1. INTRODUCTION
Acetabular dysplasia and abnormal femoral anteversion have been found to lead to osteoarthritis in the hip joint [1]. Conducting total hip arthroplasty (THA) with standard (straight) implant stems become difficult under these conditions due impingement created by the implant neck and the rim of the acetabular cup. This can lead to post-operative anterior dislocation and inefficient abductor lever arm. The modular-neck implant was designed to overcome these issues. With this design, a predetermined femoral anteversion is achievable, as well as the offset and abductor lever arm being adjustable. Furthermore, once the stem portion of the implant is inserted, the neck becomes interchangeable, giving a wide range of choices for the surgeon.

In this study, a liner finite element analysis was used to observe the effectiveness of modular-neck design THA in the presence of hip joint dysplasia and abnormal femoral anteversion. The two models were compared by examining stress and strain states on a 3-dimensional bone model and the implant itself.

2. METHODS
2.1 Geometry and Finite Element Model
Two un cemented, modular-neck stems were modelled: a straight model (straight) and a 20° anteversion (anteversion) model (Fig. 1).

![Fig. 1. Modular-neck stems. (a) standard, (b) 20° anteversion.](image)

A 3-dimensional hip model consisting of sacrum, coxa, and femur was created using computer tomography (CT) scans of a 52-year old female with hip dysplasia and femoral anteversion. The data set (resolution of 512 x 512 pixels with slice thickness of 2mm) was imported into MECHANICAL FINDER (MF) Version 6.0 (RCCM, Inc., Japan), a digital image processing and finite element analysis software, to create the model. To simplify the analysis, only the right half was considered.

The acetabular cup of the implant was oriented according to the “safe zone” as proposed by Lewinek et al. [2], with an inclination of 45° and an anteversion of 15°. The constraining component of the liner, or the lip, was positioned towards the posterior end. Fig. 2 shows the difference between the positions of the implantation of the two modular-neck stems.

![Fig. 2. Implant in femur. (a) straight, (b) anteversion.](image)

The tetrahedral elements with size ranging from 2mm to 4mm were used in the finite element models.

2.2 Material Properties and Contact Constraints
Mechanical properties of the bone were determined by a numerical integration built into MF that utilize Hounsfld unit from the CT data. The Young’s modulus was calibrated using densities determined by Keyak et al. [3]. The properties of the implant are shown in Table 1.

<p>| Table 1. Material Properties of the implant |</p>
<table>
<thead>
<tr>
<th>Geometry</th>
<th>Material</th>
<th>Young’s Modulus (GPa)</th>
<th>Poisson’s Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetabular Cup</td>
<td>Ti-Alloy</td>
<td>110</td>
<td>0.30</td>
</tr>
<tr>
<td>Liner</td>
<td>UHMWPE</td>
<td>1</td>
<td>0.46</td>
</tr>
<tr>
<td>Ball</td>
<td>Alumina</td>
<td>380</td>
<td>0.26</td>
</tr>
<tr>
<td>Neck</td>
<td>Ti-Alloy</td>
<td>110</td>
<td>0.30</td>
</tr>
<tr>
<td>Stem</td>
<td>Ti-Alloy</td>
<td>110</td>
<td>0.30</td>
</tr>
</tbody>
</table>

2.3 Boundary Conditions
A normal stepping load of 1800N [4] was applied to the upper surface of the sacrum. Displacement and rotation along the horizontal direction was fixed for the proximal end of the sacrum and the coxa. The distal end of the femur was fixed from displacement and rotation in all directions (Fig. 3).

3. RESULTS
3.1 Strain Energy Density (SED)
Figure 4 shows the SED distribution on the femur model of the two neck designs. The femur implanted with anteversion design
has a significantly lower SED compared to the straight design. The higher SED at the edge of stem in the straight model suggests failure of bone tissue in this region.

3.2 Maximum / Minimum Principal Stress
Maximum and minimum principal stress distribution also reveals that the femur with the straight stem carries a significantly higher load than the anteversion stem, with much of the stress distributed along the diaphyses (Fig. 5).

3.3 Equivalent Stress
Fig. 6 shows the Equivalent stress distribution of the two implant designs. The distribution shows that much of the stress is found around the neck for both implants, specifically around the areas where the modular neck comes in contact with stem. Compared to the straight design, the anteversion design implant manages to have an overall lower stress distribution.

4. DISCUSSION
Stress shielding is a major concern in THA as it stimulates bone resorption. This can cause aseptic loosening of the implant. SED has been one approach used in FEA of THA to simulate bone remodeling and to examine stress shielding [5]. It has been suggested that bone density increase when the SED is higher than a certain threshold derived from an intact bone, while bone resorption occurs when the SED is lower than this threshold. For bones with dysplasia and osteoarthritis, as in this case, the threshold value becomes difficult to obtain.

Comparing the SED on the femur of the two implants, it appears that stress shielding may occur for the anteversion design. Stress data also reveals that much of the stress is transferred into the implant and not to the bone. However, upon inspecting the loading on the implant itself, the stress levels are lower than that of the straight design. This difference in stress may have contributed from the rotation of the stem of the straight-neck design to compensate for femoral anteversion, of which the procedure was absent with the anteversion design.

5. CONCLUSION
While lower stress and strain distributions on the femur may initially suggest that the anteversion-neck modular implant may promote stress shielding, the lower stress on the implant itself indicates that the overall stress of the THA is significantly lower than the straight-neck design.

REFERENCES