Knee Joint Mechanics Predicted by Subject-specific and Generic Models

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I. Introduction

Osteoarthritis (OA) affects the life quality of approximately 7.2 million Canadians (18.3%) with an additional 200,000 new cases each year [1]. Knowledge of joint contact mechanics is needed to understand mechanical factors in OA progression. Patient specific knee joint modelling has been well developed over decades. The geometry of knee tissues, on the other hand, varies substantially among individuals, and these morphological variances may have significant implications in injury and disease risk [2]. In order to capture the morphological variability distributed across a set of matching surfaces, our ongoing research uses statistical shape modelling (SSM) method and a unified material to isolate the effects of patient demographics in a large population via modelling to discover generic and subject-specific biomechanical behaviors. The research objectives of the present study were to develop a generic knee model based on our previously developed poromechanical knee joint model and to investigate the contact mechanics including creep response of articular cartilages for a subpopulation.

II. Method

Two generic knee models were generated using a previously developed SSM workflow [3]. Generic39 was generated from the right knees of 39 healthy subjects (45-69 years, white male). Generic8 was generated from 8 knees randomly selected from the 39 subjects to test the effect of subject numbers on the results. Tissue geometries of each knee were reconstructed from MRIs obtained from the Osteoarthritis Initiative. The SSM approach used the Coherent Point Drift algorithm to establish node correspondence between individuals' point clouds for the bones, cartilages, and menisci. Following alignment of the point clouds, Principal Component Analysis was applied to the registered knee joint data to extract the principal modes of geometric variation. Six additional generic models were also built to consider standard deviations from Generic39. Cartilages and menisci were modelled as fibril-reinforced fluid-saturated materials which was previously developed [4]. To model articular cartilage creep response, we simulated a full extension joint load for each generic cohort and selected subject specific models. Joint loading consisted of a 600-N force ramped in 1s and remained constant for 6000s.

III. Results

The fluid pressure in medial tibial cartilages for 6000s of cohort averaged and single subject comparison are shown in Figure 1.

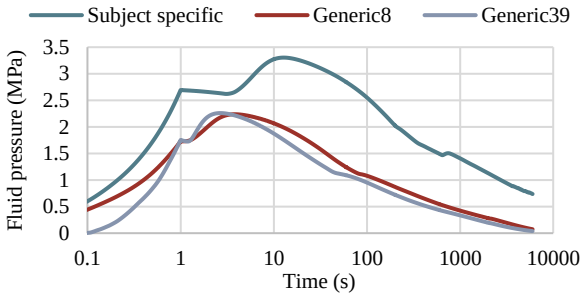

Fig. 1 Maximum fluid pressure in the medial tibial cartilages with creep loading for the generic and subject-specific knee joints.

IV. Discussion

We used 39 right knees to investigate the viability of SSM in poromechanical modelling of the human knee joint. The variation between subject and cohort averaged models was found to be considerable. Inter-subject variability should be included in subject-specific models since the results may differ from the cohort average. The principal modes and more typical subject-specific models will provide statistical results.

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