INTRODUCTION:
Paradoxical anterior translation of cruciate-retaining total knee systems has been observed in-vivo using fluoroscopic surveillance during a single-leg deep knee bend [1]. Some of the negative consequences of this paradoxical movement are: limited maximum flexion, accelerated wear of the tibial insert and the feeling of instability. The effect of the tibial insert geometry on the paradoxical kinematics of the fixed-bearing PFC® Sigma™ cruciate-retaining total knee (DePuy, Warsaw, IN) was examined in a virtual knee simulator throughout one cycle of deep knee bending. Two commercially available inserts along with a completely flat insert were considered. The ‘rollback’ of the femur relative to the tibia was compared as a function of knee flexion angle for the three different inserts.

MATERIALS AND METHODS:
A virtual knee simulator (LifeMOD/KneeSIM, LifeModeler, Inc., San Clemente, CA), based on multibody dynamics, was used to simulate a double-leg deep knee bend in a manner similar to the ‘U. Kansas Knee Simulator.’ The model included tibio-femoral and patello-femoral contact, passive soft tissue, and active muscle elements. The MCL, LCL and PCL, as well as the capsular tissues, were modeled as linear springs and the patellar tendon and ligament could wrap around the implants. Flexion/extension at the hip and ankle joints, and abduction/adduction, varus/valgus and axial rotation at the ankle joint were unconstrained while a constant vertical load of 463 N was applied at the hip. A closed-loop controller was used to apply tension to the quadriceps and hamstring muscles to match a prescribed knee flexion-extension profile. Fixed-bearing PFC® Sigma ™ cruciate-retaining femoral and patellar components were imported into the model and three different tibial inserts (Fig. 1) were added to the model separately with zero degrees of posterior slope (Curved, Posterior Lipped (PLI) and Flat). The system was subjected to one 9-second cycle of knee bending up to 120 degrees of flexion (0 – 120 – 0 degrees). The anterior-posterior (AP) positions of the lowest points on the femoral lateral and medial condyles closest to the tibial tray (the same measure used in fluoroscopy studies) were recorded relative to the dwell points for the three inserts considered.

RESULTS:
All three inserts exhibited posterior movement of the lowest condylar points during the first 40 degrees of flexion (Figs. 2 & 3). At around 35 degrees of flexion the AP motion curves for all three inserts demonstrated characteristic inflection points, which we attribute to the femoral component sagittal radius decrease, that occurs at about this flexion angle. Beyond 35 degrees of flexion, there is a ‘paradoxical’ anterior movement of the condylar lowest point on the medial condyle (Fig. 2), which is seen to a much smaller extent for the lateral condyle, until about 80 to 90 degrees of flexion, after which it also undergoes paradoxical anterior motion (Fig. 3).

DISCUSSION:
The results for AP motion of the lowest condylar points are similar to what has been reported for cruciate-retaining total knee implants in a single-leg deep knee bend [1]: In a deep knee bend, PCL-retaining total knees pivot on the lateral side, rather than the medial, in association with paradoxical anterior motion. Due to the different sagittal curvatures of the inserts, the AP movements of the centers of pressure (true contact points) in the medial and lateral compartments are different from those of the lowest condylar points. We have provided results for the latter because they correspond with what has most frequently been reported in fluoroscopic studies. The results of these simulations suggest that inserts with less sagittal plane conformity have greater posterior motion in early flexion, but also have more undesired anterior motion past 30-40 degrees of flexion. Paradoxical anterior sliding is likely to occur independently of the insert sagittal radius. The results further suggest that paradoxical anterior sliding is associated with a reduction in the condylar radius in the sagittal plane, which causes slippage at the contacts between the condyles and insert. Patients may achieve improved ‘rollback’ and deeper flexion with a lower conformity design, but may still suffer from a sense of instability due to paradoxical anterior sliding.

REFERENCES: