# ATTUNE™ Knee System

## The Influence of Design on TKR Mechanics During Activities of Daily Living


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## Introduction

Instability of the knee in total knee replacement patients has been reported during high demand activities both through clinical observations and fluoroscopic evaluation. Ploegmakers et al[1], in an *in vivo* kinematic evaluation, cited implant design factors as a determinant of knee instability. The objective of the current study was to compare anterior-posterior (A-P) and internal-external (I-E) motions of the knee for four current TKR designs in order to assess the influence of implant geometry on the inherent stability, motion, and contact mechanics of the joint. Each design was assessed in two finite element (FE) models: a laxity/stability test, and a full lower limb model during two high demand activities – stepdown (high A-P force) and stance-phase gait (high I-E torque).

## Methods

Implant design was quantified in terms of the tibiofemoral (TF) conformity ratio, calculated by dividing the femoral articular radius at 0°, 15°, 30° and 60° flexion by the radius of the insert in the dwell point (Figure 1). To assess tibiofemoral constraint, a finite element model of the femoral component was positioned in the dwell of the insert at 0°, 15°, 30° and 60° flexion under a compressive load of 667N. A 5mm anterior translation or 10° internal rotation was applied to the femur while the TF reaction force or torque was measured.

Subsequently, dynamic simulations of stepdown and stance-phase gait activities were carried out in a FE model of the lower limb (Figure 1). TF joint loads were taken from in vivo telemetric data[2] and a control system was implemented to apply external loads at the hip and ankle to create the experimentally-measured loading condition (compressive load, A-P force, I-E torque) at the TF joint for each activity using the telemetric implant geometry. The external loading condition was subsequently applied directly in the model, and the simulation was carried out for the four components, including current cruciate-retaining (CR) and posterior-stabilizing (PS) designs from several manufacturers. 6-DOF TF kinematics, medial and lateral condyle lowest point, and contact mechanics were evaluated for each design.

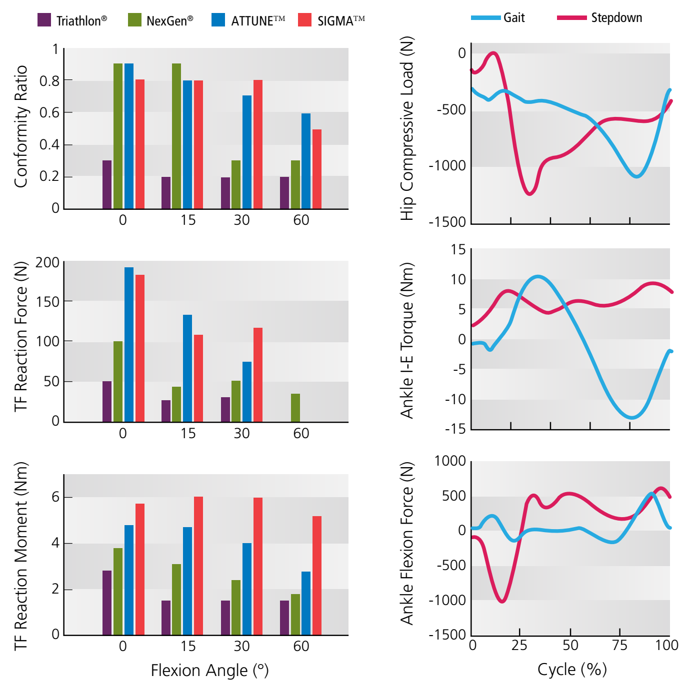
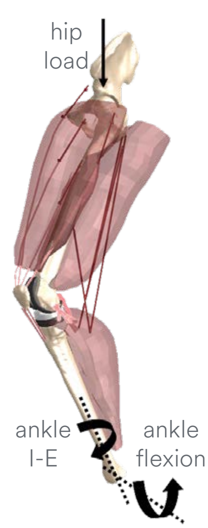



**Fig. 1.** TF conformity ratios (left, top) and laxity test reaction forces (left, middle) and moments (left, bottom) to anterior and internal motions, respectively – zero indicates post-cam impingement; FE model of the lower limb (below); external loading profiles implemented in the model to apply joint compressive load, I-E torque and A-P force during gait and stepdown activities (right)



## Results

Conformity ratios correlated well with laxity/constraint of the components (r = 0.73 for translation tests; r = 0.78 for rotation tests).

