Introduction

Background

• Total knee arthroplasty (TKA) is performed over 680,000 times per year in the US1.
• About 20% of TKA patients report poor functional outcomes2.
• Outcomes may be improved by designing implants that mimic native knee function.
• Six degree-of-freedom (DOF) kinematics of the knee have been well studied3,4, but there is limited information of the axis of rotation during functional activities.
• Previous attempts to calculate knee axis of rotation were limited by small sample size (3 subjects)5 or the movements were non-functional (supine MRI)6.

Hypotheses

• Determine the knee axis of rotation (KAR) in healthy knees during walking.

Methods

Data Collection

• 20 participants with no history of major knee injury were enrolled in this IRB approved study (10F, 10M; average age: 30.7 ± 6.3 years; BMI 24.1 ± 3.1).
• Four trials of treadmill walking were collected using dynamic biplane radiography (2 trials each of foot strike to mid-stance and mid-stance to terminal swing).
• Bilateral CT scans of the femur and tibia were acquired (0.6 x 0.6 x 1.25 voxel size).

Data Processing

• A previously validated model-based tracking method was used to determine tibiofemoral kinematics with sub-millimeter accuracy7 (Figure 1).
• The KAR was calculated using the finite helical axis method8 for each trial and averaged over all trials for each participant.
• Location of the KAR was calculated as the intersection of the knee axis of rotation and the anatomical sagittal plane of the femur.
• The average absolute SSD of the knee axis of rotation location in the anterior-posterior (AP) and proximal-distal (PD) directions was calculated.

Data Analysis

• Pearson’s correlation tested for a relationship between KAR and knee flexion angle.
• SSD in KAR location were identified at each 10% of the gait cycle using t-tests.
• Significance was set at p < 0.05 for all tests.

Results

• The KAR translated over 20 mm in the AP and PD directions during gait (Figure 2).
• All SSD in KAR location were significant (Table 1).
• Increased knee flexion correlated with a more posterior (ρ = 0.965; p < 0.001) and a more proximal (ρ = 0.431; p < 0.001) KAR location during stance.
• Increased knee flexion correlated with a more posterior KAR location during swing (ρ = 0.761; p < 0.001).

Table 1: The average absolute SSD of Knee Axis of Rotation location (significance)

<table>
<thead>
<tr>
<th></th>
<th>Anterior-Posterior (mm)</th>
<th>Proximal-Distal (mm)</th>
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</thead>
<tbody>
<tr>
<td>Stance</td>
<td>4.6 ± 3.2 (p &lt; 0.01)</td>
<td>9.6 ± 6.5 (p &lt; 0.001)</td>
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<tr>
<td>Swing</td>
<td>4.6 ± 4.0 (p &lt; 0.001)</td>
<td>7.1 ± 5.8 (p &lt; 0.001)</td>
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Discussion

Main Finding

• The average KAR was more anterior and distal at low knee flexion and more posterior and proximal at higher knee flexion.
• These results are similar to van den Bogert et al., who reported larger flexion angles were related to posterior location of KAR during stance phase of gait5.
• The average SSD in KAR location may serve as a reference to assess restoration of “normal” knee function after reconstructive surgery or arthroplasty.
• Strengths: This is the largest study of KAR during the full gait cycle. Multiple movement trials were assessed to determine KAR.
• Limitation: Finite helical axis calculations are inherently noisy and multiple trials may be required to accurately characterize the helical axis of motion.

Clinical Significance

• Knee arthroplasty implants should be designed to accommodate a changing knee axis of rotation to more closely replicate native knee motion.

References and Acknowledgements


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