INTRODUCTION
While total knee arthroplasty (TKA) is an effective method for alleviating pain due to joint diseases such as osteoarthritis (OA), many patients have suboptimal functional outcomes such as an inability to climb stairs and perform other tasks that are important in their daily lives [1]. Surgical technique is a key factor in the outcomes of a TKA [2], but a high degree of variability exists in the alignment of the femoral and tibial components. Due to difficulty in identifying proper anatomic landmarks during surgery, internal/external malalignment of the femoral component can be as high as 13° internal and 16° external, and the alignment of tibial component can range from 44° internal to 46° external [3,4]. In the frontal plane, the components have been historically aligned to create a neutral mechanical axis [5], but more recent research shows potential functional advantages to a “natural” or “kinematic” alignment [6]. Clinical studies have shown the posterior slope of the tibial component vary from -1° to 10°, and flexion of the femoral component varies from 0° to 7° [7].

We believe that variability in component alignment may contribute to the variability in post-operative functional outcomes, but a definitive link between alignment and outcomes has not yet been established. We have previously shown that variability in component alignment in the transverse plane affects ligament forces, knee kinematics, and quadriceps force [8], but the effects of malalignment in the sagittal and frontal planes remains unknown. The purpose of this study was to characterize the relationship between femoral and tibial component orientation in all three planes during a TKA on ligament forces, knee kinematics, and quadriceps force for a cruciate retaining knee implant during a simple squat motion using a forward dynamic simulation of the Oxford Rig device.

METHODS
Using methods similar to those of Thompson et.al. [8], we used a forward dynamic model of the ‘Oxford Rig’, which is commonly used for testing cadaveric samples in the flexed knee stance [9]. The forward dynamic model simulates controlled knee flexion from 20°-120°. To simulate 50% body weight, a 30 kg mass was placed at the pelvis. Resistance to lowering of the pelvis was provided by a lumped quadriceps muscle whose force was determined using a proportional derivative controller. Articular contact forces were determined using a rigid body spring model [10]. Knee angles were found using the convention determined using Grood and Suntay [11].

A cruciate retaining implant design (Scorpio CR; Stryker, Inc.) was used in all simulations. Tibial and femoral component alignments were varied individually and in combination over ranges of 6° varus to 6° valgus, 15° internal to 15° external, and 5° anterior to 10° posterior. The relationship between component alignment and the outcome variables was examined using a regression analysis, where linear, quadratic, and interaction effects were explored. Component alignments with a significant effect (p ≤ 0.05) and with coefficients greater than 1 in the resultant regression equation are summarized in Table 1, and those alignments with the largest coefficients are bolded. Results from 133 simulations with an alignment change in only one plane are presented here; our study of component malalignment in multiple planes is still in process.

RESULTS AND DISCUSSION
Ligament Forces
Internally rotating the femoral component increases the MCL force in late flexion. Placing either
component in valgus generates a MCL force in early flexion that is reduced in late flexion. The combination of both components in valgus generates a greater force than the variation of one component (Figure 1). LCL force is increased only when there are changes in the alignment of both tibial and femoral components. The PCL is most affected by changes in femoral component alignment in the transverse and sagittal planes in deep flexion.

![Figure 1: Effect of Femoral (FC) and Tibial (TC) component alignment on MCL Force.](image)

**Knee Kinematics**

Changing femoral component alignment in the frontal and transverse planes has different effects on knee kinematics (Figure 2), but variation in the frontal plane has a slightly larger effect.

**Quadriceps Force**

Quadriceps force is affected by alignment of both components in the frontal and sagittal planes with the greatest increase in force caused by femoral component alignment in the sagittal plane.

**CONCLUSIONS**

Understanding the relationship between component malalignment and functional outcomes will facilitate the design of new prosthetic components and surgical techniques. The current study suggests that femoral alignment in the frontal and transverse planes and tibial alignment in the frontal plane require the most attention at the time of surgery.

![Figure 2: Effects of FC and TC alignment on knee varus/valgus angle.](image)

**REFERENCES**


**Table 1: Alignment Factors Contributing to Biomechanical Parameters (Principal Alignment in Bold)**

<table>
<thead>
<tr>
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<th>Frontal Component Alignment</th>
<th>Sagittal Component Alignment</th>
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<td>Femoral</td>
<td>Femoral</td>
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<tr>
<td>PCL Force at 120° of Knee Flexion</td>
<td>Femoral, Tibial</td>
<td>Femoral, Tibial, Femoral</td>
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<td>LCL Force at 20° of Knee Flexion</td>
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<td>Femoral, Tibial</td>
<td>Femoral, Tibial</td>
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<td>MCL Force at 20° &amp; 90° of Knee Flexion</td>
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<td>Femoral, Tibial (20°)</td>
<td>Femoral, Tibial</td>
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<tr>
<td>Quad Force at 120° of Knee Flexion</td>
<td>Femoral</td>
<td>Femoral, Tibial</td>
<td>Femoral, Tibial</td>
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