INTRODUCTION
The kinematics of the intact knee joint are complex and dependent upon not only the loads that are applied through the joint, but also on the articular geometry and the ligamentous/soft tissue constraints of the knee. In vivo and cadaveric studies have shown that during simple loading, the intact knee joint exhibits a kinematic phenomena known as “medial pivot”. This pivot refers to the tendency of the knee joint to rotate about its medial side and primarily due to ligamentous constraint[1]. In the anterior cruciate ligament deficient (ACLSD) knee joint this pivot point has been shown to move laterally which is again attributed to the remaining ligamentous constraints[1].

With TKR surgery, both the articular geometry and the ligamentous constraints of the knee joint are altered. In an attempt to reclaim the natural kinematics of the knee joint, TKR manufacturers have introduced “pivot” knee designs. These designs utilize specialized geometries that are intended to guide the kinematics of the knee joint and recreate its natural pivot motion. It has been postulated that unconstrained TKR designs will fail to recreate the geometric conditions necessary to reproduce a pivot phenomena in the knee, especially in the post-surgical absence of primary ligamentous structures. This study utilizes a force controlled wear testing machine to quantify the location of the “pivot” for both an unconstrained and a medial pivot TKR design to assess the validity of using constrained geometries to dictate implant kinematics during a simulated functional activity.

MATERIALS AND METHODS
Four Advance® Medial Pivot size 3 femoral/tibial implants (Wright Medical Technology, Inc., Arlington, Tenn.) and four NKII standard congruent size 3 femoral/tibial implants (Sulzer Orthopedics, Austin, TX) were installed and tribologically examined during a standard gait cycle at 1 Hz on the Instron/Stanmore knee simulator using the proposed 1999 ISO force-control testing standard, #14243. In vivo capsular constraints were simulated with 20N/mm AP and 0.27Nm/deg. axial rotational (IE) springs, and a 50% (+0.2%N,3) bovine serum lubricant was used during testing. All simulator TKR components were aligned in zero (neutral) AP displacement and IE rotation with respect to the tibial condylar midline at zero degrees femoral flexion. The lubricant was replaced daily and after 2 million cycles the kinematics from 10 complete gait cycles were averaged for kinematic analysis. Using rigid body kinematic transformations, a computer algorithm was developed to determine the AP and ML location of the instantaneous axis of internal/external rotation of the tibia with respect to the femur at 100 discrete points during the gait cycle. In the case of pure tibial displacement without rotation (which would result in an infinite axis of rotation location) a data exclusion criteria that excluded data points that are further away than “twice the distance between the medial/lateral condyle contact points” from the center of the tibial component was employed. All axes were then plotted with respect to the tibial geometry for statistical comparison.

RESULTS
Figure 1 shows a graphical summary of the instantaneous axis of rotation during the walking cycle for both the Advance® “medial” pivot design (top) and NKII “lateral” pivot TKR design (bottom). The average pivot location during the stance phase of gait is shown in black, and individual pivot points over the entire gait cycle are shown in white.

Table 1 The average center of rotation locations for different phases of the gait cycle. Positive values are defined as a medial distance from the center of the implants geometry in millimeters. It is clear that during the stance phase of gait, the center of rotation is most highly constrained, and that during the swing phase of gait, the center of rotation behaves erratically.

DISCUSSION AND CONCLUSIONS
From these results it is clear that implant geometry plays a critical role in dictating post-TKR rotational kinematics. For this study, standardized loading patterns were used to study the resulting kinematics of each TKR design, insuring that the TKR design alone was the sole variable being tested. To attain true instantaneous axis of rotation results, the tibial component must be free to move in reaction to the applied loads. If the kinematics of the tibia with respect to the femur are restricted or dictated in any way, the simulation and analysis of TKR axis of rotation is not possible. This study has demonstrated that production of “medial pivot” or “lateral pivot” knee kinematics is possible through the use of specialized implant geometries, and that is phenomena can be studied using force-controlled knee simulation.

REFERENCES AND ACKNOWLEDGEMENTS


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