Overstuffing of the patella alters patellofemoral mechanics and limits flexion

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INTRODUCTION
Alignment of total knee replacement (TKR) components is known to significantly influence joint function, including the loading and kinematics of the knee. While there are several hypotheses related to the mechanical advantages of increasing the post-operative composite thickness of the patella (overstuffing), including reduced tendo-femoral contact and the risk of crepitation, and reduced bone strain with thicker post-operative bone [1], surgeons typically try to restore the thickness of the native patella when placing the patellar component. Overstuffing has been reported to lead to maltracking and wear [2], cause significant stretching of the medial patellofemoral (PF) ligament [3], and has been associated with limiting range of motion of the knee [4]. However, in some instances, such as a thin patella, or impingement of soft tissue attachment sites beyond the ideal resection plane, restoring pre-operative patella thickness is unfeasible.

Prior inter-operative and clinical studies have investigated overstuffing of the patellofemoral (PF) joint and its effect on range of motion of the knee [4,5]. Computational models are ideally suited to efficiently evaluate component perturbations independent of patient variability or other confounding factors. The purpose of this study was to quantify the effect of overstuffing of the patella on knee mechanics, including patellofemoral kinematics and contact mechanics during a simulated deep knee bend.

METHODS
A computational finite element (FE) model of the Kansas knee simulator (KKS), developed in Abaqus/Explicit (Simulia, Providence, RI), was used to assess the influence of post-TKR composite patellar thickness on PF kinematics. Two specimen-specific models were created from CT data and implant geometry, and included soft-tissue structures representing tibiofemoral ligaments and the extensor mechanism [6]. TKR components were initially positioned in neutral alignment by a surgeon. Kinematics of a simulated deep knee bend in both specimen-specific implanted knees had previously been validated against experimental data extracted from the KKS [6].

The anterior-posterior (A-P) position of the patellar component was perturbed at 2 mm intervals from 2 mm understuffed to 6 mm overstuffed in both specimens. For each perturbation, a quadriceps displacement-controlled deep knee bend was simulated and six-degree-of-freedom PF kinematics and contact mechanics were predicted through the flexion-extension cycle. As the quadriceps is in displacement control, each simulation has a constant quad muscle excursion, which will allow different tibiofemoral flexion values. Tibiofemoral range of motion, patellar sagittal plane tilt and internal-external rotation, and the required quad forces were measured and compared for the various over/understuffing conditions.

RESULTS
Increasing the composite thickness of the patella had a consistent effect on peak femoral flexion and sagittal plane patellar tilt (Figure 2). On average, each additional 2 mm thickness reduced peak femoral flexion by 3.1º and reduced patellar tilt by 3.2º. In addition, overstuffing of the patella led to greater internal-external patellar rotation for one of the specimens evaluated (Figure 3). Understanding of the patella increased the quad force required and hence increased peak and average contact pressures on the patella (Figure 3). Finally, contact locations on the patella varied directly with the degree of over/understuffing. With overstuffing, the contact patch moved superiorly on the domed patellar button.

DISCUSSION
Changes in tibiofemoral range of motion with flexion were in good agreement with those reported by Bengs and Scott [4] for inter-operative passive flexion. Additionally, the computational analysis identified changes in patellar kinematics, notably sagittal plane patellar tilt with flexion and patellar internal-external rotation, as have been determined in previous cadaveric studies [2-4].

For a given quadriceps muscle excursion, overstuffing of the patella limits flexion; thus TKR patients with overstuffing of the patella will typically require more muscle stretch to perform deep flexion activities like kneeling and gardening and may be limited in this capacity.

While there are multiple factors which influencing post-operative range of motion, including pre-operative range of motion and component design, patellar composite thickness is one that can be controlled inter-operatively. Data from these analyses can aid surgeons by quantifying the effects of component alignment on (competing) performance measures with the aim of optimizing outcomes.

REFERENCES

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