INTRODUCTION

Clinical evidence suggests that excessive contact between the femoral component of a posterior-stabilized (PS) total knee arthroplasty (TKA) and the quadriceps tendon in the suprapatellar region causes fibro-synovial hyperplasia [1]. The tissue contacts and/or becomes entrapped within the intercondylar box of the femoral component and during knee extension following active deep flexion, creates patellar crepitus or clunk syndrome [1, 2]. A recent case-controlled clinical study identified an increased incidence of crepitation in patients with decreased patellar ligament length, decreased patellar component size, decreased patellar composite thickness and increased posterior femoral condylar offset [3].

The objective of the present study was to use a computational model to evaluate the findings of the clinical study and attempt to elucidate primary causal mechanisms. To accomplish this, crepitus-control patient pairs matched by age, gender, and BMI were modeled to assess quadriceps tendon contact while wrapping on the PS femoral component throughout flexion. In the crepitus patient models, surgical interventions were suggested to improve the deleterious contact between the femoral component and tendon.

METHODS

Computational models of each knee were developed in a dynamic finite element model of the Kansas knee simulator (KKS, Figure 1) using Abaqus/Explicit (Simulia, Providence, RI). In specimen-specific implanted knees, the modeling platform has been previously validated to reproduce measured kinematics during force-controlled deep flexion conditions [4]. Soft tissue structures of quadriceps and patellar tendons were represented by fiber-reinforced composite structures capable of wrapping during flexion, while implanted components were treated as deformable (polyethylene) or rigid (femoral).

Parameters identified as affecting crepitation (patellar tendon length, component size, composite thickness) were perturbed in the model and results were compared to the clinical findings. The knee model was then scaled to patient-specific radiographic data (Figure 1) and used to evaluate tendon articulation over the PS femoral component. Matched crepitus-control patients from [3] were selected to evaluate the tendo-femoral contact differences between knees. The first crepitus-control pair had matching femoral, tibial and patellar TKA components, but different patellar tendon lengths. The second crepitus-control pair had matching femoral and tibial components, similar patellar tendon lengths (<1 SD), but different patellar component size.

Perturbations in joint line and femoral component flexion were performed in order to evaluate potential surgical interventions in the crepitus patient models. The joint line was lowered by 2 mm and 4 mm. Separately, the femoral component was flexed by 2° and 4°. Additionally, a combination of femoral component flexion and decreased joint line was evaluated. For each alignment evaluated, the cumulative region of tendon articulation over the femoral component, cumulative contact area within 2 mm of the intercondylar notch, and the minimum distance between the anterior border of the intercondylar notch and the suprapatellar tendon were calculated during knee flexion.

RESULTS

Decreased patellar component size and decreased patellar tendon length were shown to have an increased tendo-femoral contact area near the intercondylar notch, an increased total contact area, and a decreased minimum notch-to-tendon distance.

The patient-specific models showed substantially more cumulative tendon contact near the intercondylar notch in the crepitus patients, compared to their matched controls (Figure 2). Both lowering the joint line and increasing femoral component flexion showed decreased tendo-femoral contact near the intercondylar notch, and increased minimum notch-to-tendon distance (Figure 3). Simultaneously increasing femoral component flexion alignment and decreasing the joint line resulted in the best tendo-femoral contact conditions (Table 1).

DISCUSSION

Perturbations of key parameters were in agreement with results from the clinical study; decreased patellar tendon length and decreased patellar component size were shown to create tendon contact closer to the superior and lateral edges of the intercondylar box and to decrease the minimum notch-to-tendon distance, increasing the likelihood of crepitation.

Scaled models based on patient-specific radiographic data demonstrated clear differences in tendo-femoral contact surrounding the intercondylar box of the femoral TKA component in crepitus patients when compared to matched controls. The patient-specific modeling approach can provide supporting guidance to surgeons considering interventions to improve tendo-femoral contact, with the aim of decreasing the incidence of crepitus.

REFERENCES


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