oversizing and shell wall thickness on cup deformation and effects of cup deformation on the effectiveness of the modular taper junction.

METHODOLOGY

The methodology used was largely adopted from a previous study of the BHR [8] with several adaptations for modular cups. A “typical” implant geometry was used to investigate the effects of varying the amount of cup oversizing and shell wall thickness on cup deformation and effects of cup deformation on the effectiveness of the modular taper junction.

Four modular cup implants with “typical” geometries were created. The shells were made from Titanium alloy and the liners were alumina ceramic. The wall thickness of each of the shell components were 1mm, 2mm, 3mm and 4mm. In all cases the thickness of the ceramic insert was 4mm, but with diameters to match its corresponding shell component. Each implant design incorporated a shell-liner modular taper junction with an 18 deg angle. The 3-D geometry of a right cadaveric pelvis was reconstructed from CT scans. The acetabulum was under-reamed by 1mm and 2mm with respect to the size of the cup. Simplified impaction tools were created, which consisted of an impaction handle, hammer and various attachments for insertion of both the shell and liner.

The initial model consisted on the reamed pelvis, shell and impaction tools for impaction of the shell. The shell and tools were positioned such that the shell was to be impacted into the pelvis at an inclination angle of 45 degrees and anteverision angle of 30 degrees.

RESULTS

To begin with, the shell was impacted into the reamed acetabulum using ABAQUS/Explicit. Several consecutive 5.0J hammer blows were applied until the shell was seated or did not move any further. The deformed model, excluding the impaction tools, was then imported into ABAQUS/Standard to allow the model to reach static equilibrium. When this was achieved, the deformed model was then imported into ABAQUS/CAE. Following this, the undeformed liner and impaction tools for impaction of the liner were also imported and positioned. Using ABAQUS/Explicit, the liner, more, was impacted into the shell with a single 1.5J hammer blow. The model, excluding impaction tools, was then imported back into ABAQUS/Standard to reach static equilibrium. Once achieved, a hip joint contact load corresponding to peak normal walking was applied and then removed to simulate a single gait cycle. This was done to allow evaluation of the relative movement between the shell and liner to investigate uncoupling of the components under load.

In terms of the liner, the deformation of the liner was increased as (1) cup wall thickness decreased, (2) the amount of oversizing increased, and (3) the size of the cup increased. These results suggest that uncoupling of the shell and liner dislocation and increased wear between the shell and liner. Jin et al [5] and Yew et al [6] suggested that uncoupling of the shell and liner may compromise the effectiveness of the modular taper junction.

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REFERENCES