INTRODUCTION

The patella tilt angle and bisect offset index have been used to quantify the position of the patella relative to the femur (Powers 1998 and Powers 1999). Historically, these measurements have been made from images obtained from standard MR procedures with the femur stabilized and the quadriceps relaxed. Recently, such indices have been used to quantify patellofemoral joint alignment during dynamic weightbearing tasks in which movement of the femur can occur (Ward 2001). Motion of the femur in the sagittal, frontal, and transverse planes may introduce measurement error, as such indices are dependent on the visualization of standardized bony landmarks. Currently, it is not known if observed changes in these indices during activities that allow femoral motion reflect true changes in patellofemoral alignment or are the result of the femur moving out of the fixed imaging plane. The purpose of this investigation was to quantify the error associated with the bisect offset index and the patella tilt angle as a result of the femur being systematically moved through a fixed imaging plane. In addition, the error in quantifying patella rotation and femoral rotation in the transverse plane also was quantified.

METHODS

A cadaveric femur and patella were excised and stripped of soft tissue. The patella was then rigidly fixed within the trochlear groove using a number 8 nylon screw. The mechanical axis of the femur was instrumented distally with a 316 stainless Steinman pin and brass set screw collars, and proximally with a polyethylene total joint acetabulum. The instrumented femur and patella were placed into a custom made non-ferromagnetic jig that allowed controlled sagittal, frontal and transverse plane motions in 5° increments (Figure 1).

Axial plane MR images of the instrumented specimen were obtained with a 1.5T GE Signa scanner (GE medical systems, Milwaukee, WI). A fast spoiled gradient echo pulse sequence (TR 6.5 msec, TE 2.1 msec, NEX 1, flip angle 30°, matrix 256 X 128, FOV 38cm X 38cm) was used to acquire 7mm thick slices of the patella. The imaging plane was localized to the maximum width of the patella and held constant for the remainder of the experiment.

The first image was acquired with the femur in neutral (0° of sagittal, frontal and transverse plane rotation) and was used for reference measurements of bisect offset, patella tilt angle, patella rotation, and femoral rotation. Following this image, progressive positions of the femur in the sagittal plane (0° – 20°), frontal plane (–5° – 10°), and transverse plane (–5° – 25°) were imaged in 5° increments. Next, combined rotations in the sagittal, frontal, and transverse planes were acquired in 5° increments. Images in greater degrees of flexion and adduction were omitted, as appropriate bony landmarks were not visible.

Measurements of bisect offset, patella tilt angle, patella rotation, and femoral rotation were made on each image using a custom written macro for NIH Image (NIH, Bethesda, MD). Briefly, the bisect offset measurement was made by projecting a line perpendicular to the posterior femoral condyles through the deepest portion of the trochlear groove. This line was projected through a line defining the maximum width of the patella width of the patella and allowed the percentage of the patella lying lateral to the trochlear groove to be calculated (Powers 1998 and Powers 1999). The patella tilt angle was the angle formed by the intersection of the posterior femoral condylar line and a line defining the maximum width of the patella (Powers 1998 and Powers 1999). Patella rotation was the angle formed by the line defining maximum width of the patella and the horizontal portion of the imaging field of view (Ward 2002). Femoral rotation was the angle formed between the posterior femoral condyles and the horizontal portion of the imaging field of view (Ward 2002).

Measurement error was calculated by subtracting the measured values of bisect offset, patella tilt angle, patella rotation and femoral rotation from the true values obtained in the reference (neutral) image. When transverse plane rotations were added to the femur, true values of femoral and patella position were calculated and subtracted from the measured values.

RESULTS AND DISCUSSION

The maximum error for bisect offset index was 3% of patella width when the femur was in 5° of sagittal, 10° of frontal and 15° of transverse plane rotation. Maximum error for the patella tilt angle was 2° when the femur was in 10° of...
frontal and 10° of transverse plane rotation. Maximum error for patella rotation was 5° when the femur was rotated 10° into the sagittal plane. Maximum error for femoral rotation was 5° when the femur was for rotated 15° into the sagittal plane.

Increasing the rotation of the femur beyond 5° in any single plane did not produce a linear increase in measurement error. Therefore, mean measurement error across the range of tested rotations could be reported (Table 1). In general, combined rotations in the frontal and transverse planes produced the largest errors.

<table>
<thead>
<tr>
<th>Plane</th>
<th>Bisect Offset</th>
<th>Patella Tilt Angle</th>
<th>Patella Rotation</th>
<th>Femoral Rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sagittal</td>
<td>+/- 1%</td>
<td>+/- 1°</td>
<td>+ 3.1°</td>
<td>- 3.2°</td>
</tr>
<tr>
<td>Frontal</td>
<td>+/- 1%</td>
<td>+/- 1°</td>
<td>+ 1°</td>
<td>- 1°</td>
</tr>
<tr>
<td>Transverse</td>
<td>+/- 2%</td>
<td>+/- 1°</td>
<td>+ 2.9°</td>
<td>- 2.7°</td>
</tr>
<tr>
<td>Combined</td>
<td>+/- 1%</td>
<td>+/- 1°</td>
<td>+ 3.1°</td>
<td>- 3.2°</td>
</tr>
</tbody>
</table>

Positive values indicate overestimates; negative values indicate underestimates.

SUMMARY

The maximum measurement errors of the bisect offset index and the patella tilt angle (3% of patellar width and 2° respectively) are small and clearly within the range of errors associated with repeated measurements of the same image (Powers 1998). The larger maximum errors associated with patella and femoral rotation (5° each) appeared to be influenced most dramatically by sagittal plane motion. Interestingly, medial femoral rotation was consistently underestimated while lateral patella rotation was consistently overestimated across all single and combined plane rotations. The underestimation and overestimation of these variables tended to reduce the measurement error associated with patella tilt angle.

Investigations aimed at assessing patellofemoral alignment during weightbearing movements should consider the impact of femoral motion through a fixed imaging plane. Observed differences less than the mean measurement error for the bisect offset index (2%), patella tilt angle (2°), patella rotation (3°) and femoral rotation (3°) are likely due to measurement error. Observed differences less than or equal to 5° for patella and femoral rotation should be interpreted with caution as they are within the range of maximum error for these measurements.

REFERENCES


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