INTRODUCTION

The menisci provide conforming surfaces between the femur and tibia that reduce the contact stresses between them during motions. (Mow et al. 1992). Loss or damage to the menisci results in an increased risk of cartilage degenerative disease (Roos et al. 1998 and Englund et al. 2003). The menisci help distribute load over an incongruent joint surface and are able to move to maintain congruency during knee motion (Vedi et al. 1999). The movement of the menisci during knee flexion and extension has been previously investigated (Thompson et al. 1991) but the mechanism by which the menisci may reduce tibiofemoral contact stresses is not yet well understood.

The purpose of this study was to develop and apply an image based in vitro test bed designed to investigate the movement of the menisci and tibiofemoral contact motion during simulated normal walking kinematics.

METHODS AND PROCEDURES

The test bed (Figure 1) was manufactured out of PVC, UHMWPE, and fiberglass to ensure compatibility with MRI. The device allows prescribed displacements (flexion angles, anterior-posterior (AP) displacements, and internal-external (IE)) to be applied to the tibia relative to a femoral reference frame.

<table>
<thead>
<tr>
<th>Flexion Angle°</th>
<th>HS</th>
<th>MS</th>
<th>TO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tib. Ant. Disp.(mm)</td>
<td>13</td>
<td>-1</td>
<td>-5</td>
</tr>
<tr>
<td>Tib. Int. Rotation°</td>
<td>-6</td>
<td>-1</td>
<td>-1</td>
</tr>
</tbody>
</table>

Table 1. Flexion angles, tibial displacements, and rotations for tested instances during gait cycle tested.
A 1.5 T GE Signa MR scanner with a GE head coil were used. Fat-saturated 3D spoiled gradient recalled echo (SPGR) and a 3D balanced-steady state free precession (SSFP) scans were used to image the cartilage and meniscus, respectively. A 256 x 256 x 74 matrix with 0.5469 mm x 0.5469 mm pixel size and 1.5 mm slice thickness covered a 140 x 140 x 111 mm³ volume of the knee for both MR scans. Three-dimensional models of the menisci, tibial and femoral cartilage were then created (Koo et al. 2005). The centroids of the contact areas between the femoral and tibial cartilage and the centroids of the lateral and medial meniscus on the medial and lateral tibial plateaus were determined at each time point.

RESULTS
The change in location of cartilage contact medial plateau was substantially larger (11.7 mm) than movement of the medial meniscus 1.7mm). The lateral meniscus showed larger (5.98 mm) movement than the medial meniscus while the location of cartilage contact remained relatively small on the lateral plateau (1.8 mm) (Figure 2).

DISCUSSION
The results with this in vitro test bed are consistent with qualitative studies that suggest that the lateral meniscus is more mobile and provides better conforming surfaces than the medial meniscus (Rath et al. 2000).

The test bed provides for quantitative evaluation of the movement of the meniscus in positions representing the knee position during functional activities such as walking. The large movement of the lateral meniscus found using the test bed provides insight that helps to explain why damage to the lateral meniscus typically leads to earlier development of osteoarthritis (Covall et al. 1992). Specifically, the large movement of a healthy lateral meniscus during walking is required to maintain conformity in the lateral compartment where the articular tibiofemoral geometry is less conforming than in the medial side.

These results also provide insight as to why a rotational offset can lead to the chronic medial meniscal damage frequently observed following ACL rupture. This damage to the medial meniscus and the sensitivity of the medial compartment to shifts in contact location provide a functional explanation for the greater frequency of medial compartment relative to lateral compartment osteoarthritis following ACL injury. These results support the general hypothesis that rotational shifts in the locations of load bearing to regions of cartilage that cannot adapt to these loads (Andriacchi et al. 2004) result in degenerative changes that initiate the early stages of knee OA.

REFERENCES