In Vivo 6-DOF Assessment of Knee Kinematics During a High Flexion Lunge: A Comparison Between Asymmetrical Bearing Geometry Cruciate Retaining Total Knee Arthroplasty and Contralateral Native Knee

John Drago SB, Paul Arauz PhD, Christian Klemt PhD, Shuai An MD, Andy Wang, Alexander Veith, Sakkadech Limmahakhun MD, PhD, Young-Min Kwon MD, PhD
Bioengineering Laboratory, Department of Orthopaedic Surgery, Massachusetts General Hospital,
Harvard Medical School, Boston, MA 02114, USA
ymkwon@mgh.harvard.edu

Disclosures: JD (N); PA (N); CK (N); SA (N); AW (N); AV (N); SL (N); YMK (5- Stryker;5- Zimmer Biomet; 5- Depuy;5- Corentec; 5- Smith&Nephew)

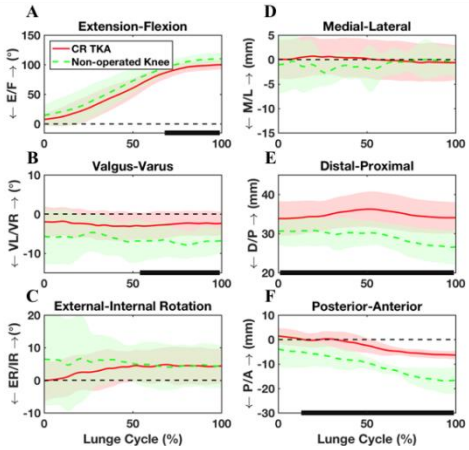
INTRODUCTION: As the population of patients receiving TKAs becomes younger [1], the necessity for implants to support higher intensity activities of exercise will become paramount. The recently-introduced Asymmetrical Bearing Geometry cruciate retaining (CR) TKA was designed to preserve proprioception and deep flexion kinematics of the native knee by retaining the PCL. Additionally, the CR TKA was designed to restore native knee kinematics, such as lateral condyle rollback and rotation during deep knee flexion, by introducing concave medial and convex lateral tibial components, with a posterior medial lip. The purpose of this study was to compare the *in vivo* 6-degrees-of-freedom (6-DOF) knee kinematics of the newly designed CR TKA against the contralateral non-operated knee during functionally strenuous high flexion lunge using a validated dual fluoroscopic imaging system [2].

METHODS: Eleven well-functioning Asymmetrical Bearing Geometry CR TKA patients (7 females and 4 males) with no history of post-operative complications were included in this study in accordance with the Institutional Review Board's policies. The average age (± SD) was 67.0 years (± 5.8; range: 60.5-80.6), and patients had an average BMI of 31.4 kg/m^2 (± 11.1; range: 19.6-60.9). All eleven patients underwent a computed tomography (CT) scan to create 3D subject-specific, anatomic models of both knees. The coordinate systems of the femur and the tibia were determined using bony anatomical landmarks, according to a previously described protocol [3]. Patients then performed a weight-bearing high-flexion lunge under dual fluoroscopy to generate 2D projections of each knee that were imported into a virtual DFIS environment. The femoral translations relative to the tibia and the tibial rotations relative to the femur were reported. The kinematic differences between the CR TKA and native knee at identical flexion points were assessed using a two-sided Wilcoxon rank sum test, with the significance level set at α = 0.05.

RESULTS: Asymmetrical Bearing Geometry CR TKAs demonstrated differing *in vivo* kinematics relative to the native knee throughout the lunge cycle (Figure 1). Distal-proximal translation of the CR TKA differed significantly from the non-operated knee throughout the entirety of the lunge cycle, with the CR TKA being displaced more proximally by an average of 5.6 mm (± 1.5). Through the final 85% of the lunge cycle, the posterior-anterior translation of the non-operated knee was greater than that of the CR TKA by an average of 8.0 ± 1.6 mm. Differences between the CR TKA and the non-operated knee were also demonstrated when the patient was in deep flexion. The maximum flexion of the CR TKA (100.0º) was significantly less than that achieved by the non-operated knee (110.0º). Significant differences between the CR TKA and the non-operated knee in flexion were observed through the final 20% of the lunge cycle with an average difference of 9.5 ± 0.8º. The CR TKA also demonstrated less valgus rotation when patients approached and were within the deep flexion segment of the lunge cycle, with an average difference of 4.5 ± 0.6º over the final 45% of the lunge cycle. No significant difference in external/internal rotation was observed over the course of the lunge cycle, but the non-operated knee was more internally rotated during the first 10% of the lunge cycle by an average of 6.1 ± 0.5º.

DISCUSSION: Despite the addition of a convex lateral tibial insert component in the Asymmetrical Bearing Geometry CR TKA design to aid in femoral posterior rollback during deep flexion, the CR TKA was unable to achieve similar posterior translation to the native knee during the majority of flexion. As the population of patients receiving TKAs become younger, preserving native knee kinematics during complex movements will allow patients to remain active and functional in their daily lives post-operatively. Further study evaluating the long-term outcomes of patients with the CR TKA design is warranted.

SIGNIFICANCE/CLINICAL RELVANCE: A 3D *in vivo* analysis of Asymmetrical Bearing Geometry CR TKA knee kinematics during flexion was performed, revealing an asymmetry of the CR TKA with the contralateral non-operated knee.



REFERENCES:
[1] S. M. Kurtz, et al., "Future young patient demand for primary and revision joint replacement: National projections from 2010 to 2030," in *Clinical Orthopaedics and Related Research*, 2009.
[2] G. Li, et al., "Validation of a non-invasive fluoroscopic imaging technique for the measurement of dynamic knee joint motion," *J. Biomech.*, 2008.
[3] W. Qi, et al, "In vivo kinematics of the knee during weight bearing high flexion," *J. Biomech.*, 2013.

Figure 1: Average and standard deviation of knee kinematics over 6DOF. (A), knee valgus/varus (B), knee external/internal rotation (C), tibial lateral/medial (D), posterior/anterior (E), and femoral inferior/superior (F) translations for the operated and non-operated knees in unilateral CR TKA patients during gait. Black bars on the horizontal axis indicate statistical significant difference between limbs.