THE KINEMATICS OF DEEP FLEXION IN BI-CRUCIATE RETAINING RESURFACING KNEE ARthroplasty

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Introduction

Patient satisfaction with knee arthroplasty depends in large measure on the activities that can be performed comfortably, especially activities involving large knee flexion. It has been demonstrated that knees exhibiting posterior femoral translation with flexion achieve a significantly higher range of weight-bearing motion than those where the femur remains central on the tibia. Unfortunately, it is difficult to achieve reproducible femoral rollback when retaining only the posterior cruciate ligament, and a post and cam mechanism substitution for the ligaments is commonly used to achieve this function. The question remains whether near-physiologic knee motions, including posterior femoral translation, can be achieved in a knee arthroplasty using only natural ligamentous structures.

The purpose of this study was to determine the motions in knees receiving bi-cruciate retaining resurfacing arthroplasty during weight-bearing deep flexion activities. Prior reports on bi-cruciate retaining knee arthroplasty have indicated good clinical results and functional capabilities, but have not addressed knee function in deep flexion activities. It was hypothesized that maintaining both cruciates would provide for physiologic femoral rollback and external rotation with knee flexion.

Methods

Five patients with unilateral bi-cruciate retaining resurfacing knee arthroplasty were studied. All patients provided written consent for this IRB approved study. Patients were 62±15 years of age (range 41-79), 72±7kg weight, and were 22±11 months post-surgery with excellent clinical and functional outcomes. Patients received unicompartmental arthroplasty components in the medial and lateral compartments of the knee (Allegretto, Centerpulse). The components were placed to reproduce normal anatomical joint surfaces, including independent slope and rotation in each tibial compartment. The cruciate ligaments were intact and were not disturbed during surgery.

Patients performed straight-legged standing, kneeling to maximum flexion on a padded bench, and a ‘lunge’ activity where the foot was placed on a 25cm step and the patient flexed the knee to maximum comfortable flexion (above, left). A lateral view of the knee was recorded using fluoroscopy for each activity. Computer assisted shape matching techniques were used to determine the three-dimensional position/orientation of the knee components using shape models developed for each knee (above, right).

The relative locations of the arthroplasty components in each bone segment were determined from a CT scan of the knee. Composite models of the proximal tibia and distal femur were created by placing CAD surface models of the arthroplasty components in registration with the reconstructed bone surfaces (right).

Joint angles were computed using standard methods [Groot and Suntay]. Statistical comparisons were performed using paired t-tests.

Results

<table>
<thead>
<tr>
<th>Knee Flexion (deg)</th>
<th>Kneeling</th>
<th>Lunge</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>123±14</td>
<td>124±12</td>
<td>0.806</td>
<td></td>
</tr>
<tr>
<td>Tibial Abduction (deg)</td>
<td>0±2</td>
<td>0±3</td>
<td>0.897</td>
</tr>
<tr>
<td>Tibial External Rotation (deg)</td>
<td>-3±7</td>
<td>-4±6</td>
<td>0.427</td>
</tr>
<tr>
<td>Medial A/P Translation (mm)</td>
<td>0±5</td>
<td>1±5</td>
<td>0.401</td>
</tr>
<tr>
<td>Lateral A/P Translation (mm)</td>
<td>-4±9</td>
<td>-3±9</td>
<td>0.214</td>
</tr>
</tbody>
</table>

There were no statistically significant differences in joint motions from extension to kneeling or lunge (table above). In both activities the average knee flexion was approximately 124 degrees, ranging from 108 to 136 degrees. For neither activity was there a significant coronal rotation (varus or valgus). Knees exhibited an average of 4 degrees femoral external rotation (tibial internal rotation) at the maximum flexion position. On average, medial condylar location did not change from extension to flexion, while there was an average of 4mm posterior translation of the lateral condyle.

The medial condyle remained anterior to the lateral condyle in deep flexion in all knees (table below). In three knees (patients 2,3,5), there was a net posterior translation of the femur with respect to the tibia during flexing averaging 4.9mm. Two knees (patients 1,4) exhibited a net anterior translation of the femur with flexion averaging 5.3mm.

<table>
<thead>
<tr>
<th>From Extension to Lunge</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee Flexion (deg)</td>
<td>115</td>
<td>134</td>
<td>107</td>
<td>128</td>
<td>133</td>
</tr>
<tr>
<td>Tibial Abduction (deg)</td>
<td>-3</td>
<td>-2</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Tibial External Rotation (deg)</td>
<td>-3</td>
<td>-13</td>
<td>0</td>
<td>-4</td>
<td>2</td>
</tr>
<tr>
<td>Medial A/P Translation (mm)</td>
<td>7</td>
<td>-6</td>
<td>-1</td>
<td>6</td>
<td>-1</td>
</tr>
<tr>
<td>Lateral A/P Translation (mm)</td>
<td>3</td>
<td>-16</td>
<td>-1</td>
<td>6</td>
<td>-7</td>
</tr>
</tbody>
</table>

Discussion

All five knees exhibited weight-bearing knee flexion similar or greater than has been reported for posterior cruciate retaining total knee arthroplasty (TKA). On average, these bi-cruciate retaining knee arthroplasties exhibited a small amount of femoral external rotation and posterior translation with deep flexion activities; three knees exhibited posterior femoral translation and two knees showed anterior femoral translation.

Bi-cruciate retaining arthroplasty appears not to guarantee posterior femoral translation with deep flexion, yet all patients achieved clinically excellent flexion in weight bearing postures. MRI studies of healthy knees indicate that both tibiofemoral translation and axial rotation in deep flexion can be strongly influenced by the axial alignment of the tibia, corresponding to the posture assumed by the patient in performing the motion. Patients in this study were allowed to align themselves in whatever position was comfortable for reaching the greatest flexion. It is interesting to note that the motions for the lunge and kneeling activities were nearly identical for each patient, despite the fact that the external forces acting on the joint were very different for these activities.

In relatively young patients with intact cruciates, bi-cruciate retaining resurfacing arthroplasty appears to be a viable approach to achieving a highly functional joint reconstruction while maintaining maximum bone stock, soft-tissue, and neuromuscular integrity.

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