INTRODUCTION
Abnormal patellar tracking is one of the main causes of anterior knee pain and revision of total knee arthroplasty (TKA) [1]. High contact pressure, varying contact points, and complexity of the patellofemoral (PF) soft tissue cause the PF joint to be susceptible to pain after TKA. Several in vivo and in vitro studies have examined patellar tracking in the intact and TKA knees in passive flexion [2]; however, there is limited research that investigates how patellar tracking changes during gait after TKA. A better understanding of patellar tracking in both the native and implanted knee will help improve future prosthetic designs. The purpose of this study was to observe in vitro how patellar tracking is altered after TKA with two implant designs: cruciate-retaining (CR) and posterior stabilized (PS).

METHODS
Eleven fresh frozen cadaveric knee specimens (age: 65 ± 12 years; BMI: 25.2 ± 3.9) were thawed at room temperature and dissected. Each knee was sectioned approximately 22 cm proximal and approximately 19 cm distal to the epicondylar axis. Soft tissue within 10 cm of the knee joint remained intact. The femur and tibia were potted into aluminum fixtures, and the knees were mounted into the Kansas Knee Simulator (KKS) [3]. The KKS is a five-axis hydraulically controlled machine that simulates physiologic dynamic loading activities on cadaveric knees. The International Organization for Standardization (ISO) 14234 walking profile was simulated at half body weight.

An Optotrak 3020 motion capture system (Northern Digital, Ontario) was used to record the kinematics of each bone. Anatomical landmarks on each bone were digitized to describe the PF kinematics using a three cylindrical open-chain coordinate system adapted to the PF joint [4].

Three walk cycles were collected for each knee. After native knee evaluation, an orthopedic surgeon performed TKA. Five specimens received a posterior CR design and six received a PS design (P.F.C.® Sigma fixed bearing, DePuy Orthopedics, Warsaw, IN). All eleven patellar components were a symmetric domed surface. Kinematic measures (flexion, rotation, tilt, and shift) were analyzed for the native and implanted knee with the native knee considered to be the baseline motion.

Differences in PF kinematics between the native and implanted knees were estimated, and a repeated measures three-way MANOVA was performed to find significant difference (p < 0.05). A Tukey post-hoc test was conducted to distinguish differences.

RESULTS
The implanted knees showed a similar tracking pattern to the native knee in both flexion and rotation (Figures 2A & 2B). During the swing phase, the native knee tilted medially with flexion about 5.5°, a phenomenon not observed in either the CR or PS design. Also, the native knee translated laterally approximately 2.5 mm with flexion, but both implanted designs shifted medially with flexion during the same period in the gait cycle (Figure 2D).

Both implant designs demonstrated a significant change in patellar tracking after the knees underwent TKA (Table 1). Patellar rotation and shift were significantly different between the CR and native knee but not between the PS and native knee. The CR and PS designs significantly differ from each other in all four kinematics.

DISCUSSION
The interaction of the surface geometries of the femur and patella affects patellar tracking. The symmetrical dome patella, used in both designs, does not have the asymmetric shape of the native patella, so it may not result in anatomical patellar tracking. Modifying the surface geometry of the PF joint, stuffing the PF joint, releasing patellar ligaments, and surgeon variation change patellar tracking after TKA [5]. Variation in component alignment during TKA affects patellar tracking and yields variation in patellar tracking. This study observed that the tracking pattern differed from the native knee to the implanted designs in patellar flexion and tilt.

The CR and PS designs were different from each other in all four kinematics. The geometrical differences between the two designs may have directly altered patellar tracking. However, tibiofemoral kinematics differ between the two implant designs [6] which causes the patellar tracking to differ between the CR and PS design.

There are a few limitations in this study. The KKS uses only the quadriceps to drive the gait simulation since there is no co-contraction of the hamstrings present in the simulation. Subject-to-subject variation and kinematic description were also sources of uncertainty. The variation in identifying the anatomical landmarks causes the variation in the PF kinematics [7].

This study identified that patellar tracking during gait does change after TKA. Future work will focus on evaluating the effects of component alignment during TKA on patellar tracking.

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REFERENCES

FIGURE 2. Mean patellar flexion (A), rotation (B), tilt (C), and shift (D) motion for all eleven knees across the gait cycle for native knee (solid), CR design (long dash), and PS design (dash dot). Standard deviations for the native knee, CR design, and PS design for flexion were 5.0°, 6.6°, and 4.0°, for rotation were 7.4°, 9.2°, and 6.4°, for tilt were 3.0°, 2.9°, and 5.8°, and for shift were 3.5 mm, 5.2 mm, and 4.7 mm.

TABLE 1. Mean differences (standard error) between the native knee and both the CR and PS designs.

<table>
<thead>
<tr>
<th>Implant Design</th>
<th>Flexion (deg)</th>
<th>Rotation (deg)</th>
<th>Tilt (deg)</th>
<th>Shift (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR</td>
<td>4.8 (0.6)*</td>
<td>-1.9 (0.9)*</td>
<td>-4.5 (0.5)*</td>
<td>1.5 (0.5)*</td>
</tr>
<tr>
<td>PS</td>
<td>1.5 (0.6)**</td>
<td>0.7 (0.9)*</td>
<td>1.8 (0.5)**</td>
<td>-1.0 (0.5)*</td>
</tr>
</tbody>
</table>

* Statistically significant (p<0.05) from native knee
+ Statistically significant (p<0.05) from CR design

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