57. A COMPUTATIONAL PLATFORM FOR DESIGN-PHASE EVALUATION OF KNEE REPLACEMENT

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SUMMARY

Computational models are the primary tools for efficient design-phase exploration of knee replacement concepts before in vitro testing. To improve design-phase efficiency, a computational platform was developed that allows designers to assess devices under a series of important loading conditions.

Early in the design-phase of new implant design, numerous in vitro tests would be desirable to assess the influence of design parameters or component alignment on the performance of the device. However, cadaveric testing of knee replacement devices is a costly and time-consuming procedure, requiring manufacture of parts, preparation of cadaveric specimens, and personnel to carry of the experiments. Validated computational models are ideally suited for pre-clinical, high-volume design evaluation. Initial development of these models requires substantial time and expertise; once developed, however, computational simulations may be applied for comparative evaluation of devices in an extremely efficient manner. The objective of the current study was to develop a suite of semi-automated tools which perform a series of knee simulations of varying complexity, from basic contact to simulation of activities of daily living. The system integrates with commercially available finite element software to allow for direct, efficient comparison of designs and surgical alignment under a host of different boundary conditions.

Patients & Methods:

A suite of five simulation tools were developed, which modeled (1) basic tibiofemoral (TF) component contact (Figure 1), (2) TF mechanical constraint, or joint laxity assessment [Haider and Walker, 2005], (3) TF joint laxity including ligamentous constraint, (4) TF wear during gait [Knight et al., 2007], (5) whole joint (TF and patellofemoral (PF)) mechanics during dynamic activities of daily living (e.g. gait, squat, chair-rise) (Figure 2). These models were developed in a software environment with a custom interface developed to allow easy conversion from rigid to deformable structures, adjustment of mechanical properties and component alignment, editing of material properties and boundary conditions, and presentation of simulation results.

Results:

The suite of tools provides a platform for baseline evaluation of design factors, comparison of new implant designs with predicate devices, and assessment of robustness to surgical alignment during five different loading conditions. Implant material properties, ligament properties and initial conditions can be varied, and results compared, to evaluate the influence of a host of design, surgical and subjectspecific factors on implant performance. The interface allows users without complex finite element expertise to setup, analyze and compare devices and interpret results.

Discussion/Conclusion:

A platform which allows implant designers to evaluate their design ideas and compare with predicate devices has the potential to substantially decrease the development time for new devices. Designers can perform iterative modification to their devices to focus on an optimal design solution prior to in vitro testing, reducing the number of pre-clinical cadaveric experiments that may be required, and ultimately improving TKR mechanics in the patient population.

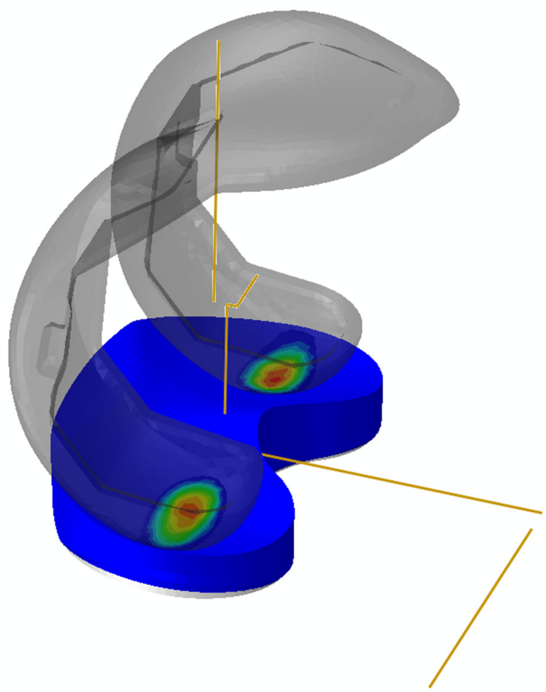

Figure 1: Basic contact analysis of the tibiofemoral joint, showing actuators through which loads (compressive force, internal-external and varus-valgus torque, anterior-posterior force) and kinematics may be applied.

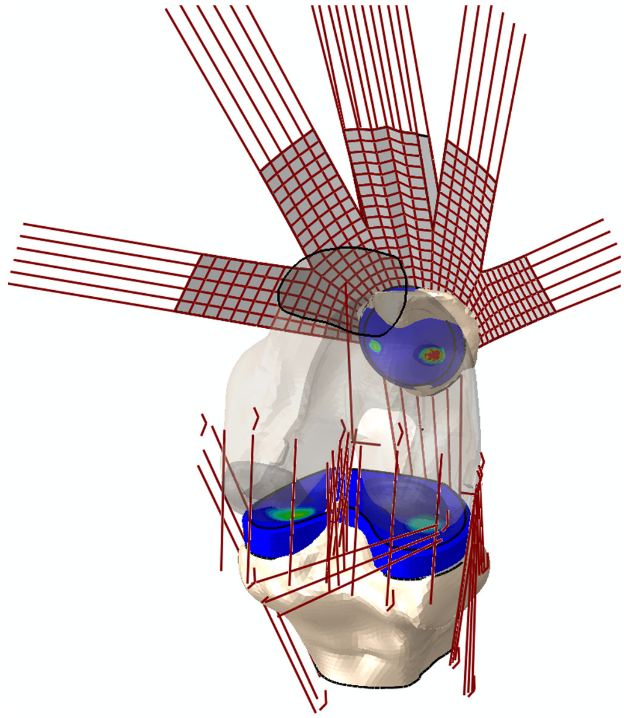

Figure 2: Whole joint (including extensor mechanism and 1-D tibiofemoral ligaments) during a squat simulation (shown with transparent femoral bone and implant).