Effect of Tibial Baseplate Mal-Rotation on Knee Kinematics

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Disclosures:
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Introduction: Patellar mal-tracking, patella instability and anterior pain after total knee replacement (TKR) are clinically reported phenomena and are potential causes of revision surgeries [1]. These are most often associated with tibial or femoral component mal-positioning [2]. However, the root cause of these phenomena, especially of anterior pain, is not completely known. Several clinical studies have shown a relationship between mal-rotated femur and tibial components and anterior pain with the focus on tibial baseplate mal-rotation [3]. Nicoll et al. [4] found in a clinical study that a 9° internally mal-rotated tibial baseplate was a significant cut off value associated with pain. Additionally, tibial baseplate rotational mal-alignment can result in improper joint kinematics. However, there are only few studies in literature that have investigated the kinematic consequence of mal-rotated tibial baseplate placement. Thompson et al. [5] showed the effect of rotational variability in femoral and tibial component alignment on the functional outcome of TKR using a simplified computer model of a single knee specimen in an Oxford Rig. Anterior-posterior (AP) translation was found to be more sensitive to tibial component rotational alignment than femoral rotational component alignment. Thus, the objective of this current study is to simulate the effect of internal tibial baseplate mal-rotation on knee kinematics using experimentally (robotically) validated knee models with patient-specific geometry and soft-tissue mechanical properties.

Methods: Specimen use was approved by the local ethics commission. Specimen-specific computer models of four cadaveric knees were created by reconstruction of computer tomography scans and co-registered magnetic resonance images. All mechanically significant soft-tissue structures were incorporated in each model and calibrated by multi-axial robotic testing of each cadaveric specimen. The modeling method had been validated in a previous study [6]. The computer models were driven by in-vivo forces and moments from a previous in vivo study [7] representing a lunge activity. Virtual TKA was performed using the appropriate sizes of contemporary CR, PS and UC designs. Each TKA was virtually implanted in each knee with the tibial baseplate in both neutral and internal mal-rotation (15°). The neutral rotation was defined by aligning the baseplate AP-axis with the PCL-tubercle medial third-axis [8]. The resulting knee kinematics was expressed by the AP motion of the lowest points of the medial and lateral femoral condyles. Additionally, the geometrical relationship between the sulcus of the femoral component and the tibial tubercle was quantified by the lateral offset of the tibial tubercle with respect to the trochlear groove (TTTG) measured along the medial-lateral axis of the femoral component [9].

Results: For 15° of internal tibial baseplate mal-rotation, the differential rollback (lateral rollback minus medial rollback, example: Figure 1 A) and B) decreased by 152 % (3.2 mm to -1.7 mm) for the CR design, by 94 % (2.9 mm to 0.2 mm) for the PS design and by 82 % (2.4 mm to 0.4 mm) for the UC design relative to neutral rotation. This results in an overall average decrease in differential rollback of 109%. On average, with 15° of internal tibial baseplate mal-rotation the TTTG increased by 10.1 mm ± 0.9 mm (-3 mm to +7.1 mm) for the CR design (Figure 2), by 8.8 mm ± 0.5 mm (-1.9 mm to +6.9 mm) for the PS design and by 10.4 mm ± 0.4 mm (-2.8 mm to +7.6 mm) for the UC design relative to a neutral rotation.

Figure 1: A) lateral average rollback and B) medial average rollback
Discussion: The results presented here have shown that a tibial baseplate internal mal-rotation has an influence on the resulting knee kinematics. For all examined designs the differential rollback between lateral and medial femoral condyle was nearly eliminated for an internally mal-rotated tibia baseplate. For the CR design even more medial than lateral rollback was experienced. This decrease in differential rollback stands in contrast to the natural differential rollback and may be related to anterior pain due to anterolateral overstuffing. In literature the TTTG was reported to be greater than 20 mm for 56% of examined individuals with a history of patella dislocation [10]. In our study, the TTTG measure showed an average increase of 9.8 mm for a 15° internally mal-rotated tibial baseplate. This trends toward the value of 20 mm, for which clinical problems have been associated. Furthermore, since a TTTG greater than 20 mm is related to patellar dislocation, there is a probability of inducing anterior pain for lower values. In conclusion, the results of the present study demonstrate that tibia baseplate internal mal-rotation affects knee kinematics in terms of rollback and TTTG. The observed kinematic aberrations could contribute to patella mal-tracking and anterior pain.

Significance: Anterior knee pain is a source of patient dissatisfaction after TKR for which the root cause is not well known. The results of the present study showed the direct effect of tibial baseplate internal mal-rotation after TKR on knee kinematics. Decreased differential rollback and increased TTTG measures were observed, which could be a predictor of patella mal-tracking and anterior pain.

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