Trends during the dynamic activities were in agreement with those predicted during the laxity simulations; higher conformity increased constraint and hence the loads carried by the insert instead of the surrounding soft tissue. These designs with higher conformity had, in general terms, higher contact area, and lower contact pressure than the less conforming components (Figure 2).

Both laxity tests and dynamic simulations highlighted substantial variation in the constraint provided by current implant designs. The range of A-P and I-E motion for the least constrained design was twice that of the most constrained design during dynamic activity (Figure 3).

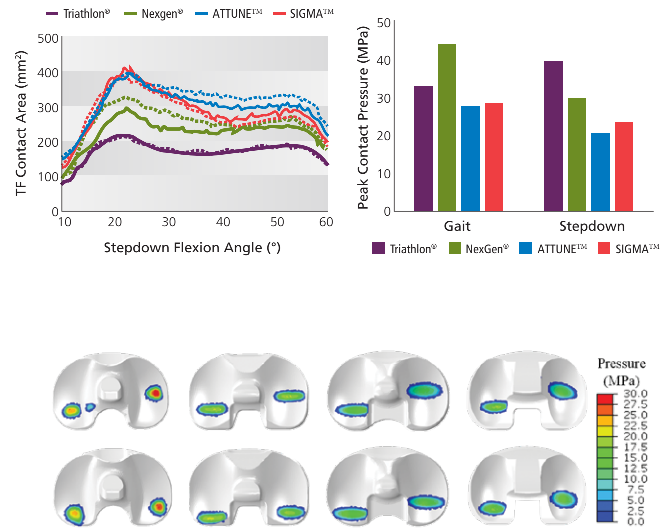



**Fig. 2.** Contact area during stepdown (top left); peak contact pressure for PS components during both activities (top right); contact patch for PS components at peak external torque during gait (center) and peak posterior force during stepdown (bottom)

## Discussion

In the current analysis, each component was analyzed under the same external loading conditions with the same soft-tissue representation, allowing for direct comparison between components. Varying ligament mechanics would alter the magnitude of motions, but relative performance of each implant would be consistent.

Other factors, aside from geometry, contribute to instability of the knee joint, notably, ligamentous balance/tension. Some knees, through natural mechanics or injury, have a tendency towards instability. Component designs with inherent geometric stability may aid in maintaining knee stability during dynamic activity for these patients.

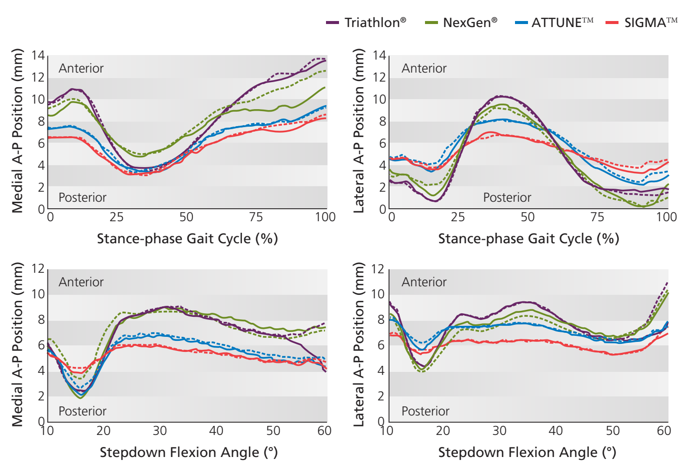



**Fig. 3.** Medial and lateral A-P kinematics for each PS (solid) and CR (dashed) component shown for gait (top) and stepdown (bottom)

## Significance

Understanding the variation in constraint provided by differing current implant designs may aid clinicians in determining which type of implant is most appropriate, given the soft-tissue quality of their patient, to provide adequate stability during activities of daily living while maintaining range of motion.

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2. 2. Kutzner, E., Heinlein, B., Graichen, F., Bender, A., Rohlmann, A., Halder, A., Beier, A., Bergmann, G. Loading of the knee joint during activities of daily living measured in vivo in five subjects. Journal of Biomechanics. 2010; 43: 2164-2173.