Introduction

Patellofemoral Pain Syndrome (PFPS) is a prevalent and poorly understood musculoskeletal disorder characterized by anterior knee pain that limits mobility and is thought to lead to arthritis. PFPS is believed to be related to abnormal tracking of the patella in the femoral groove during activities such as walking, running and squatting. The causative role of patellar maltracking in PFPS is not clear because there are few methods for measuring three-dimensional patellar motion in vivo during symptom-generating activities.

We have developed a fluoroscopy-based method to measure three-dimensional kinematics of the patellofemoral joint (PFJ) through its range of movement in loaded flexion in order to distinguish specific patterns of tracking abnormalities that are related to anterior knee pain. The objective of this study was to determine how accurately the fluoroscopy-based method measures patellar tracking.

Methods

Four unembalmed cadaver knees with soft tissue intact (mean age = 44.5 years, minimum/maximum age = 19/65 years) were prepared for imaging by implanting 0.8 mm tantalum beads (n = 6 in each bone) into the femur, tibia and patella of each knee. The knees were imaged using computed tomography (CT, 1.25 mm slice thickness at 1.25 mm intervals), and a surface model of the knee was generated. The coordinates of each of the implanted tantalum beads were determined from the CT images.

Patellar tracking was measured during loaded flexion in each knee with the fluoroscopic technique. Knees were loaded in a rig that holds the femur horizontal and extends the joint by pulling a cord sutured to the quadriceps tendon. A series of single fluoroscopic images (anteroposterior, left anterior oblique and right anterior oblique views) were obtained for approximately ten different positions of knee flexion varying from full extension to 90 degrees. The image intensifier of the fluoroscope machine (OEC 9800, General Electric Company) was fitted with a calibration drum (Figure 1) that permitted the images to be post-processed to correct for distortion and determine the x-ray source location. The calibrated images were then analyzed to determine the locations of the implanted tantalum beads. The two-dimensional location of the markers were registered to the CT coordinate system such that the high-resolution CT model was matched to the position of knee flexion associated with each fluoroscopic image. The position of the patella relative to the femur was then reconstructed for each position of knee flexion and described using a gyroscopic joint coordinate system to determine parameters describing patellar position and orientation.

The two x-ray tubes were oriented at 30 degrees from the perpendicular and positioned 60 inches from the x-ray films secured behind the calibration cage. Pairs of x-ray images were acquired at each of about ten equally spaced positions of flexion as the loaded knee was flexed from full extension to approximately 90 degrees. The films were digitized and analyzed to determine the three-dimensional coordinates of the tantalum beads implanted in the femur, patella and tibia.

Fluoroscopy-based and RSA data describing patellar flexion, tilt and spin and proximal, lateral and anterior translation were plotted as a function of knee flexion angle and splines were fit to both sets of data. Fluoroscopy-based technique of measuring PFJ kinematics has two key advantages over the RSA method. First, it is more broadly applicable because it uses a portable imaging system (C-arm) and does not require a static calibration cage and two static x-ray tubes. Second, because fluoroscopy can record dynamic activity, the fluoroscopic technique can be applied to measure patellar tracking during continuous knee movement. These two advantages make it possible to evaluate patellar tracking during a variety of activities that are known to aggravate anterior knee pain in individuals with PFPS.

<table>
<thead>
<tr>
<th>Patellar Motion</th>
<th>Accuracy</th>
<th>Mean error</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patella Orientation (degrees)</td>
<td>Flexion</td>
<td>1.86</td>
<td>1.55</td>
</tr>
<tr>
<td></td>
<td>Spin</td>
<td>1.16</td>
<td>1.14</td>
</tr>
<tr>
<td></td>
<td>Tilt</td>
<td>1.15</td>
<td>1.10</td>
</tr>
<tr>
<td>Patella Translation (mm)</td>
<td>Proximal</td>
<td>2.11</td>
<td>2.16</td>
</tr>
<tr>
<td></td>
<td>Lateral</td>
<td>0.59</td>
<td>0.47</td>
</tr>
<tr>
<td></td>
<td>Anterior</td>
<td>1.24</td>
<td>1.18</td>
</tr>
</tbody>
</table>

**Table 1. Mean errors (SD) for quantities describing patellar orientation and translation through loaded knee flexion for four cadaver specimens.**

Discussion

The fluoroscopy-based technique successfully measured three-dimensional patellar tracking using planar fluoroscopic images. The accuracy of the fluoroscopy method of measuring patellar tracking in loaded knee flexion was poorer than the reported accuracy of RSA (varying from 0.03 to 0.6 degrees and 0.01 to 0.25 mm). However, the measurement errors are sufficiently low, particularly for patellar orientation, to detect clinically significant differences in patterns of patellar tracking. The fluoroscopy-based method of measuring PFJ kinematics has two key advantages over the RSA method. First, it is more broadly applicable because it uses a portable imaging system (C-arm) and does not require a static calibration cage and two static x-ray tubes. Second, because fluoroscopy can record dynamic activity, the fluoroscopic technique can be applied to measure patellar tracking during continuous knee movement. These two advantages make it possible to evaluate patellar tracking during a variety of activities that are known to aggravate anterior knee pain in individuals with PFPS.

References:

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ACCUillance of a Fluoroscopy Imaging Technique for Assessing Patellar Tracking

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