INTRODUCTION:

High tibial osteotomies (HTOs) are commonly performed to treat lower extremity malalignments. Traditionally, this technique is used to correct varus-valgus deformities in the coronal plane. However, tibial slope may be inadvertently altered in the sagittal plane as well [1]. The effects of this alteration on knee biomechonics are not well understood. The objective of this study was to evaluate the effects of increasing tibial slope on knee kinematics and *in situ* forces in the cruciate ligaments under axial and anterior-posterior (A-P) tibial loads. We hypothesized that increasing tibial slope would increase anterior tibial translation and *in situ* force in the ACL while decreasing posterior tibial translation and *in situ* force in the PCL.

METHODS:

Five human cadaveric knees (60-78 years) were tested using a robotic/universal force moment sensor (UFS) testing system [4]. A lateral radiograph was taken at 30° of flexion and the slope of the medial tibial plateau was measured. The path of passive flexion-extension (F-E) of the intact knee was determined from 0° to 120° by minimizing external forces and moments in the other 5 DOF at each flexion angle. These positions served as references for the measurement of kinematics and application of external loads. Two external loads were applied at 30° and 90° of flexion: 1) 200 N axial compression (along the tibial axis), and 2) combined 134 N A-P tibial load and 200 N axial compression. The 5 DOF kinematics of the intact knee under each load were recorded.

To increase tibial slope, an anterior opening wedge osteotomy was performed and rigidly fixed using a 5 mm Puddu plate (Arthrex) on the anteromedial aspect of the tibia. The gap in the bone was filled using PMMA, and the new tibial slope was measured. A new path of passive F-E of the osteotomized knee was then determined. All subsequent measurements of knee kinematics were made relative to these new resting (i.e., starting) positions [5]. The two external loads were again applied and the resulting kinematics were recorded.

The ACL or PCL was then transected with the order of sectioning alternated between specimens. The previously determined knee kinematics for the osteotomized knee were repeated and a new set of forces was measured. Using the principle of superposition, the vector difference in force between the two tests is the *in situ* force in the ACL or PCL [4]. The *in situ* force in the remaining cruciate ligament was found in the same manner.

Statistical analysis of kinematic data consisted of repeated measures ANOVA with multiple contrasts. The *in situ* forces in the cruciates for the osteotomized knee were compared to previous data from the intact knee [3] using a two factor ANOVA (p<0.05).

RESULTS:

Tibial slope averaged 6.5 ± 1.0° in the intact knee. Following opening wedge osteotomy, the slope increased to 10.5 ± 1.5°. This increase caused an anterior translation of the resting (i.e., starting) position of the tibia relative to the femur ranging from 3.0 ± 2.1 mm at 30° to 1.8 ± 1.4 at 120° (Figure 1).

Under 200 N axial load, osteotomy caused a significant relative anterior tibial translation compared to the intact knee of 3.4 ± 2.1 mm and 1.6 ± 1.5 mm at 30° and 90°, respectively (p<0.05, Figure 2). Under combined A-P and axial loading, differences between the total A-P translation at 30° or 90° were less than 1 mm. There were no differences between the *in situ* forces in the cruciates for the intact and osteotomized knees under either loading condition.

DISCUSSION:

In this study, an increase in tibial slope caused an anterior shift in the resting position of the tibia relative to the femur throughout the range of knee flexion. Furthermore, axial loading caused an additional increase in anterior tibial translation in the osteotomized knee compared to the intact knee condition. Anteromedial opening wedge HTOs have recently been described for the treatment of the PCL deficient knee [1]. Our data suggest that increasing tibial slope may may reduce posterior tibial sag in this setting.

Under the combined A-P and axial load, increasing tibial slope could not be shown to significantly affect tibial translations or *in situ* forces in the cruciate ligaments. This finding is contrary to our hypothesis and may be a result of the change in the relative positions of the cruciate insertions. Our data suggest that small inadvertent increases in tibial slope that can occur during medial opening-wedge HTOs may not impact the overall knee laxity or have adverse effects on the cruciate ligaments. However, the changes observed in resting position with the osteotomy suggest that tibiofemoral contact is affected. Further study is needed to delineate the full implications of altered tibial slope on contact pressures and biomechanics of the intact and ligament-deficient knees.

**REFERENCES**


**ACKNOWLEDGMENTS**: Theodore Rudy, MA, Jennifer Zeminski, BS, and C. Benjamin Ma, MD, and support of the NOSFF and AOSSM.