INTRODUCTION: Mobile-bearing (MB) prostheses for total knee arthroplasty (TKA) have theoretical advantages over fixed-bearing (FB) prostheses in terms of reducing shear forces on the polyethylene insert and the bone-cement prostheses interface, minimizing polyethylene wear, self-aligning, and preventing losses in range of motion. However, clinical studies have not yet proven the superiority of MB prostheses over FB prostheses with regard to range of motion, clinical score, or long-term survival rates.

Several in vivo studies using fluoroscopic imaging and shape-matching techniques have examined knee kinematics after MB TKA. However, few in vivo studies have been conducted to compare the kinematics of MB and FB posterior stabilized (PS) prostheses with an otherwise identical implant design. We believe the kinematic characteristics of MB implants should be contrasted with identical FB designs to elucidate any actual in vivo kinematic differences, preferably in single- or matched-patient series.

Therefore, we have analyzed in vivo kinematic patterns of MB- and FB-PS knee prostheses with the same design with the purpose of detecting implant-related kinematic differences. We hypothesized the MB prostheses would have greater axial rotation, less valgus/varus rotation, and similar ante- and posterior (AP) translation compared with the FB prostheses.

METHODS: We analyzed a total of 48 knees implanted with PS TKA with an identical femoral component. They were classified into 3 groups: 16 knees with MB prosthesis (MB group), matched 16 knees with FB prosthesis (FB group), and 16 knees with FB prosthesis with severe pre-operative varus deformity (SFB group). All patients gave informed consent to take part in the study, which was IRB approved.

Flat-panel radiographic knee images were recorded during dynamic squatting and during static knee postures including full extension standing, lunge and kneeling at maximum flexion. All subjects participated at least 1.5 years after their surgery.

The three-dimensional position and orientation of the implant components were determined using model-based shape matching techniques. The results of this shape-matching process have standard errors of approximately 0.5° to 1.0° for rotations and 0.5 to 1.0 mm for translations in the sagittal plane.

Unpaired t-tests and chi-squared tests were used for comparison of pre-operative demographic data. Analysis of variance (ANOVA) with post hoc tests (Tukey) was used for kinematic comparisons. Probability values less than 0.05 were considered significant.

RESULTS: The maximum implant flexion angles were not significantly different among the MB, FB, and SFB groups either in dynamic and static radiographs. They averaged 105 ± 10°, 108 ± 14°, and 104 ± 14° in squatting, 106 ± 9°, 110 ± 14°, and 105 ± 12° in lunge, and 109 ± 8°, 113 ± 15°, and 110 ± 13° in kneeling, respectively.

The medial condylar AP translations were significantly different between the SFB and the other two groups in dynamic radiographs (Fig. 1a). The lateral condylar AP translations were significantly different between all the three groups (Fig. 1b). However, the total amount of medial and lateral posterior translation was not significantly different between the three groups. Similar AP condylar translation patterns were observed in the static radiographs (Table 1).

There were significant differences in femoral rotation between the FB and the other two groups in dynamic radiographs, (Fig. 1c). However, the total amount of external rotation was not significantly different between the three groups. Similar trends in femoral rotation were observed in the static radiographs (Table 1).

DISCUSSION: To clarify potential kinematic differences between MB and FB PS prostheses, we examined knee kinematics during weight-bearing deep knee flexion in three 16 knee cohorts. Statistically significant, but small differences were observed between matched FB and MB knees, and SFB knees. Similar kinematic results for knees with different initial conditions and tibial inserts indicate a robust treatment with this implant design. However, knees did not exhibit normal tibial rotations or functional flexion ranges. (Note: We report implant flexion angles, which are an average of 12° less than the clinical flexion angles due to posterior tibial slope and anterior femoral bow.)

This is a single-surgeon retrospective study of 48 knees. All surgeries were performed in the same manner, including the surgical approach, bone cutting, soft tissue balancing, and other surgical maneuvers. Having eliminated surgical technique as a significant influence on post-operative kinematics, we focused on the kinematic differences between MB and FB prostheses with an identical femoral component.

The results of this study have not confirmed our first hypothesis: MB knees did not show greater tibial rotations than the FB knees. Our second and third hypotheses were confirmed, as valgus/varus rotations were smaller in the MB knees, and tibio-femoral translations were not significantly different between the three groups. Tibiofemoral translations were well controlled during dynamic weight-bearing activity with similar patterns in all three groups. We did not observe uncontrolled anterior femoral sliding with flexion. LPS Flex FB and MB variants appear to restore stable knee kinematics in static deep flexion postures and in dynamic squat activities. However, these knees did not demonstrate normal tibial rotations or functional flexion ranges.

SIGNIFICANCE: This study is useful for development of implant designs, the indication of TKA, and prediction of post-operative knee kinematics.

Figure 1: Knee kinematics in weight-bearing knee bending. (a) Medial condylar AP translation showed a sigmoid-shaped pattern, and the SFB knees showed a more posterior medial location over the flexion range. (b) Lateral condylar AP translation also showed a sigmoidal-shaped pattern. (c) Femoral external rotation increased with flexion, and the FB group had significantly greater rotation over the flexion range. (d) Valgus/varus angles varied mostly in the FB knees as the condyles rotated and translated on the sagittally curved tibial insert. (Data are shown as the mean ± 1SD. Circles and rectangles indicate significant pair-wise differences.)

Table 1: Knee kinematics in three static knee postures.

<table>
<thead>
<tr>
<th>Group</th>
<th>Posture</th>
<th>Medial AP position (mm)</th>
<th>Lateral AP position (mm)</th>
<th>Femoral external rotation (°)</th>
<th>Valgus / Varus (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FB</td>
<td>Standing</td>
<td>0 ± 2</td>
<td>0 ± 3</td>
<td>1 ± 6</td>
<td>-1 ± 1</td>
</tr>
<tr>
<td></td>
<td>Max lunge</td>
<td>-1 ± 4</td>
<td>-9 ± 3</td>
<td>11 ± 7</td>
<td>0 ± 1</td>
</tr>
<tr>
<td></td>
<td>Max kneeling</td>
<td>-3 ± 4</td>
<td>-8 ± 3</td>
<td>6 ± 7</td>
<td>0 ± 1</td>
</tr>
<tr>
<td>SFB</td>
<td>Standing</td>
<td>-3 ± 2</td>
<td>3 ± 4</td>
<td>0 ± 4</td>
<td>0 ± 1</td>
</tr>
<tr>
<td></td>
<td>Max lunge</td>
<td>9 ± 5</td>
<td>11 ± 6</td>
<td>9 ± 5</td>
<td>1 ± 2</td>
</tr>
<tr>
<td></td>
<td>Max kneeling</td>
<td>9 ± 3</td>
<td>11 ± 3</td>
<td>8 ± 3†</td>
<td>1 ± 7</td>
</tr>
</tbody>
</table>

*: Significant pair-wise difference between the MB and FB group
‡: Significant pair-wise difference between the FB and SFB group
‡: Significant pair-wise difference between the SFB and MB group