INTRODUCTION
Kneeling is considered an important activity by more than 50% of patients with total knee arthroplasty (TKA) [1], but patients often experience anterior knee pain and reduced functionality during kneeling-type activities [2,3]. In addition, implanted patellae have a greater risk of patellar fracture [4]. Noble et al. have performed cadaveric studies to assess patellar contact and tibiofemoral kinematics during kneeling [5]. Many factors influence the ability to kneel, including articular geometry, soft tissue impingement and implant design. The objective of the current study was to perform a comparative evaluation of patellofemoral joint mechanics and patellar bone strain distributions in the natural and implanted knee during simulated kneeling in multiple specimens.

METHODS
Specimen-specific finite element models for eight male specimens were developed from computed tomography (CT) and magnetic resonance (MR) scans of cadaveric knees. The patellar bone geometry was extracted from CT data to develop heterogeneous material properties using BoneMat [6] and an empirical density-modulus relationship [7]. MR data was used to reconstruct the femoral and tibial bone, cartilage, and musculotendon and ligament attachment sites. Geometry segmentation was performed with Simpleware (Exeter, UK) and hexahedral meshes of the articular cartilage were generated using custom mesh morphing techniques [8].

Two model representations were developed for each specimen in Abaqus/Explicit (Simulia, Providence, RI): a natural model with cartilage, and an implanted model with a size-matched domed patellar button, femoral component and tibial insert (Figure 1) [9]. Patellofemoral soft tissue was represented with 2-D fiber-reinforced membrane models of the extensor mechanism (patellar ligament, vasti and rectus femoris) and medial and lateral patellofemoral ligaments [10]. Corresponding to a foot propped kneeling condition, the knee was flexed to 110° using tibiofemoral positions prescribed from fluoroscopy data and a 1000 N distributed quadriceps load [10]. To simulate kneeling, the knee contacted the floor with a load of 660N, while the relative position of the femur and tibia was constrained. Contact pressure and area, and minimum and maximum principal strains were computed in the natural and implanted conditions. For comparison, the volume of highly strained bone (strains > 0.5%, just below bone yield strain [11]) were determined in four quadrants of the patella: inferior, superior, medial and lateral.

RESULTS
Kinematics and bone strain distributions were predicted for the eight specimens. Prior to kneeling, patellar tilt relative to the long axis of the tibia was greater in the implanted case than the natural case, resulting in a more inferior contact patch on the anterior surface of the patella against the floor (Figure 2). Bone strains were greater in the implanted case both before and after kneeling, as the cortical bone has been resected. Due to the compression-dominated loading, min principal bone strains and highly strained volumes were larger in magnitude than the max principal strains. The bone strain distribution after kneeling reflected the differences in patellar contact and resulted in larger compressive strains centrally in the natural and inferiorly in the implanted case (Figures 2 and 3). The min principal highly-strained bone volumes were on average 1.34X larger in the implanted than natural cases. The medial and lateral quadrants experienced a modest (16-42%) increase in highly strained volume in the implanted cases (Figure 4). However, statistically significant differences (ct=0.05) were only noted in the inferior (2X increase) and superior (2/3X decrease) regions of the implanted patellae compared to the natural.

DISCUSSION
Computational models of 8 cadaveric specimens were used to assess the kinematics, contact mechanics and patellar strain distribution during a kneeling activity. In the natural patella, the cartilage and patellar cortical bone distributed the kneeling loads around the periphery of the patella with minimum principal strains centrally in the softer cancellous bone. In the implanted patella, the increased tilt in TKA caused the strain distribution to shift inferiorly in both the flexed and kneeling conditions, resulting in statistically significant differences in inferior and superior highly strained bone volumes. This study did not consider bone remodeling and the strain distributions are accordingly representative of conditions immediately post-operative. The applied loading was not varied with specimen size, but rather held constant for all specimens to facilitate comparison. The results of the current study can ultimately provide guidance related to the amount of bone resection and component placement to reduce the likelihood of patellar fracture.

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REFERENCES