INTRODUCTION
Injuries to the superficial medial collateral ligament (sMCL) and its supporting structures are the most common knee injuries.[1, 2] While many medial knee injuries can be treated conservatively, a complete understanding of medial knee functional anatomy and biomechanics is necessary when making treatment decisions. Due to most previous studies collecting data by indirect measurement techniques, a complete and thorough understanding of the biomechanics of the medial knee structures and their response to injury has not yet been fully achieved.[3] Thus, the purpose of this study was to determine the biomechanical effects and load distributions on medial knee structures in the face of varying grades of knee injury with the utilization of a direct measurement technique.

MATERIALS AND METHODS
Twenty-four non-paired, fresh frozen, cadaveric knees without evidence of injury were utilized for this project. The femur was sectioned 20 cm proximal to the knee joint and potted in polymethylmethacrylate (PMMA) for secure fixation in a customized knee testing apparatus.[3] Following severing of the tibia 12.5 cm distal to the knee joint, the tibial intramedullary cavity was reamed with a 13 mm drill bit. A threaded rod was inserted into the tibia, parallel with the long axis of the tibia, and fixed in position with PMMA to inhibit any rotation of the rod with respect to the tibia. A customized hexagonal nut with an eye-screw was attached to the tibial rod 22.9 cm distal to the knee joint, the tibial intramedullary cavity was reamed with a 13 mm drill bit. A threaded rod was inserted into the tibia, parallel with the long axis of the tibia, and fixed in position with PMMA to inhibit any rotation of the rod with respect to the tibia. A customized hexagonal nut with an eye-screw was attached to the tibial rod 22.9 cm distal to the joint line for the application of valgus torques. The superficial muscles and tendons were removed and deeper dissection isolated the posterior oblique ligament and superficial medial collateral ligament.

A customized knee testing apparatus firmly secured the femur at a horizontal angle, while allowing uninhibited movement of the tibia at the measured knee flexion angles. After the knee was aligned in the testing apparatus, buckle transducers were fastened to the posterior oblique ligament, the proximal division of the superficial medial collateral ligament, and the distal division of the superficial medial collateral ligament. The use of these devices has been previously described in detail.[3,4,5,6] Knees were randomly assigned to three groups of eight knees each. Sequential sectioning sequences encompassed the proximal and distal divisions of the sMCL (Figure 1), posterior oblique ligament (POL) (Figure 1), meniscofemoral and meniscotibial portion of the deep MCL (Figure 2). Each knee was tested at 0°, 20°, 30°, 60°, and 90° of knee flexion. The following external forces were applied: 10 Nm valgus load, 88 Nm anterior and posterior drawer, and 5 Nm internal and external rotational moments. Two-way ANOVA was conducted. A significant difference was determined to be present at p < .05.

RESULTS
Overall, sectioning of the structures produced variable load responses when compared to the native intact knee ligament forces. We demonstrated that after sectioning all of the structures except for the POL there was a load increase on the POL with an applied valgus moment at 0° (14.9 N vs. 24.3 N), 20° (12.0 N vs. 28.3 N), and 30° (12.0 N vs. 26.4 N) of knee flexion (p<.05). Our study also documented a significant load decrease with an applied valgus load on the proximal and distal divisions of the superficial medial collateral ligament compared to the intact state after sectioning the posterior oblique ligament and meniscofemoral divisions of the deep medial collateral ligament at 20° (68.8 N vs. 52.1 N), 30° (57.3 N vs. 48.6 N), and 60° (59.3 N vs. 45.0 N) of knee flexion (p<.05). It was also observed that with an applied external rotation torque on the proximal division of the superficial medial collateral ligament, there was a significant load decrease from the intact state after sectioning the posterior oblique ligament, meniscofemoral and meniscotibial divisions of the deep medial collateral ligament, and distal division of the superficial medial collateral ligament at 30 degrees of knee flexion (48.6 N vs. 19.0 N) (p<.05). With an applied external rotation torque, the distal division of the superficial medial collateral ligament experienced a significant load decrease from the intact state after sectioning the posterior oblique ligament at 0 degrees of knee flexion (42.5 N vs. 34.9 N) (p<.05). Lastly, we noted a significant decrease in observed load on the distal division of the sMCL with an applied valgus moment when comparing the intact to the meniscofemoral division of the deep medial collateral ligament sectioned knee at 0° (72.3 N vs. 68.1 N), 20° (85.6 N vs. 73.9 N), and 30° (87.3 N vs. 78.8 N), 60° (87.4 N vs. 86.2 N), 90° (75.4.0 N vs. 78 N) of knee flexion (p<.05).

DISCUSSION
Our study found alterations in the native load-sharing relationships of native knee structures following injury. Our experimental setup allowed us to directly measure the changes in force experienced by ligaments in an injury state, unlike many previously conducted studies which have utilized indirect measurements. Our multiple sectioning sequences demonstrated the effects of injury to secondary stabilizers when the primary stabilizers are intact. With an applied valgus and external rotational moment we noted an increase in load response on the POL. This could be attributed to its role as a secondary stabilizer for valgus and external rotation. With the main stabilizer sectioned it is plausible that the load was transferred to the secondary stabilizer. The noted decrease in load response on the sMCL with a valgus moment application could potentially be attributed to the transfer of load to structures that were not measured in this study, such as the deep medial collateral ligament or the cruciate ligaments.

In conclusion, we were able to measure the tensile load responses on the sMCL and POL in intact and injured states, compare load distributions in multiple sectioned states and demonstrate that both divisions of the sMCL, POL, and deep MCL should be repaired or reconstructed in isolated or combined medial knee injuries to best reproduce the native intact load distribution of the medial knee. Although this study comprehensively analyzed the main medial knee structures, further research encompassing the entire knee is needed to determine which knee structures take over the residual load after medial knee structure sectioning.

REFERENCES

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