In Vivo Analysis of Knee Pivot Location in Osteoarthritis: Role of Laxity and Disease Severity

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INTRODUCTION: Knee osteoarthritis (OA) alters joint mechanics through cartilage degeneration, misalignment, and ligament injury, leading to pain, instability, and reduced mobility. Although total knee arthroplasty (TKA) restores function, most studies focus on post-surgical outcomes or healthy contralateral limbs during simple tasks like walking, overlooking how OA severity and joint laxity affect preoperative knee motion. Reduced range of motion altered tibial position, and joint instability often begin before surgery, but their influence during diverse functional activities remains unclear. We hypothesize that OA severity and knee laxity significantly alter tibial translation, rotation, and pivot location, and contribute to post-TKA limitations. This study examines how these factors affect knee kinematics during multiple daily activities.

METHODS: With Institutional Review Board approval, eighteen patients with primary knee OA (9 F | 9 M, age: 70 ± 4.5 yrs; BMI: 26.4 ± 3.3 kg/m²) scheduled for TKA were recruited. OA severity was quantified using B-Score derived from preoperative CT scans. Patients performed five activities of daily living (gait, lunge, stair descent, leg press, knee extension), under high-speed stereo radiography (HSSR) synchronized with optical motion capture. In-vivo knee laxity (anterior, internal-external) was measured at 45° flexion using a validated rig. Patient-specific bone models were tracked with a CNN-based automated workflow. Femoral low-point motion was used to compute pivot location via principal component analysis. Linear mixed effects models tested the influence of OA severity and laxity on kinematics and pivot behavior across flexion ranges. OA knee data were compared to prior data from healthy and TKA cohorts performing the same activities.

RESULTS: A significant association of OA severity (B-Score) and anterior laxity was identified ($R^2 = 0.36$, $F(1, 10) = 5.58$, $P = 0.040$, 95% CI [1.35, 5.98]). OA severity had a 0.60 mm increase in anterior laxity for each unit increase in B-Score (Figure 1). There was no significant association between OA severity and internal and external rotational laxity. Across all five activities, a medial pivot emerged as the primary location of pivot accounting for 104 instances (37%), followed by lateral with 82 instances (29%), central 74 (26%) and 20 (7%) no pivot (**Error! Reference source not found.** 2). Knee flexion was associated with a significant posterior shift in anterior-posterior pivot location (beta = -0.24, 95% CI [-0.30, -0.19], $t(276) = -8.92$, $P < .001$). The anterior-posterior pivot location was characterized by an anterior-medial to posterior-lateral slope (Figure 3).

DISCUSSION: This study demonstrates that OA severity is significantly associated with increased anterior knee laxity, supporting prior findings of greater translational motion in more advanced OA. However, unlike previous static measurements that suggested reduced laxity in severe OA, our in vivo fluoroscopy-based method aligns more closely with dynamic behavior observed during activity. Across five functional tasks, medial pivot was most common, but greater variability and increased prevalence of lateral pivot were observed compared to healthy and PS-TKA knees, indicating altered rotational control in OA joints. Pivot location shifted posteriorly with increasing knee flexion and OA severity, consistent with prior work but also highlighting that more severe OA results in earlier anterior positioning and more pronounced posterior translation of the femoral condyles. These spatial changes in pivot and low-point motion reflect deeper structural and functional alterations associated with disease progression. The findings underscore the value of evaluating OA knees under multiple activities and suggest preoperative kinematic abnormalities and joint laxity should be considered when planning interventions or predicting surgical outcomes.

SIGNIFICANCE: Understanding how OA severity and knee laxity affect joint mechanics across diverse activities provides critical insight into preoperative joint function. These findings may help optimize surgical timing, personalize TKA planning, and improve long-term outcomes by accounting for disease-related kinematic changes.

REFERENCES: Hamilton et al, J Biomech 2023 Mar:149:111487, Higinbotham et al, Clin Biomech,.2024 Dec:120:106350

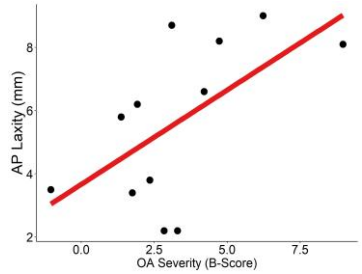

Figure 1. The effect of OA severity (B-Score) on measures of AP knee laxity at 45 degrees of knee flexion.

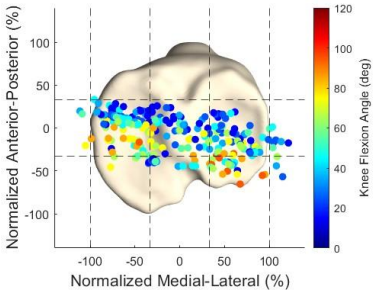

Figure 3. Distribution of pivot locations across all subjects and activities

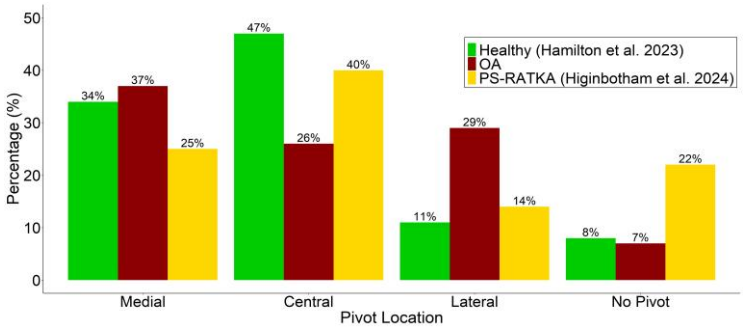

Figure 2. Distribution of pivot locations across all subjects and activities. Healthy refers to a healthy, asymptomatic cohort, and PS-RATKA is a TKA cohort implanted with a posterior stabilizing implant via robotic-arm assisted surgery