Mobile-bearing kinematics in PCL-retaining total knee arthroplasty. A study of 51 cases

Julien Chouteau1,2,3, Jean-Luc Lerat1, Rodlph Testa1, Bernard Moyen1,2, Michel-Henry Fessy1, Scott A. Banks3

1Department of Orthopaedics, trauma and sport medicine, Lyon-Sud Hospital, Pierre-Bénite, France; 2Université Lyon 1, F-69003; Institut National de Recherche sur les Transports et leur Sécurité, Bron, F-69675, Laboratoire de Biomécanique et Mécanique des Chocs - UMR_T 9406, Faculté de médecine Lyon Sud, Oullins, F-69921, France; 3Orthopaedic Biomechanics Lab, Mechanical and Aerospace Engineering, University of Florida, Gainesville, FL
jchoute@hotmail.com

Introduction: Mobile bearing total knee arthroplasty (MB-TKA) was developed to provide low contact stress and reasonably unrestricted joint motion. The rotational freedom of the articulation and the potential anterior-posterior glide of the bearing provide a self-aligning characteristic, i.e. the bearing has the ability to align according to individual forces and anatomical conditions. The design goal is to enhance conformity between femoral and tibial components in all positions.

The purpose of this study was to evaluate mobility of the PE mobile-bearing relative to the femoral and tibial components under weight-bearing conditions, at an average of 23 postoperative months. We hypothesized that, according to the specific MB-TKA design used, tibiofemoral AP translation and axial rotation would mostly occur between the mobile-bearing and the tibial tray.

Materials and Methods: Kinematic analyses were performed on a series of 51 primary TKAs. Mean age was 71±8 years (22 to 84) at operation. All knee arthroplasties were performed through an anteromedial approach. All patients had a cementless, mobile-bearing, posterior cruciate ligament-retaining knee arthroplasty (INNEX® Anterior-Posterior Glide, Zimmer). Detailed preoperative planning, as reported by Lerat [1], guided surgical cuts. The extra-medullary tibial cut guide was placed to provide 6° of posterior tibial slope. Final release of collateral ligaments was conducted after implanting trial components.

All patients had radiographic examinations at an average 23 postoperative months follow-up (10-65) that included three lateral views according to a standard clinical protocol: weight-bearing radiographs at full-extension, 30° flexion and maximal flexion.

Three metallic beads had been inserted at known positions into each PE insert at the time of manufacture. 3D CAD models of the femoral, tibial and bearing were used to determine 3D kinematics via 3D-to-2D model-image registration [2-5]. Paired t-tests were used to compare mean parameters (Stat View 5.0®, SAS Institute Inc).

Results: The mean maximal implant flexion angle achieved was 104°±12° (72° to 127°) at 23 postoperative months. All flexion occurred between the femoral component and the mobile-bearing - no flexion was observed between the mobile-bearing and tibial tray. Implant hyperextension averaged -6°±9° (-25° to 21°) and no hyperextension was observed between mobile-bearing and tibial tray. The average weight-bearing range of implant motion was 110°±14° (64° to 136°).

Flexion produced a progressive internal rotation of the tibial tray relative to the femoral component from an average of -1°±7° (-19° to 13°) at full-extension to an average of -9°±7° (-24° to 3°) at maximal flexion. We found a statistically significant increasing internal rotation of the bearing with flexion up to -3°±3 between the femoral component and mobile bearing (p=0.0001), and up to -5°±7 between the tibial tray and mobile-bearing (p=0.0001).

The medial femoral condyle, with respect to the mobile bearing, didn't translate from full extension to 30° flexion and from 30° flexion to maximal flexion [0±2mm (-2 to 5)]; 0±3mm (-7 to 7); respectively. The lateral femoral condyle exhibited a statistically significant average of ±11mm (-4 to 3) posterior translation from full extension to 30° flexion (p=0.0001), and 1±3mm (-10 to 5) posterior translation from 30° flexion to maximal flexion (p=0.004). The mobile bearing didn't translate relative to the tibial base plate from full extension to 30° flexion [0±2mm (-5 to 6)]. A statistically significant anterior translation of the mobile bearing (p=0.0001) occurred between 30° flexion and maximal flexion, averaging 1±2mm (-2 to 9).

Discussion: Surgical balancing of the ligaments and soft tissues can have a significant effect on weight-bearing TKA kinematics, especially when unconstrained prosthetic designs are employed [6]. Mobile-bearing TKA kinematics also can be restricted by fibrous tissue at the periphery of the mobile bearing insert [7]. Previous studies have reported relatively small bearing motions because of nonconforming femur-bearing articular surfaces allowing "top-side" translation [7,8]. Others have reported PE bearing rotation relative to the tibial tray and minimal rotation relative to the femoral component[9,10]. In the current study, the mobile-bearing exhibited mobility at all positions. Mobility mainly occurred between the tibial base plate and the mobile-bearing. However, with flexion, an increasing mobility occurred between the femoral component and the mobile-bearing, probably because of lower conformity between components.

Mobile bearing rotation with MB-TKAs appears to vary with designs. One study of posterior cruciate sacrificing MB-TKA, maximal internal rotation of the mobile bearing of 5.9° and 10.8° for the femoral component was reported [7]. Greater internal rotation of mobile bearing with flexion, from 8.4° to 10.3°, also has been reported [9]. In this study, the mobile-bearing exhibited increasing internal rotation with flexion. Rotation was confined to bearing-baseplate rotation when the knee was extended. With increasing flexion, the amount of femoral component rotation relative to the mobile bearing increased.

With the LCS anterior-posterior glide MB-TKA [9], mobile bearing AP translation averaged 5.6mm (1 to 12.5mm). In our study, there was significant variability in translations which were equally distributed anterior and posterior to the tibial midline – hence 0mm average translation. AP translation did occur between the femoral component and mobile bearing and between mobile bearing and tibial base plate, but mobile-bearing AP translation was unpredictable with this unconstrained design.