

# Test-Retest Reliability and Concurrent Agreement of a Novel Physiological *Ex-Vivo* Knee Joint simulator

Orçun Taylan<sup>1</sup>, Thomas Louwagie<sup>1</sup>, Darshan Shah<sup>1</sup>, Ilse Jonkers<sup>2</sup>, Lennart Scheys<sup>1,3</sup>

<sup>1</sup>Institute for Orthopaedic Research and Training (IORT), KU Leuven, Belgium. <sup>2</sup>Human Movement Biomechanics Research Group, KU Leuven, Belgium.

<sup>3</sup>Division of Orthopaedics, University Hospitals Leuven, Belgium.

orcun.taylan@kuleuven.be

**Disclosures:** Orçun Taylan (N), Thomas Louwagie (N), Darshan Shah (N), Ilse Jonkers (N), Lennart Scheys (6; Euros (Grant), Medtronic (Grant), Nuvasive (Grant), V!GO/Ottobock (Grant), Zimmer-Biomet (Grant), SRS-Biedermann Award (Grant), Smith and Nephew (Grant), Medacta Int. (Research support))

**INTRODUCTION:** A variety of ex-vivo physiological knee simulators have been developed over time with the goal of replicating more intricate and precisely controlled motions in contrast to their predecessors. Nevertheless, when new simulators are introduced, a quantitative comparison of the simulated kinematics and kinetics behavior of the knee with existing simulators is typically lacking. As a result, the consistency in replicating knee joint biomechanics across simulators remains poorly documented, limiting the potential pooling of the data towards more robust conclusions, increased sample size, and enhanced generalizability of findings in the knee joint biomechanics research. Therefore, the aim of the study is to introduce a novel paradigm for thoroughly assessing the concurrent agreement of a novel knee simulators by repeating squatting motions in multiple simulators within a single cohort of ex-vivo specimens.

**METHODS:** After obtaining approval from an Ethics Committee, six fresh-frozen cadaveric specimens were prepared for squatting motion in a novel (2<sup>nd</sup> Gen) simulator, which allows the control of translations in three planes and independent control of quadriceps and bilateral hamstring muscle groups, namely femur (6° of valgus) and tibia potting, quadriceps tendon clamping and the bilateral hamstrings suturing. Thereafter, the specimens were subjected to squatting motion while actively controlling the quadriceps and bilateral hamstrings (50N each) using an optimized control strategy that aims to maintain a constant vertical ground reaction force. Each specimen was then implanted with a cemented total knee arthroplasty (GMK Sphere, Medacta International) and retested in the 2<sup>nd</sup> Gen. Following retesting the femur and reclamping the quadriceps tendon, the specimens were subjected to squatting in the 1<sup>st</sup> Gen, which is mechanically restricted to squatting motion, and has single active quadriceps control and a constant force spring of 50N on each hamstring. To ensure consistency across the simulators, same knee flexion range (35°-100°), target vertical ankle load (ground reaction force (GRF), 110N), and squatting cycle duration (24 sec) were applied on both simulators in quintuplicate. A six-camera optical motion capture system (Vicon) was used to record the trajectories of the markers attached to the femur, tibia and patella to calculate tibiofemoral and patellofemoral kinematics. A time-series pointwise intraclass correlation (ICC, 95% CI poor<0.4 and 0.74<excellent) and standard error of measurement (SEM) were used to analyze the test-retest reliability of the resulting tibiofemoral-patellofemoral kinematics and ankle-quadriceps loads within the 1<sup>st</sup> Gen and 2<sup>nd</sup> Gen as well as the inter-simulator agreement of tibiofemoral kinematics across the simulators. Additionally, a generalized mixed-model was used to compare both simulators ( $p < 0.05$ ).

