Do Intraoperative Passive Laxity Tests Predict Post-Operative Knee Function in Total Knee Arthroplasty?

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Summary

This study examined whether passive knee laxity tests performed during total knee arthroplasty (TKA) can effectively predict joint kinematics and kinetics during postoperative dynamic activities. Using stochastic musculoskeletal modelling, this study analysed the impact of medial and lateral collateral ligament (MCL and LCL) laxity or stiffness on both passive and loaded knee joint mechanics. Our findings indicate that knees with greater passive laxity exhibited slightly increased abduction-adduction (AA), internal-external (IE) rotation, and anteroposterior (AP) translation during walking, though these changes do not appear to critically impact dynamic joint stability. As a result, passive laxity tests may not be sensitive enough to completely predict the dynamic joint function.

Introduction

During total knee arthroplasty (TKA), surgeons routinely perform passive knee laxity tests after implantation to assess the restoration of knee stability. However, some patients continue to report instability or pain during weight-bearing activities, raising concerns about the reliability of passive tests in predicting functional performance.

Using a previously validated TKA model [1], we simulated various medial and lateral collateral ligament (MCL and LCL) laxity and stiffness scenarios to investigate the relationship between intraoperative laxity and postoperative knee joint mechanics during walking.

Methods

Computational simulations were performed using a validated subject-specific musculoskeletal (MS) model incorporating a TKA implant [1]. To simulate real-world scenarios where patients may leave the operation room with either overly lax or over tense ligaments, a set of 400 Monte Carlo (MC) simulations were conducted, incorporating within ±20% stochastic variations in the initial strains of MCL and LCL.

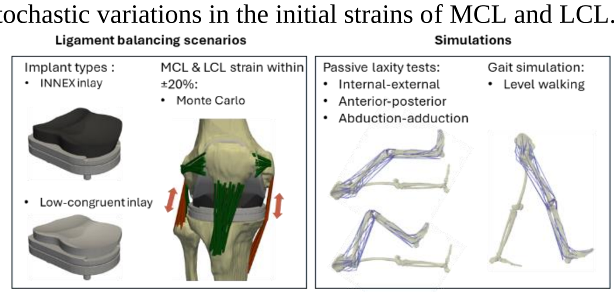

Figure 1: Passive laxity and dynamic gait simulations were conducted across various collateral ligament balancing scenarios, using both the INNEX (contact radius arc = 66 mm) and a low-conformity inlay (contact radius arc = 66 mm).

Each model first underwent passive laxity tests at 0°, 30°, and 90° of knee flexion (Fig. 1) using a customized OpenSim forward simulation tool [2]. IE and AA laxity were assessed under ±5 Nm external torques, whereas 100 N force applied at tibial tuberosity for AP laxity test. Subsequently, marker trajectories and ground reaction force data from a representative walking trial in the CAMS dataset [3] were input into the COMAK optimization algorithm to evaluate joint mechanics during walking. Results from both passive and walking simulations were analysed to identify potential relationships between knee behaviour in passive laxity tests and during loaded functional activity.

Results and Discussion

Overall, soft-ligament balancing scenarios with extreme collateral ligament laxity primarily influenced tibiofemoral kinematics, whereas scenarios with extreme ligament tightness led to excessive knee contact forces (Fig. 2). Additionally, MCL laxity or tightness caused more pronounced alterations in joint mechanics compared to the LCL, whose strain condition primarily affected IE rotation.

Our findings indicate that knees with greater passive laxity exhibited slightly increased AA and IE rotation, as well as AP translation during walking, though these changes do not appear to critically impact dynamic joint stability. For example, a ligament balancing scenario resulted in passive AP displacement of 8 mm resulted in only 3 mm additional AP shift during the stance phase of gait. However, in low-conformity implants, these additional movements were more pronounced and may increase the risk of dynamic instability.

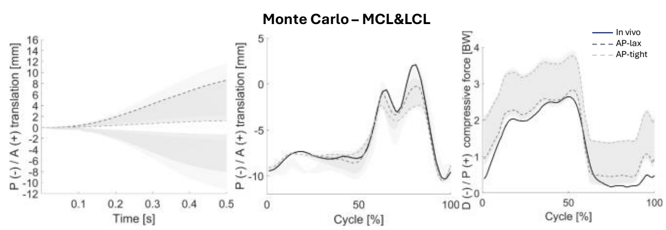

Figure 2: Results of the Monte-Carlo simulations: AP translation of the knee during passive laxity test at 90° flexion (left) and during walking (middle), along with KCF during walking (right). Light shading represents the low-congruent inlay, while dark shading shows the INNEX inlay.

Conclusions

Ligament balancing scenarios resulting in excessive tibiofemoral motions during intraoperative laxity tests are associated with increased joint laxity during walking, although the functional impact is minimal. As a result, passive laxity tests may not be sensitive enough to reliably predict the dynamic joint function, highlighting the need for complementary assessments to optimize postoperative outcomes.

References

[1] Guo et al, *Front. Bioeng. Biotechnol*, **12**, 1352794. Taylor et al, *J Biomech*, **65**:32-39, 2017.

[2] Smith et al, https://github.com/clnsmith/opensim-jam/tree/master/opensim-jam-release.

[3] Taylor et al, *J Biomech*, **65**:32-39, 2017.