INTRODUCTION:
Patellofemoral (PF) complications remain a primary cause for revision surgery in total knee arthroplasty, and include anterior knee pain, patellar fracture, polyethylene wear, instability, maltracking and loosening [1]. Strain in the natural or implanted patella likely plays a significant role in patellar fracture and potentially knee pain. The strain distribution in the implanted patella is not currently well quantified, especially in comparison with the natural PF joint. Additionally, the alignment of the patellar component on the resected bone is thought to be a factor contributing to these complications. During implantation, the patella is typically cut freehand or with the aid of a patellar clamp, and the implant is placed to reproduce the original thickness of the patella. The patellar component may also be medialized or placed superiorly, depending on the surgical philosophy and design, which results in substantial component alignment variability. Hence, the objectives of this study were to compare strain distributions in the natural and resected patella during a simulated deep flexion cycle, and subsequently to evaluate discrete perturbations of patellar implant alignment and their resulting impact on strain distribution.

METHODS:
Explicit finite element (FE) models of the PF joint were developed for the natural (Figure 1a) and implanted conditions (Figure 1b) in ABAQUS Explicit (Dassault Systems, Providence, RI). The femur, tibia and patella were extracted from computed tomography (CT) scan data. In all cases, local material properties were assigned to each element of the patella based on Hounsfield Unit using BoneMat [2] (Figure 1c). In the natural condition, patellar and femoral cartilages were modeled as deformable structures with linearly isotropic material. For the implanted cases, a surgeon identified the resection plane and a layer of cement and size-matched dome button was aligned. The cement layer and the button, meshed with 8-noded hexahedral elements, were represented with linear isotropic material properties. For computational efficiency, the femur and tibia or femoral and tibial components were represented as rigid bodies with a pressure-overclosure relationship. Soft tissue structures, including the patellar ligament (PL), rectus femoris (RF) and vasti, were represented as deformable hyperelastic two-dimensional membrane elements [3]. Linear actuators representing the quadriceps muscles were attached to the proximal portions of the RF and vasti and fixed to the femur according to orientations described in the literature [4]. A ramped quadriceps load (up to 1000N) was applied to the actuators and distributed according to physiological cross-sectional area (RF=15%, Vl=20%, VLL=35%, VLO=10%, VML=15%, VMO=10%) [4].

Tibiofemoral kinematics were prescribed based on fluoroscopy data and the femur was flexed from 10° to 105°, whereas kinematics of the patella in both natural and implanted conditions was completely based on PF contact and soft tissue constraints. The attachment sites of the soft tissues on the anterior side of the patella were identical for the natural and implanted cases.

After evaluating the natural patella and well-aligned implanted model, a series of alignment perturbations were evaluated. The dome patellar component was evaluated with inferior (3 mm), superior (1 mm), medial (3 mm) and lateral (3 mm) translations on the resected plane. In addition, flexion and extension alignment (±5°) were also evaluated, requiring rotation of the cutting plane. Care was taken to avoid overhang in these alignment perturbations.

RESULTS:
Peak minimum principal strains increased with flexion angle and the increasing quadriceps loading. Load transfer through the natural cartilage contact was substantially different than the implanted models. Compressive strain in the natural was concentrated directly under the contact location. Particularly high strains were found under the distal tip of the implant, consistent with the location of patellar fracture reported previously [5], and this may be exacerbated with a superior button placement. It should be noted that the resected patella will remodel over time, so the results here are most indicative of an early post-operative period. The changes to the strain distribution with the implanted patella may play a role in knee pain and fracture, and further study is warranted to understand mechanisms for optimizing PF load transfer for clinical success.

REFERENCES: