INTRODUCTION:
During knee replacement surgery, surgeons aim to optimize knee component placement for postoperative performance but can only judge patellofemoral mechanics by observing passive knee flexion intraoperatively. To our knowledge, intraoperative passive joint mechanics have not been compared to postoperative weightbearing mechanics either in vivo or ex vivo. Our research questions were: how well do patellar kinematics (tilt and shift) correlate between passive intraoperative flexion and weightbearing flexion in cadaveric specimens, and how do the contact forces differ?

METHODS:
We tested 8 cadaveric knee joints (6F/2M, ages 51-80) in 2 different rigs (an IRB-approved study): 1) In the custom-designed1 intraoperative rig, a hip joint was pushed along a horizontal track to mimic passive intraoperative flexion. A spring mounted between the quadriceps tendon and the simulated hip joint provided passive muscle tension. 2) In the Oxford-type weightbearing rig, a 54 N vertical load at the simulated hip joint caused the knee to flex, mimicking a squat. A motor attached to the quadriceps tendon controlled flexion and extension. We recorded femoral, tibial and patellar kinematics using Optotrak 3020 optoelectronic markers (Northern Digital, Waterloo, Canada) and recorded patellofemoral force distributions using custom-calibrated1 J-Scan 5051 electronic pressures sensors (Tekscan, Boston, USA). A new sensor was glued to the patellar component for each specimen and each rig and then lubricated to reduce shear forces. All specimens were implanted with modified NexGen posterior-stabilized components (Zimmer, Warsaw, USA) that allowed five different types of component variation: femoral rotation, tibial rotation, patellar resection, angulation, patellar medialization, and increased patellar thickness. A total of 10 clinically representative component position variations were studied. Baseline measurements, with all components in neutral position, were taken between each type of component variation. Correlations between the two rigs were evaluated using the Pearson correlation coefficient, r, with α = 0.05. For each specimen, the absolute tilt and shift measurements for the baseline position + 10 variations as well as the zero-to-baseline tilt and shift for the 10 variations were correlated between the intraoperative and weightbearing rigs; these correlations were then averaged across specimens. The reported correlations therefore represent the degree to which postoperative joint mechanics relate to intraoperative mechanics for an individual patient. Seven specimens were available for kinematic comparisons due to the failure of one specimen in the weightbearing rig. Five specimens were available for force comparisons due to sensor degradation in the first specimen and a punctured sensor in another.

RESULTS:
Correlations between intraoperative and weightbearing kinematics for both absolute and relative tilt and shift were strong (>0.8) or very strong (>0.9), with the exception of shift in early flexion, which was only moderate (0.54) (Fig. 1). However, absolute tilt and shift across component variations were offset by the baseline tilt and shift. Differences in absolute kinematics between rigs, 4.2°±3.6° for tilt and 4.3±3.9 mm for shift, were therefore notably larger and more variable than differences in relative kinematics, 2.2°±1.8° for tilt and 1.6±1.7 mm for shift. Baseline kinematics had greater variability in the intraoperative rig compared to the weightbearing rig, particularly in early flexion (Figs. 2,3). Forces were 4-5 times higher and were more variable in the weightbearing rig than in the intraoperative rig (Fig. 4).

DISCUSSION:
Our finding of a strong correlation for patellar kinematics between the intraoperative and weightbearing test rigs, especially in later flexion, is consistent with the view that patellar kinematics are predominantly controlled by the geometry of the femoral groove. Differences in soft tissue forces may explain much of the remaining differences between the two rigs: the lower quadriceps force in the intraoperative rig likely resulted in greater relative contributions of the lateral and medial retinaculum to patellar mechanics. By contrast, the higher quadriceps force (and hence contact force) in the weightbearing rig appeared to stabilize the patella, resulting in smaller variability for the kinematic variables in the weightbearing rig. Results may be specific to the component design. A limitation of the current study is that neither the intraoperative simulation nor the weightbearing simulation fully replicate physiological conditions at the joint; nevertheless, we believe this experiment captured the fundamental differences between the two loading conditions (lower, passive, horizontal loading versus higher, active, vertical loading) such that the conclusions would remain unchanged under physiological conditions. The results of this study suggest that if a surgeon adjusts a component position to improve patellar kinematics intraoperatively, the effects of such a geometric change will likely carry through to the postoperative joint, especially in later flexion.