AN ADVANCED MODELLING FRAMEWORK FOR ASSESSING KNEE ARTICULAR MECHANICS AND SOFT TISSUE LOADING AFTER TOTAL KNEE ARTHROPLASTY

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Introduction

Generic musculoskeletal models often present substantial errors in the prediction of joint function after total knee arthroplasty (TKA) [1]. Therefore, subject-specific modelling is necessary to understand mechanics of the knee and personalize revision surgeries. This study introduces an advanced modelling framework towards understanding the influence of different surgical parameters on the knee joint mechanics after TKA. The framework was verified using a detailed musculoskeletal model personalized to a subject measured within the CAMS-Knee project [2]. Loading and kinematics of the knee during level walking and squat were estimated and compared against data obtained from vivo measurements.

Methods

The subject-specific skeleton geometry was derived from CT images of a TKA patient K5R in the CAMS-Knee datasets (K5R, [2]). Bone segments were then linked to form a multibody model (Fig 1). Implant components were positioned within the subject-specific model based on their 3D pose within the CT images.

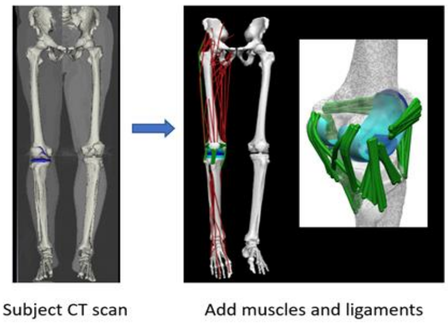

Figure 1: Model development framework.

The ligament footprints were identified based on guidelines reported in previous anatomical literature. Ligaments were modelled as 1D nonlinear spring elements connecting the ligament attachment sites on the bones. Muscle attachment points and muscle parameters were scaled and adjusted from a previously developed model [3]

The knee was modelled as a 12 degree of freedom (DOFs) joint guided by elastic foundation contact. Skin-marker trajectories and ground reaction force data were inputs to the COMAK tool [4] to estimate knee kinematics and loading during five trials of simulated level walking and squat. The outcomes were validated against in vivo data collected from the same subject.

Results and Discussion

Overall, the model was able to accurately predict tibiofemoral kinematics and loading patterns measured in vivo (Fig 2). Results showed knee contact forces of up to 2.5 and 3.3 BW during walking and squatting, which indicate slight overestimation of the loads likely due to non-personalized parameters (e.g., muscle strength and ligament properties). Importantly, the framework also enables estimation of ligament and muscle forces as well as patellofemoral joint mechanics and thus allows further exploration towards understanding interrelationships between different joint structures.

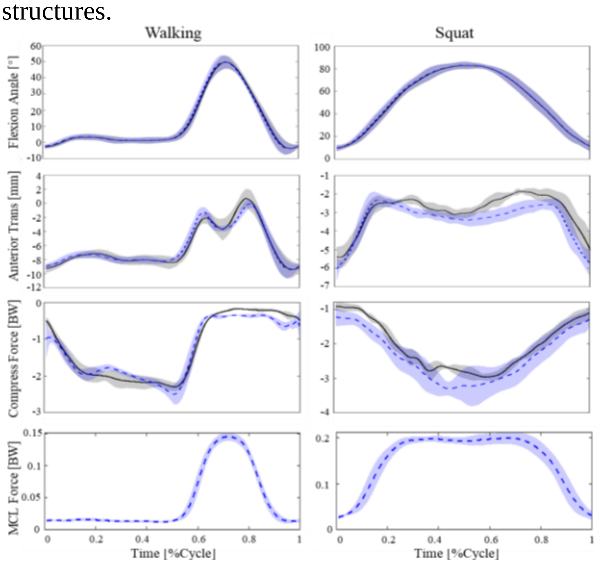

Figure 2: Forces and kinematics at knee during walking and squat.

Conclusions

Our modelling framework enables reliable estimation of the knee joint mechanics during dynamic and quasi-static activities, thus providing a predictive tool for future investigations into the influence of surgical parameters (e.g., ligament release and implant alignment) on the joint function after TKA.

References

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