The effect of joint line elevation on in vivo knee kinematics in bi-cruciate retaining total knee arthroplasty

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INTRODUCTION: Although total knee arthroplasty (TKA) is a highly successful treatment for patients with symptomatic arthritis, up to 20% of patients may be dissatisfied following well-performed surgery. Bi-cruciate retaining (BCR) TKA has the potential to restore healthy knee biomechanics by retaining the anterior and posterior cruciate ligament. Recent studies demonstrated differences in in-vivo knee kinematics between BCR TKA and the healthy knee. Joint line elevation has been identified as contributing factor to alter knee kinematics, affecting cruciate retaining (CR) TKA and posterior stabilized (PS) TKA designs. Previous studies reported a negative correlation between joint line elevation and clinical outcomes as well as patient-reported outcomes. However, there remains a paucity of literature confirming these findings in BCR TKA designs. The aim of this study is to quantify the effect of joint line elevation on in-vivo knee kinematics in unilateral patients with bi-cruciate retaining (BCR) TKA.

METHODS: Twenty-nine well-functioning unilateral BCR TKA patients (14 males and 15 females) with no history of any surgical complication were included in this study with the institution's Internal Review Board approval. The average age was 65.7 years (± 7.7, range 47 to 76). All twenty-nine patients received computer tomography (CT) scan for the creation of 3D surface models of the knees. The anatomical coordinate systems of the operated knee were determined using a previously validated and published 3D mirroring technique, allowing minimization of residual surface-to-surface registration errors between the remaining bone on the operated side and the mirrored non-operated one. All unilateral BCR TKA patients performed single-leg lunges under dual fluoroscopic imaging system (DFIS) surveillance (Figure 1). The 2D fluoroscopic images and the 3D subject-specific knee models were imported into the virtual DFIS environment for determination of knee six degree-of-freedom (6DOF) kinematics. The knee model was registered when its projection to the virtual image intensifiers best matches the fluoroscopic outlines of the actual knee. A Spearman correlation analysis was performed to establish correlations between joint line elevation and knee kinematics and patient-reported outcome measures.

RESULTS: There was a significant negative correlation between joint line elevation and the WOMAC score (p=0.01), KOOS-PS (p=0.03) and PROMIS SF physical (p=0.07) during single-leg deep lunges (Table 1). There was a significant negative correlation between joint line elevation and the varus/valgus range of motion (p=0.04) and femoral rollback (p=0.03) in patients with BCR TKA during single-leg deep lunges. There was no significant correlation between joint line elevation and flexion range of motion (p=0.31) as well as condylar lift-off (p=0.55).

DISCUSSION: The findings of this study demonstrate a negative correlation of joint line elevation with both knee kinematics and patient-reported outcome measures. This suggests that in concordance with prior literature on PS and CR TKA, restoration of the joint line is essential to optimize outcomes after BCR TKA. As previous studies only demonstrated the negative effect of joint line elevation on functional outcomes, this is one of the first studies to illustrate the adverse effect of joint line elevation on in-vivo knee kinematics during single-leg deep lunges.

SIGNIFICANCE/CLINICAL RELEVANCE: Joint line elevation is negatively correlated with both in-vivo knee kinematics and patient-reported outcome measures in patients with BCR TKA, suggesting that is essential to optimize outcomes after BCR TKA.

Table 1: Correlation between joint line elevation and in-vivo kinematics in patients with BCR TKA.

	Kinematics	p-value
WOMAC score	7.3 ± 3.1	**0.01**
Sincinatti score	14.1 ± 3.3	0.39
KOOS-PS	81.2 ± 14.8	**0.03**
PROMIS SF mental	67.9 ± 25.5	0.18
PROMIS SF physical	84.1 ± 10.5	**0.07**
Maximum flexion	99.4 ± 20.4	0.45
Minimum flexion	8.5 ± 7.8	0.51
Range of motion flexion	93.4 ± 13.3	0.31
Maximum varus	0.8 ± 2.5	0.22
Minimum varus	5.6 ± 2.7	0.16
Range of motion varus	4.8 ± 2.2	**0.04**
Maximum internal rotation	6.7 ± 4.9	0.38
Minimum internal rotation	0.2 ± 5.4	0.21
Range of motion internal rotation	6.9 ± 2.7	0.17
Femoral rollback	7.6 ± 3.8	**0.03**

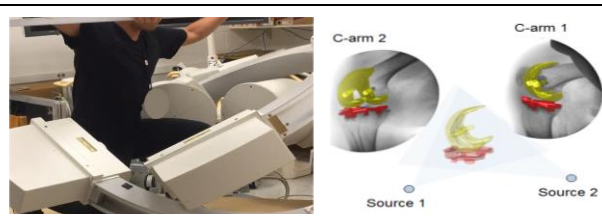

Figure 1: Dual fluoroscopic imaging environment (left) and 3D implant to 2D fluoroscopic image registration.