Comprehensively Quantify Tibiofemoral Kinematics and ACL Loading by Changing Tibial Osteotomy in a Computational Model

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Summary:
We developed a technique to virtually assess the biomechanical impact of slope changing tibial osteotomy in a computational model to aid surgeons in selecting a target tibial slope in revision ACL reconstruction on a patient-specific basis.

Data:
Introduction Increased posterior-inferior directed slope of the tibial plateau (i.e., tibial slope) is related to elevated risk of ACL reconstruction failure [1]. Biomechanical studies link this risk factor for ACL graft tear to increases in both anterior tibial translation (ATT) and ACL graft force [2]. Therefore, some surgeons combine ACL graft revisions with anterior closing wedge high tibial osteotomy (ACWHTO) [3]. Too small of a correction, however, may not adequately reduce ACL forces while too large of a correction may increase PCL forces and elevate risk of injury to this ligament or cause knee recurvatum [4]. Unfortunately, the relationship between tibial slope and important biomechanical outcome measures such as cruciate ligament forces and tibiofemoral kinematics remains poorly understood. Thus, we had two goals. First was to develop a technique to conduct virtual tibial osteotomy in a computational model. Second was to quantify sensitivity of ACL, PCL, and meniscal root forces and tibiofemoral kinematics to tibial slope changes. Methods A computer model of the tibiofemoral joint was developed from CT and MRI data of a right cadaveric knee of a 25-year-old female. Volumetric reconstructions of the tibia, femur, cartilage, and menisci along with the insertions of the cruciates, collaterals, capsular tissues, and peripheral and root attachments of the menisci were imported into the modeling pipeline. ACWHTO was simulated by removing a 10° wedge from the volumetric reconstruction of the tibia. The osteotomy was perpendicular to the sagittal plane and intersected the posterior-most aspect of the PCL. The computer models were loaded with 100 N compression and with loads simulating a clinical pivot shift maneuver consisting of serially applied compression (100 N), valgus (4 Nm), internal rotation (2 Nm), and an anterior force (30 N) at 15° of flexion. Outcomes measures were ATT, internal tibial rotation (ITR), and forces carried by the ACL and PCL and posterior roots of the menisci at the peak applied loads. Results With the simulated pivoting load, a 10° decrease in tibial slope caused a 63 N decrease and a 6 N increase in ACL and PCL force, respectively. The 10° decrease in tibial slope also decreased ATT by 7 mm and increased ITR by 2°. With isolated compression, the 10° decrease in tibial slope caused a 37 N decrease and an 8 N increase in ACL and PCL force, respectively, and a 7 mm decrease in ATT and 0.5° increase in ITR. Changes in posterior root forces of both menisci were minimal (±5.4 N). Discussion We developed a technique to virtually assess the biomechanical impact of slope changing tibial osteotomy in a computational model. Model predictions of decreased ACL force and increased PCL force with reduced tibial slope corroborate cadaveric studies [2,5]. This workflow could be used to determine cruciate forces and tibiofemoral kinematics to aid surgeons in selecting a target tibial slope on a patient-specific basis.

Category: Knee - Osteotomy

Joint Line Obliquity (JLO) has an Independent and Significant Effect on Peak Lateral Compartment Compressive Load During Walking after Medial Opening Wedge High Tibial Osteotomy (HTO)

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Summary:
Combined analysis of radiological and clinical results following DLO showed that large preoperative JLCA was a significant prognostic factor affecting the radiological and clinical outcomes. In cases with JLCA of 4° or more, accuracy of the deformity correction was impaired resulting in less optimal postoperative alignment.

Data:
Background: Double level osteotomy (DLO) has been indicated for symptomatic severe varus malalignment with the intent of restoring physiologic joint anatomy. However, there is a paucity of information regarding the efficacy of this procedure in attainment of physiologic alignment as well as the relationship between the pre- and postoperative radiological parameters and clinical outcomes. Purpose: To examine coronal alignment and bony geometry before and after DLO and their effects on the clinical outcome. Method: The study population was composed of 74 consecutive patients with mean age of 61.1 years (range, 45-76 years) who underwent DLO for severe varus osteoarthritic knees. DLO was adopted as a surgical option when there were combined varus deformities both in the distal femur and the proximal tibia. As for the intended limb alignment, the postoperative hip-knee-ankle angle (HKAA) was set to +1° valgus. The pre- and postoperative radiological and clinical data were retrospectively reviewed for the data acquisition and subjected to the analysis. All the patients could be followed up with for a minimum of 2 years. In the radiological evaluation, mechanical lateral distal femoral angle, mechanical medial proximal tibial angle, joint line convergence angle (JLCA) and HKAA were measured as parameters for the analysis. Outliers were defined as those with deviation of more than 3° from the intended postoperative HKAA (+1° valgus). The relationship between clinical outcomes using the Knee Injury and Osteoarthritis Outcome Score (KOOS) and radiological parameters were statistically assessed. Results: The radiological evaluation showed that the HKAA was corrected from 13.2 ± 3.0° varus to 0.5° ± 2.8° varus at 2 years after DLO, indicating slight undercorrection on average. Assessment of clinical outcome using the KOOS showed significant improvement from 185 ± 74 before surgery to 388 ± 72 at 2 years. As for the analysis of relationship among various radiological parameters, incidence of the postoperative outlier was significantly higher in patients with preoperative JLCA > 4° than those with JLCA < 4° (39.5% vs. 16.1%, p = 0.03). Correlation analysis between clinical score and postoperative alignment showed positive correlation between KOOS at 2 years and postoperative HKAA (r=0.47, p < 0.01), and the average KOOS at 2 years was significantly lower in the outliers than in the non-outliers (343 ± 62 vs 410 ± 57, p < 0.01). Conclusions: Combined analysis of radiological and clinical results following DLO showed that large preoperative JLCA was a significant prognostic factor affecting the radiological and clinical outcomes. In cases with JLCA of 4° or more, accuracy of the deformity correction was impaired resulting in less optimal postoperative alignment. Consequently, clinical outcomes were inferior in that group of knees.

Category: Knee - Osteotomy

Computational Model of Slope Changing Tibial Osteotomy to Comprehensively Quantify Tibiofemoral Kinematics and ACL Loading

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Summary:
We developed a technique to virtually assess the biomechanical impact of slope changing tibial osteotomy in a computational model to aid surgeons in selecting a target tibial slope in revision ACL reconstruction on a patient-specific basis.

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