

Comparison of Midflexion Laxity Measurements in Multiple Planes Across Healthy and Total Knee Arthroplasty Cohorts and their Relationship with Patient Reported Outcome Measures

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INTRODUCTION:

Patient perceptions of knee instability are a leading cause of dissatisfaction and revision surgery following total knee arthroplasty (TKA) [1]. Knee instability, especially in midflexion, can involve heightened laxity in one or multiple planes, including varus-valgus (VV) angulation, anterior-posterior (AP) translation, and internal-external (IE) rotation [2]. These laxities are clinically assessed post-TKA via qualitative and subjective exams that are variable across evaluators [3]; as such, a quantitative measure of laxity post-TKA is lacking. Furthermore, as new methods for measuring intra-operative laxity become available (e.g., robotic-assisted TKA and calibrated tensor tools), the challenge remains for defining appropriate laxity targets to improve patient satisfaction. A comparison of post-TKA laxity measurements to those of the healthy native joint could provide insight into identifying these targets. Under an IRB-approved protocol and with written subject consent, we measured laxity using a safe and objective multiplanar arthrometer asking the following questions: 1) Are laxity measurements different between (a) 1-year post-operative TKA cohort and (b) a young, healthy cohort? 2) In the TKA cohort, are laxity measurements in any plane related to patient reported outcome measures?

METHODS:

Our arthrometer uses an instrumented linkage with 5 degrees of freedom (Fig. 1) [4]. Applied forces and moments were measured using a 6-axis force/torque sensor (Mini58, ATI, Inc) fixed to the arthrometer behind each subject's proximal tibia. To start each test, the subject rested in a chair with their leg aligned in the arthrometer oriented at 20° of flexion. The distal thigh was fixed to the chair, and the proximal calf was fixed to the arthrometer with controlled compressive forces ranging from 90 to 110 N via ratcheting mechanisms. Laxities in the VV, AP, and IE planes were measured in both legs of 20 healthy subjects (10 males; mean age 28±6; mean BMI 24±4) and the TKA leg of 19 subjects 1 year after TKA surgery (9 males; mean age 67±6; mean BMI 30±4). TKA subjects had different implant designs (12 posterior stabilized, 5 mid-level constrained, and 2 cruciate retaining). The TKA cohort completed a Knee Injury and Osteoarthritis Outcome Score for Joint Replacement (KOOS JR) survey at the time of testing (mean score 80±12). 12 TKA patients had also completed a pre-operative KOOS JR (mean score 54±10). Testing consisted of the examiner manually applying 4 cycles of VV moments (±3 Nm), AP forces (10 N posterior to 30 N anterior), and IE moments (±2.5 Nm) to the lower leg. The load-displacement responses were recorded, and net laxities were defined as the net planar translation or rotations between load targets. The unidirectional laxities were defined as translation or rotation from the zero-load position to the load target. Each leg was measured twice by a single examiner, and the laxities were averaged together; for the healthy cohort the left and right leg laxities were further averaged. Regarding our first question, after confirming the data's normality, net laxities were reported as means and standard deviations (SD) and compared between cohorts via unpaired t-test ($\alpha=0.05$). To answer our second question, for the TKA cohort the net, unidirectional, and difference between unidirectional laxities in each plane were correlated to post-op KOOS JR score and the improvement in score (pre-op to post-op) using linear regression with regression coefficient (β), p-value, and coefficient of determination (R^2) reported.

RESULTS:

Laxities in the TKA cohort were lower on average by 0.9° (2.6° vs 3.5°, $p=0.01$), 2.4mm (3.4 vs 5.8, $p<0.001$), and 13.2° (12.6° vs 25.9°, $p<0.001$) in the VV, AP, and IE planes, respectively, compared to the healthy cohort (Fig. 2). None of the net laxities were correlated with KOOS JR score; however, valgus laxity had a weak negative relationship with KOOS JR score ($p=0.06$; $R^2 = 0.20$). The difference between valgus and varus laxity was correlated with KOOS JR score ($\beta=-14.6$ pts/°, $p=0.01$; $R^2 = 0.32$) (Fig. 3). This difference between valgus and varus laxity was also correlated with improvement in KOOS JR score ($\beta=-18.0$ pts/°, $p=0.04$; $R^2 = 0.36$).

DISCUSSION:

Joint laxity in the TKA cohort was lower in all three planes. This in vivo study builds upon previous cadaveric work that reported reduced VV laxity after TKA [5]. Reduced laxity may be due to disease state affecting soft tissue properties or increased constraint of the implant systems compared to the native knee. As a preliminary analysis, no differences in laxities were found among implant types ($p>0.20$). The difference between valgus and varus laxities being correlated with post-operative KOOS JR score supports recent studies demonstrating that patients with medial flexion gaps less than lateral gaps can have better PROMS [6-8]. However, this existing literature evaluates laxity exclusively in the VV plane and intra- rather than post-operatively. Future directions for our work include measuring laxity in TKA patients prospectively and collecting PROMs potentially more applicable to patient satisfaction such as the Forgotten Joint Score or KOOS Quality of Life sub-score.

SIGNIFICANCE/CLINICAL RELEVANCE:

This preliminary study characterized post-operative laxity in multiple planes for a TKA cohort. By comparing these measures to a young healthy cohort and to PROMS, we are moving closer to developing intra-operative laxity targets to improve TKA patient satisfaction.

REFERENCES: [1] Paxton. JBJS 2010. [2] Abdel. BJJ 2014. [3] Elmasry. CORR 2022. [4] Shamritsky. JOA 2023. [5] Shalhoub. JOA 2018. [6] Keggi. Arch Orthop Trauma Surg 2021. [7] Meneghini. JAAOS 2023. [8] Itoh. JISAKOS 2023.

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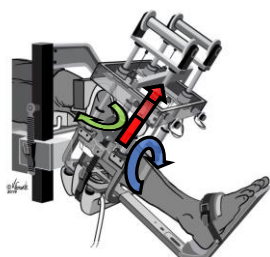


Figure 1. Knee arthrometer with three directions of joint laxity (AP, red; VV, green; IE, blue) indicated.

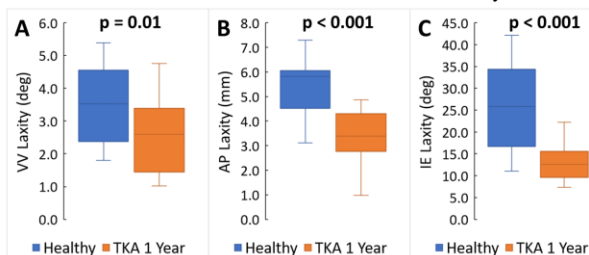


Figure 2. Boxplots of laxity measurements for Healthy (blue) and 1-Yr post-TKA (orange) cohorts in the A) Varus-Valgus, B) Anterior-Posterior, and C) Internal-External rotation directions.

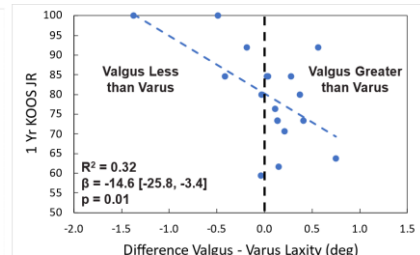


Figure 3. KOOS JR score 1-Yr post-TKA vs. valgus minus varus laxity. Dashed line indicates 0° difference, with positive values indicating greater valgus laxity than varus.