In-vivo Articular Contact Analysis during Functionally Strenuous Activities in Patients with Asymmetrical Bearing Geometry Cruciate Retaining Total Knee Arthroplasty

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

INTRODUCTION: The precise knowledge of in-vivo articular contact mechanics of Cruciate Retaining (CR) Total Knee Arthroplasty (TKA) during functional daily activities is essential as abnormal knee kinematics following knee replacement may alter joint biomechanics and lead to poor patient satisfaction and outcome. A new Asymmetrical Bearing Geometry CR TKA design with concave medial and a convex lateral tibial insert was introduced to more closely replicate normal knee kinematics. However, there is no existing literature regarding in-vivo articular contact kinematics in this contemporary CR TKA design during functional activities. A single deep lunge and sit-to-stand represent commonly performed strenuous functional daily activities. Therefore, this study aimed to investigate in-vivo articular contact kinematics of CR TKA utilizing a validated dual fluoroscopic imaging system (DFIS) during strenuous activities such as lunges and sit-to-stand.

METHODS: In this Institutional Review Board approved study, 15 unilateral Asymmetrical Bearing Geometry CR TKA patients (6 male, 9 female; 68.4 ± 5.8 years; BMI 31.8 ± 9.9) with an average follow-up of 14.5 ± 12.6 months were enrolled for this study. All fifteen patients received computer tomography (CT) scan for the creation of 3D surface models of the knees. For the contralateral non-operated knee, the femoral and tibial local coordinate systems were constructed using anatomical bony landmarks [1]. The anatomical coordinate systems of the operated knee were determined using a previously validated and published 3D mirroring technique. All unilateral CR TKA patients performed single deep lunges and sit-to-stand test under dual fluoroscopic imaging system (DFIS) surveillance [2]. The 2D fluoroscopic images and the 3D subject-specific knee models were imported into the virtual DFIS environment for determination of knee 6 DOF kinematics. Medial and lateral condylar contact positions were quantified as the lowest point on the medial and lateral condyles with respect to the tibia and tibial tray. Average and standard deviation of the contact position along anterior/posterior and medial/lateral were calculated. A signed-rank Wilcoxson test was performed to determine if there is a significant difference in contact excursion between CR TKA and the native knee during functionally strenuous activities ($\alpha = 0.05$).

RESULTS: In Asymmetrical Bearing Geometry CR TKA, the contact point of the medial epicondyle shows significantly larger anterior excursion throughout the entire range of knee flexion angles for single deep lunges (3.1 ± 2.3° vs -4.5 ± 6.1°, Figure 1) and sit-to-stand (2.6 ± 2.3° vs -5.8 ± 2.8°, Figure 2), when compared to the non-operated knee. CR TKA demonstrated significantly smaller lateral excursion of the lateral epicondyle contact point during knee flexion for single deep lunges (21.4 ± 0.8° vs 23.7 ± 2.2°, Figure 1) and sit-to-stand (21.4 ± 1.8° vs 24.6 ± 3.8°, Figure 1), when compared to the native knee. There was no difference in lateral excursion of the medial epicondyle contact point across the entire range of knee flexion angles between CR TKA and the non-operated knee for single deep lunges (25.2 ± 2.5° vs 26.5 ± 5.6°, Figure 1) and sit-to-stand (25.1 ± 1.1° vs 27.1 ± 3.5°, Figure 2). Single deep lunges and sit-to-stand exhibited notable pivoting variability with 82% (9/11) and 80% (12/15) of patients displaying lateral pivoting while the remaining patients showed medial pivoting. In addition, medial condyle contact rollback was noticed in CR TKA when extending the knee during the initial phase of the lunge activity, with 73% (8/11) of patients experiencing a paradoxical excursion (2.1 ± 2.0 mm) prior to forward motion during single deep lunges, while 86.6% (13/15) of patients experiencing a retrograde excursion (2.5 ± 0.6 mm) prior to forward motion during sit-to-stand.

DISCUSSION: The precise understanding of in-vivo articular contact kinematics is essential to optimize intrinsic joint biomechanics and thus improve patient satisfaction and outcome. A new Asymmetrical Bearing Geometry CR TKA design with concave medial and a convex lateral tibial insert was introduced to more closely replicate normal knee kinematics. For the single deep lunge activity, this study demonstrated contact kinematic patterns of lateral pivoting as well as medial condyle contact roll forward during the lunge activity in the majority of patients in CR TKA patients, in contrast to those reported in the healthy knee. In addition, this study has demonstrated different medial contact excursions between CR TKAs and the non-operated knee. Thus, this contemporary CR TKA design did not fully restore the non-operated knee articular contact kinematics during single deep lunge.

SIGNIFICANCE/CLINICAL RELEVANCE: The majority of Asymmetrical Bearing Geometry CR TKA patients with concave medial and a convex lateral tibial insert design demonstrated femoral roll forward and lateral pivoting, opposite to those in the healthy knee. Furthermore, differences in medial and lateral epicondyle excursions were observed during single leg deep lunges.

REFERENCES:
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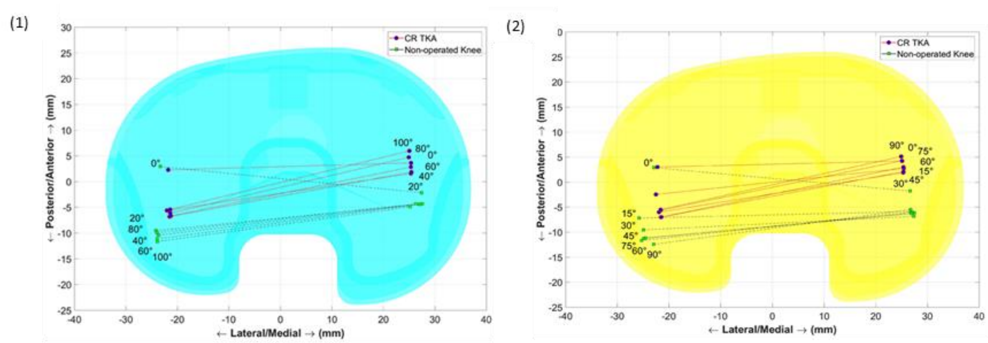

Figures: Average excursion of condylar contact points shown on the medial and lateral polyethylene inserts of CR TKA patients at selected knee flexion angles during lunges (Figure 1) and sit-to-stand (Figure 2). Average and standard deviation of contact trajectory is shown along anterior/posterior and medial/lateral directions during lunges (b-f).