

COMPUTATIONAL ASSESSMENT OF ANTEROPOSTERIOR LAXITY FOLLOWING PARTIAL PCL RELEASE IN CRUCIATE-RETAINING TKR

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INTRODUCTION

Proper tensioning of the posterior cruciate ligament (PCL) achieved by adequate joint line restoration has been cited as a key determinant of success in PCL retaining total knee replacement (PCR-TKR) [1]. Tensioning of the PCL is thought to be important because it affects anterior-posterior (AP) stability and knee kinematics following PCR. Modifying the joint line following total knee replacement (TKR) could affect PCL tensions and consequently alter knee stability and function. Joint line elevation commonly follows PCR-TKR [2] and has the potential to tighten the PCL and restrict range of motion (ROM). In cases where PCL tightness limits ROM, a partial PCL release has been advocated [1], but few studies have addressed the effect of this procedure on AP laxity. The purpose of the present study was to create a computational model to investigate the effect of partial PCL release on AP laxity characteristics following PCR-TKR as compared to a posterior cruciate-substituting (PS) knee design. Varying degrees of release and three PCR tibial insert designs (condylar, anteriorly-lipped, and ultra-conforming) were tested for AP laxity. It was hypothesized that partial PCL release would increase AP displacements at higher flexion angles, but an ultra-conforming insert would limit these displacements more than the other two designs.

METHODS

A forward-dynamic computer simulation of the American Society for Testing and Materials protocol for testing AP constraint (ASTM F1223-04) was created and its output was found to compare well to experimental results obtained for PS knee components [3]. The model for this study incorporated 8 spring-like elements representing the anterior-lateral (AL) and posterior-medial functional bundles of the PCL respectively. Ligament insertions, stiffness, and slack lengths were assigned based on values reported in literature [4, 5]. The natural knee motions reported by Walker et al. were applied to the model and the resulting ligament length patterns were found to compare favorably to experimental values [6]. Anterior-posterior laxity test simulations were run at 0°, 30°, 75° and 90° for all three PCR tibial inserts and for intact PCL, partial AL-PCL release (half of the bundle was released), and complete AL-PCL release. At each flexion angle an 80 N anterior force and 80 N posterior force were applied to the tibial insert and the total AP displacement was recorded. The inserts were under a constant 200 N compressive axial load, the femoral component was free to move in the frontal plane, and contact friction was not modeled.

RESULTS

With the PCL intact, the design of the tibial insert affected AP laxity measures at smaller flexion angles but did not influence displacements at either 75° or 90° flexion. The standard condylar insert exhibited 70% more and 215% more AP displacement than either the anterior-lipped or ultra-

conforming inserts at 0° and 30° flexion, respectively. AL-PCL release, either partial or complete, affected AP laxity measures at larger flexion angles while having minimal influence at smaller flexion angles (Figure 1). With a partial release of the AL bundle over all angles, the standard condylar and anterior-lipped insert displayed an average displacement increase of 1.2 mm, while displacement for the conforming insert increased by only 0.6 mm. With a complete release of the AL bundle, the standard condylar and anterior-lipped insert displayed an average displacement increase of 3.3 mm, while the conforming insert increased only 1.9 mm.

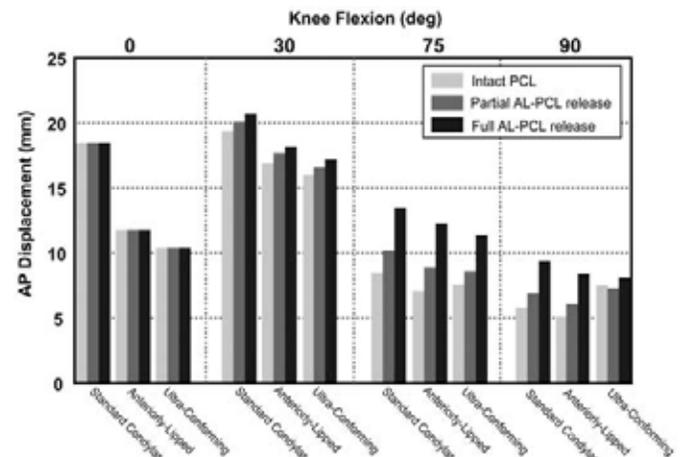


Figure 1: Effect of partial and complete release of the anterolateral (AL) bundle of PCL on AP laxity.

DISCUSSION

Selective release of the PCL to attain a proper flexion arc substantially increased the maximum AP displacement at 75° and 90° flexion regardless of insert design. At higher flexion angles PCL tension contributes more to AP stability than does insert conformity. When the knee is near full extension and PCL tensions are lower, conforming designs provide a more stable joint. The changes in AP displacement determined in this study are likely to be functionally significant; smaller changes in displacement have been used clinically to differentiate between injured and healthy knees [7].

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