In Vivo Kinematics for Customized, Individually Made vs. Traditional TKA During a Chair Rise and Deep Knee Bend Activity

Bradley A. Meccia, B.S., Harold Cates, MD, Matthew Anderle, B.S., William Hamel, PhD,Adrija Sharma, PhD, Richard D. Komistek, PhD.

University of Tennessee - Center for Musculoskeletal Research, Knoxville, TN, USA, Tennessee Orthopaedic Clinic, Knoxville, TN, USA.

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Introduction: Previously, fluoroscopic studies have been conducted using a stationary fluoroscopy unit to record movement of a patient. However, these studies may fail to reproduce day to day kinematics as subjects must alter the way they perform the activity to keep the artificial knee in the fluoroscopic viewing area. More recently, a robotic mobile fluoroscopy unit was developed which tracks the motion of the implanted knees (Figure 1). In this way, the kinematics of a more natural motion are captured as subjects perform unconstrained motions that accurately replicate the everyday demands placed on their operated knees. The objective of this study was to determine the in vivo kinematics for subjects having either a customized individually made (CIM) posterior cruciate retaining implant or an off-the-shelf (OTS) posterior cruciate retaining (CR) implant while performing both a deep knee bend to maximum knee flexion and while rising from a chair. We hypothesized that since the CIM implants are constructed using a Computed Topography scan to manufacture an implant which accurately reproduces the patients’ articulating geometries, patients implanted with the CIM TKA will exhibit more normal kinematic patterns than patients implanted with an OTS TKA.

Methods: Twenty subjects, having either a CIM or standard OTS CR knee implants, implanted by the same surgeon, were assessed in this study. Ten subjects had a CIM CR total knee arthroplasty (TKA) and 10 were implanted with a standard OTS CR TKA. Fluoroscopic videos were captured for the patients while they performed both a deep knee bend activity to maximum knee flexion and while performing a chair-rise under mobile fluoroscopic surveillance. Each video was digitized, corrected for distortion, and then analyzed to determine kinematics using a 2D to 3D image registration technique (Figure 2). This method has been validated to have an error of less than 0.5° for rotational values and 0.5 mm for in-plane translations.

Results: Subjects in this study having a CIM TKA achieved greater axial rotation and more normal femorotibial contact patterns than their OTS counterparts. During a deep knee bend, on average, subjects having a CIM TKA experienced -3.5 mm of posterior femoral rollback compared to only -1.3 mm for subjects having a standard OTS TKA. The average amount of axial rotation was similar for the two groups (CIM = 4.6°, Standard OTS = 4.4°). However, all subjects having a CIM CR TKA experienced posterior femoral rollback of their lateral condyle, while 50% of the subjects having a standard OTS CR TKA experienced an anterior slide of their lateral condyle during flexion, consistent with a paradoxical motion opposite to the normal knee. During a chair-rise, on average, subjects having a CIM CR TKA experienced 4.9 mm of roll forward for their lateral condyle, while this amount was only 3.15 mm for a
standard OTS CR TKA. Also, subjects having a CIM CR TKA experienced, on average, 7.0° of normal axial rotation, while subjects having a standard OTS CR TKA experienced 6.3° of axial rotation. During a deep knee bend, subjects having a CIM CR TKA achieved 106° of weight-bearing knee flexion, while subjects having a standard OTS CR TKA achieved only 103°.

**Discussion:** Previous to the introduction of CIM TKA, knee implants were designed based on J-curves that had been derived from anatomic averages in order to fit a majority of the population. More recently, an implant has been designed based on the anatomical geometry for each individual patient correcting any underlying deformities (flattening, osteophytes, etc.). In this study, patients having a CIM CR TKA seemed to experience a benefit as they achieved more normal kinematic patterns. During both a deep knee bend and rising from a chair, subjects having a CIM CR TKA achieved more normal motion of their lateral condyle and greater magnitude of axial rotation. Most interesting was the fact that all subjects having a CIM CR TKA experienced normal motion of their lateral condyle, while 50% of the subjects having a standard OTS CR TKA experienced an anterior slide of their lateral condyle during a deep knee bend consistent with a paradoxical motion, opposite of the motion pattern of the normal knee.

**Significance:** Subjects in this study, having a customized individually made implant, experienced a more normal rollback pattern and an absence of paradoxical sliding during a deep knee bend activity. Furthermore, the subjects having a customized individual implant also experienced more anterior roll forward during a chair rise activity.

![Figure 1: Subject performing a DKB using a mobile fluoroscopy unit.](image-url)