INTRODUCTION:
Achieving deep flexion after total knee arthroplasty (TKA) is an important goal for many patients in Asia and the Middle East, where lifestyle or religious practices demand floor-sitting postures, and for many Western patients who express a desire for greater knee flexion\(^1\). TKA implant designs are evolving to meet these demands for greater knee function, especially greater knee flexion.

Mobile-bearing TKA's were developed in the late 1970s as a strategy primarily to reduce the risk of aseptic loosening and polyethylene wear. In vitro wear studies have shown mobile-bearing prostheses produced less polyethylene wear than fixed-bearing prostheses\(^2\). Considering contact stresses can be quite high in deep knee flexion, a properly designed mobile-bearing prosthesis might have some advantages in terms of implant function and longevity.

A variety of posterior-stabilized (PS) mobile-bearing TKA designs are marketed. One interesting design difference is the anteroposterior location of the rotation axis for the mobile bearing. In some designs this pivot location is anterior, while in others it is centrally located on the tibial baseplate. The purpose of our pilot study was to characterize the kinematics of a PS mobile-bearing TKA with a central insert pivot location during deep knee flexion activity. We hypothesized the TKA design with a central bearing pivot location will exhibit greater tibial rotation in deep flexion than previously has been reported.

METHODS:
Twelve knees in eleven consecutive patients that underwent mobile-bearing TKA with PFC sigma RP-F (DePuy, Warsaw, IN) were enrolled. The study design was approved by the Institutional Review Board, and all patients provided written informed consent for participation in this study. All TKAs were performed by the same surgeon (YK) from September 2005 to July 2007. A minimally invasive approach with posterior cruciate ligament resection and patella resurfacing were used in all cases. Intraoperatively, appropriate soft tissue releases were done to achieve ligament balance. Two TKAs were excluded from functional assessment due to complications (CVA and dementia), thus ten TKAs were assessed. The average age of patients at surgery was 75 years old (range, 64-86). The average height, weight and body mass index were 155±4 cm, 54±5 kg and 23±2, respectively. The study observations were performed 13±7 months after the operation.

Static radiographs and model-image registration techniques were used to provide detailed three-dimensional knee kinematics during deep flexion. Lateral radiographs were taken in three positions using previously reported protocols\(^3,4\): (1) weight-bearing standing with the leg fully extended, (2) kneeling at maximal flexion with a pad under tibial tubercle and (3) maximum flexion lunge position. The radiographs were digitized and analyzed using published techniques.\(^5\) The three-dimensional position and orientation of the implant components were determined using model-based shape matching techniques, using nonlinear least-squares minimization to refine an initial manual solution.

Three-dimensional angles between femoral and tibial components and anterior-posterior condylar locations at each posture were evaluated. The locations of medial and lateral condyles were estimated as the lowest point on each femoral condyle relative to the transverse plane of the metal tibial baseplate. Paired t-tests were used to compare mean values of parameters for different postures. Pearson correlation was used to explore relations among variables. Values of \(p<0.05\) were considered statistically significant.

RESULTS:
Non-weight bearing maximum knee flexion measured with a goniometer preoperatively and the day of the study was 108°±14° and 114°±12°, respectively. Average knee flexion was 1° in extended stance, 112° in kneeling, and 110° in the lunge posture (Table 1). Maximum knee flexion in the lunge position was significantly correlated with post-operative knee flexion (\(R=0.69, \ p=0.027\)), but not significantly correlated with pre-operative knee flexion (\(R=0.57, \ p=0.085\)).

All knees exhibited tibial rotation with extension to maximum kneeling (10°±7°, range 1°-16°) or lunge (12°±4°, range 4°-18°). Varus-valgus angles averaged 0° for all four postures with small variance. A significant correlation between flexion and tibial internal rotation was not detected (\(R=0.11, \ p=0.77\)). From extension to lunge, the lateral femoral condyle moved 8mm backward, while the medial condyle moved 1mm forward (Table 1). The lateral condyle moved backward with flexion in all cases, whereas the medial condyle moved forward in eight of ten knees.

<table>
<thead>
<tr>
<th>Posture</th>
<th>Flexion (°)</th>
<th>Varus (°)</th>
<th>Tibial External Rotation (°)</th>
<th>Medial Condyle AP (mm)</th>
<th>Lateral Condyle AP (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extension</td>
<td>1°±10°</td>
<td>0°±1°</td>
<td>-7°±8°</td>
<td>3±3</td>
<td>-9±4</td>
</tr>
<tr>
<td>Maximum</td>
<td>12°±12</td>
<td>0°±2°</td>
<td>-14°±10°</td>
<td>2±4</td>
<td>-12±4</td>
</tr>
<tr>
<td>Maximum Lunge</td>
<td>110°±20</td>
<td>0°±1°</td>
<td>-17°±7°</td>
<td>3±4</td>
<td>-16±4</td>
</tr>
</tbody>
</table>

Table 1. Knee three-dimensional angles between femoral and tibial components in each posture.

DISCUSSION:
Our study results show this TKA design provides posterior femoral translation and tibial internal rotation from extension to maximum knee flexion. Several previous reports have examined knee kinematics with PS mobile-bearing TKAs flexing beyond 100° using similar protocols and measurement techniques\(^3,4,5,6\) (Table 2). Our results show larger tibial internal rotation from extension to maximum flexion than previous reports on TKA (2-sample t-test), similar to knees with severe mediolateral OA\(^7\).本次活动 had less rotation than healthy knees\(^10\).

We believe these differences were attributed to location of the pivot. An anterior axis of rotation implies mediolateral translation of the tibial articular surfaces with rotation, potentially causing insert/tissue impingement and diminished total rotation (Fig. 1). The central rotation axis results in less mediolateral translation of the tibial surfaces and might explain why larger tibial rotations were observed.

One study reported very small tibial rotations during deep bending activity using a central pivot prosthesis, albeit a different design than used in this study. Other factors must be considered as contributing to axial traction in flexed postures, including surgical procedures, soft tissue balancing, and ethnicity and lifestyle of patients.

![Figure 1](image-url) Figure 1. The insert rotates 10° relative to tibial baseplate. A) RP-F insert and baseplate (the rotation axis locates center). B) Same insert and baseplate with pivot center located at 1/3 anterior.

REFERENCES: