INFLUENCE OF POSTERIOR CRUCIATE LIGAMENT TREATMENT ON QUADRICEPS DEMAND IN TKR: A COMPUTER SIMULATION STUDY

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INTRODUCTION

Treatment of the posterior cruciate ligament (PCL) is an important consideration for surgeons who perform total knee arthroplasty. Cruciate-retaining (CR) knee replacement designs rely upon the natural PCL to control anteroposterior movement of the femur upon the tibia, while posterior-stabilized (PS) designs sacrifice the PCL and employ a cam-post mechanism to accomplish the same task. These different approaches have the potential to affect the efficiency of the extensor mechanism, which is critical to regaining function postoperatively. Yoshiya et al. (2005) measured tibiofemoral contact points *in vivo* and found PS knees to have more 'posterior rollback' than did CR designs, but it was not clear if these kinematic differences corresponded to changes in extensor mechanism efficiency. The purpose of this study was to use a computational model to investigate the influence of PCL treatment (CR versus PS) on the demands of the quadriceps and location of the axis of rotation following knee arthroplasty.

METHODS AND PROCEDURES

The lower extremity model described by Delp et al. (1990) was reconfigured into a 12-degree-of-freedom forward-dynamic model to replicate an 'Oxford Rig' cadaver test arrangement in which a controlled knee flexion from 20° - 120° was performed under quadriceps control. A 30 kg mass was placed at the pelvis to simulate body weight, and the attachments of the vastus intermedius were used to represent a lumped quadriceps muscle group. The quadriceps force necessary to lower the pelvis at a constant rate (3.9 cm/s) was determined using a modified version of the Computed Muscle Control algorithm described by Thelen et al. (2003).

The PCL was modeled by ten ligament fibers with slack lengths chosen such that the PCL engaged at 80° of knee flexion when normal knee motions were applied (Makino et al., 2006). Passive muscle forces and collateral ligaments were modeled with force-length and force-velocity relationships. PS and CR versions of the same knee replacement design (Scorpio; Stryker Orthopaedics, Inc.) were compared using the simulation. Patellofemoral and tibiofemoral contact was modeled using a rigid body spring model (Li et al., 1997).

Knee joint angles were computed following the convention of Grood and Suntay (1983). Axes of rotation between the femur and tibia were located throughout the flexion movement by computing finite helical axis.

RESULTS AND DISCUSSION

The quadriceps forces required to perform the knee flexion task were found to be similar for PS and CR designs at low knee flexion angles. At angles higher than 70°, however, the quadriceps in the CR model were required to exert forces that were 5% - 10% higher than those demanded of the quadriceps when effecting the same motion for the PS-implanted model (Figure 1).

The axes of rotation between the tibia and femur were nearly immobile in the femoral frame of reference for both PS and CR knees from 20° - 70° of flexion (Figure 2). At higher flexion angles, however, there was substantial motion of the axis of rotation for the PS design, while the axis for the CR design remained in place. The greater motion of the axis of rotation in the PS design is likely caused by the action of the cam-post mechanism, which was found to engage at 70°.

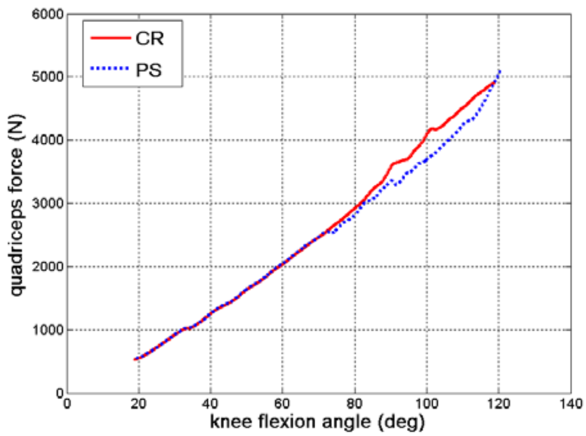

Figure 1: Vastus intermedius forces plotted against knee flexion angle for CR and PS knees.

SUMMARY/CONCLUSIONS

Investigations of the determinants of knee extensor efficiency afforded by different implant designs are important for improving functional outcomes following knee replacement. In this study, the movement of the axis of rotation at high flexion angles mediated by the cam-post mechanism of the PS design appears to lessen the demands on the quadriceps at high flexion angles.

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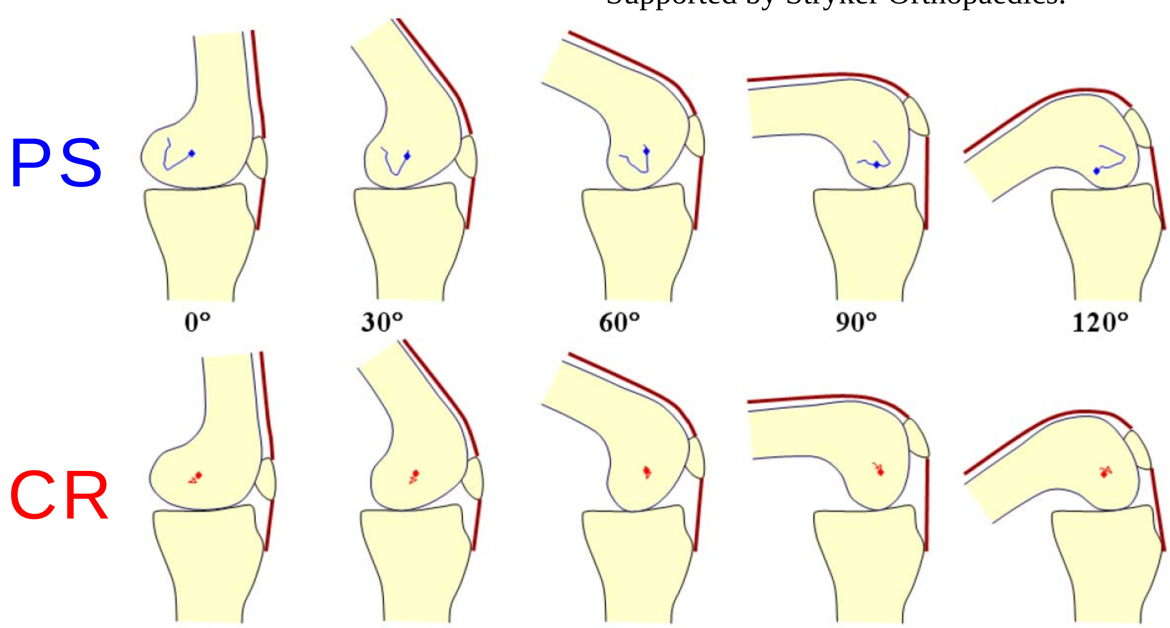

Figure 2: A cartoon representing the paths of the axes of rotation. Translations are noted by the blue lines (PS) and red lines (CR) on the femur. The colored dot represents the current location of the axis of rotation for the knee flexion angle shown.