Effect of Femoral Component Rotation in a Mobile-Bearing Knee Design on Patellofemoral Biomechanics

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Introduction: Patellofemoral complications after total knee arthroplasty are still one of the major factors leading to revision. Abnormal patellar tracking has been implicated as one of the reasons. Femoral component malrotation affects mediolateral knee balance in flexion and can also alter patellofemoral biomechanics. However, this effect has not been well defined. Rotating platform, mobile-bearing designs can correct rotational mismatch between tibial and femoral components. We tested the hypothesis that mobile-bearing designs may also correct the patellofemoral biomechanical changes induced by femoral component malrotation.

Materials and Methods: Cadaver model: A normal fresh-frozen cadaver, lower extremity specimen was CT scanned and segmented to obtain the surface geometry of the femur and tibia. The knee was surgically implanted with Scorpioª CR (Stryker Orthopaedics, Mahwah, NJ) components using a Stryker Navigation system. The femur was implanted perpendicular to the mechanical axis of the femur in the coronal and sagittal planes and parallel to the transepicondylar line in the axial plane. The tibial tray was implanted perpendicular to the tibial axis in coro-nal and sagittal planes. The bony attachments of the collateral ligaments, posterior cruciate ligaments, patellar tendon, and quadriceps tendon were digitized using the Stryker Navigation system.

The femur was mounted rigidly in the horizontal position (parallel to the floor) in a custom testing rig. An electric motor applied tensile force on the quadriceps tendon via a nylon strap to extend the tibia against gravity (simulating a seated open-kinetic-chain knee extension). The tibial tray was instrumented with force transducers to measure the tibiofemoral force. Navigation trackers mounted on the femur, tibia and patella measured knee kinematics.

Computer model: CAD models of the femoral, tibial and patellar components (Scorpio CR) were virtually “implanted” in the bony geometry obtained from the CT scan of a cadaver specimen using digitized landmarks obtained by the Stryker Navigation system. A Scorpio CR insert design was used for the fixed condition and a Scorpio Rotating Platform design was used for the mobile-bearing condition. The soft tissues (collateral ligaments, posterior cruciate ligaments, patellar tendon and quadriceps tendon) were modeled as non-linear springs. The model computed tibiofemoral and patellofemoral kinematics and contact forces during simulated quadriceps contraction when the femoral component was malrotated ±3° relative to the epicondylar axis.

Model validation: Experimentally measured tibial forces and tibial axial rotation during knee extension were used to validate the computational model. A maximum absolute error of 10% between experimental measurements and predictions was used as acceptable validation.

Results: Femoral component was rotated ±3° of axial rotation and tibial rotation correlated well (R² = 0.96) but with a lower magnitude (slope = 0.6). Tibial rotation pattern changed substantially with femoral component rotation during knee extension (0 – 90°). Patellar tilt (Fig 2) also changed with the patella tilting laterally (relative to the femur) with femoral component external rotation and tilting medially with femoral component internal rotation; however, patellar shift did not change significantly. Femoral component internal rotation increased lateral patellar shear while external rotation reduced lateral shear.

Mobile bearing: The mobile bearing tended to rotate with the femoral component thus minimizing the effect of femoral component malrotation on tibiofemoral rotation. However, changes in patellar tilt and lateral shear with femoral component malrotation in the mobile-bearing condition were similar to those in the fixed-bearing condition (Fig 2).

Discussion: As expected, rotation of the femoral component affected tibial rotation and affected patellar tilt and shear in the fixed-bearing condition. In the mobile-bearing condition, the bearing aligned with the femoral component (especially in extension) leaving the extensor mechanism aligned with the tibia. Therefore, internal rotation of the femoral component increased lateral stresses on the patella in the fixed-bearing condition.

However, the effect of femoral rotation on patellofemoral biomechanics is more complex. In extension, internal rotation of the femoral component was associated with internal rotation of fixed bearing and the tibia (including the tibial tubercle attachment of patellar ligament) thus countering some of the increased lateral shear on the patella. In the rotating-platform design, the bearing aligned with the femoral component but left the tibia relatively externally rotated resulting in later- al patellar shear. In flexion, external rotation of the femoral component tends to medially direct the trochlear groove with increased lateral patellar shear and drives the tibial tray into varus, which cannot be corrected by the rotating platform design.

These results indicate that the mobile-bearing insert may reduce malalignment in tibiofemoral rotation but cannot correct the altered patellar biomechanics produced by axial malalignment of the femoral component. Increased accuracy in aligning the femoral component in axial rotation is therefore necessary.


Fig 1. A rigid body dynamic model of knee arthroplasty was developed in MSC.ADAMS (MSC Software, Santa Ana, CA).

Fig 2. Patellar lateral tilt was substantially altered with femoral component rotation. No significant differences were noted between fixed-bearing (dotted lines) and mobile-bearing (solid lines) conditions.