**RESULTS SECTION:** The overall inter-simulator agreement was good to excellent for tibiofemoral (ICC=0.89) and patellofemoral (ICC=0.8) kinematics; however this was not the case for translational kinematics ( $0.52 < \text{ICC} < 0.74$ ). Additionally, statistically significant differences across simulators were observed for tibial external rotation, patellofemoral tilt and its translations in frontal and sagittal planes ( $< 0.049$ ) across simulators. Within each simulator, the mean reliability of 1<sup>st</sup> Gen and 2<sup>nd</sup> Gen throughout flexion-extension were excellent for both tibiofemoral (ICC>0.9) and patellofemoral kinematics (ICC>0.9) during squatting motion. Furthermore, the mean reliability of vertical ankle (ICC=0.95) and quadriceps (ICC=0.97) forces were excellent for the 2<sup>nd</sup> Gen.

**DISCUSSION:** We detected statistically significant differences in patellar mediolateral translation, patellar tilt and tibial rotation, although overall kinematics agreement between both simulators was good to excellent. This suggests a potential offset (Fig. 1) associated with shift of Q-angle due to reclamping. Consequently, the comparable trends in kinematics behavior measured in different simulators imply the possibility of data pooling, owing to the minimal variations in biomechanical outcomes despite the differences in their design and control strategy. Nevertheless, it's important to note that the inter-simulator comparison was only performed on post-op knees, which may not be representative for the consistency in native knee kinematics. On the other hand, 2<sup>nd</sup> Gen exhibited excellent kinematics and kinetics test-retest reliability. Furthermore, the offset from the targeted GRF for 2<sup>nd</sup> Gen was negligible, which the peak offset from the target was 1.8N across all tested knees. Although 1<sup>st</sup> Gen also showed excellent kinematics and kinetics reliability, the peak offset from the target was 53N. This finding potentially suggests that the impact of deviated GRF and muscle load on reliability of kinematics is minimal.

**SIGNIFICANCE/CLINICAL RELEVANCE:** Despite potential differences in design as well as control strategy, the primary biomechanical outcomes post-TKA during squatting are similar across simulators, supporting future cross-simulator comparisons.

**ACKNOWLEDGEMENTS:** Material and financial support for this study was provided by Medacta International, Castel San Pietro, Switzerland.

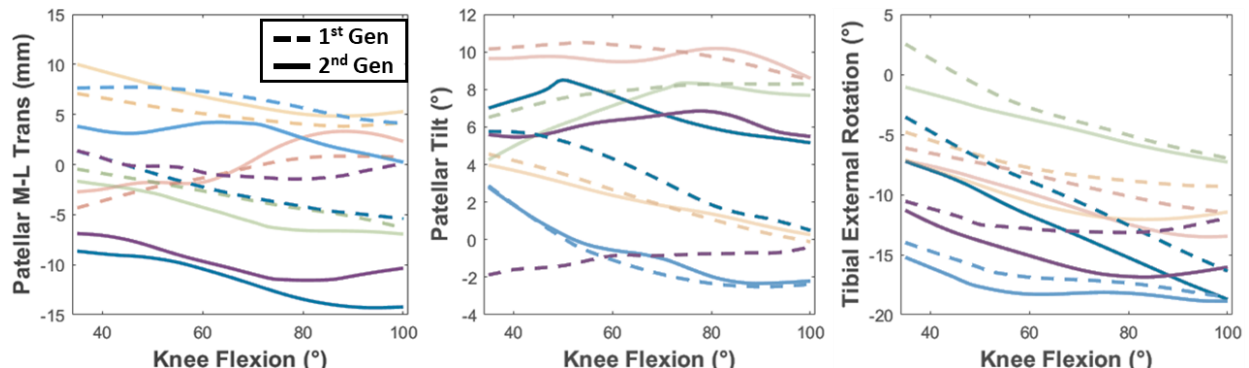


Figure 1. Patellar mediolateral translation (mm, left), patellar tilt (°, middle) and tibial external rotation (°, right) of 6 post-TKA knees tested in 1<sup>st</sup> Gen (solid) and 2<sup>nd</sup> Gen (dashed).