INTRODUCTION
The mechanical environment due to different implant designs and fixation methods has received relatively little attention despite the fact that femoral component loosening is a major contributor to the need for revision surgery. This study considers the stresses in the distal femur due to two different implant geometry variations: a pegged or cruciate retaining (CR) implant and a box section or posterior stabilizing (PS) implant. Three dimensional finite element (FE) models of the intact femur and femur with the above implants were constructed and computationally subjected to loading representing a walking cycle to evaluate changes in the stress field.

METHODS
The femur model used for these studies is the third generation composite femur made freely available in the public domain [1]. The modification to the intact femur to accommodate the implants was carried out in accordance with surgical protocols. The FE models of the intact femur and femur with implants are shown in Fig. 1.

RESULTS AND DISCUSSION
Typical von Mises stresses for cancellous bone in a frontal plane section are shown in Fig. 2. It can be seen that there is considerable reduction in stresses post-implantation.

To better understand the resulting von Mises stress distributions in the bone post implantation the distal femur was divided into four regions of interest (Fig 3), these regions were chosen to permit comparison with studies on change in bone mineral density (BMD) post TKA [3,4]. The motivation was to find if these regions are subject to stress shielding which results in reduction of bone mineral density.

Figure 1: FE models: (a) of intact femur; (b) with CR implant; and (c) with PS implant

The forces corresponding to the walking cycle were taken from a previous study that used in vivo telemetric implants [2]. The forces comprised of vertical forces (appropriately split over the medial and lateral condyles), anterior-posterior shear force, patellar-femoral force and internal external moment. These were applied to the distal femur over realistic contact areas. This study examined three flexion angles (0°, 22°, and 48°) during a walking cycle.

Figure 2: Sectional view in the frontal plane of von Mises cancellous bone stress

Figure 3: Periprosthetic regions of interest selected in a) FE model and b) from literature [3, 4].
Table 1: Average reduction in stresses over walking cycle

<table>
<thead>
<tr>
<th>Region</th>
<th>% reduction (CR)</th>
<th>% reduction (PS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region 1</td>
<td>64</td>
<td>62</td>
</tr>
<tr>
<td>Region 2</td>
<td>65</td>
<td>68</td>
</tr>
<tr>
<td>Region 3</td>
<td>63</td>
<td>61</td>
</tr>
<tr>
<td>Region 4</td>
<td>3</td>
<td>-5</td>
</tr>
</tbody>
</table>

The above results indicate that regions 1-3 experience considerable stress shielding, while region 4 shows a small reduction in the case of CR implanted femur and an actual increase in stress of 5% in the case of the PS implanted femur. These results are found to be in good agreement with the observed patterns of BMD reduction as seen in the clinical situation [3,4].

CONCLUSIONS

The study shows that the cancellous bone in the distal femur experiences significantly lower stresses after knee arthroplasty. The stress shielding evident from the results occurs in a similar pattern to reported instances of reduction in BMD in clinical scenarios. Results from these analyses also highlighted stress concentrations for the PS implanted case. These in conjunction with reduction in bone quality due to stress shielding can lead to peri-prosthetic fractures.

It must be noted however that there are a number of limitations to this study, simplified material properties have been applied to both cancellous and cortical structures and only a walking gait cycle has been investigated.

REFERENCES

2. Bergmann, G. In-vivo forces from telemetry. 2008; Available from: www.orthoload.com