Improving VMO Function Reduces Pressure Applied to Lateral Patellofemoral Cartilage

INTRODUCTION
Patellofemoral disorders are commonly attributed to lateral malalignment. Malalignment can lead to overloading of the lateral cartilage and subsequent areas of degeneration (lesions) or lateral dislocation, which frequently damages cartilage on the medial facet of the patella. Impaired function of the vastus medialis obliquus (VMO), as either weakness or delayed activation, is believed to contribute to lateral malalignment. Although physical therapy regimens commonly focus on improving VMO function, the biomechanical benefit of improved VMO function has yet to be established. The current hypothesis is that improving VMO function reduces the pressure applied to lateral cartilage, and that the pressure decrease is magnified when a lesion is present within the lateral cartilage.

METHODS
Ten cadaveric knees were secured to a testing frame at 40°, 60°, and 80° of flexion with the femur horizontal. Loads were applied along the anatomic orientations of the VMO, the vastus lateralis (VL), and the combination of the vastus intermedius, the vastus medialis longus, and the rectus femoris (VI/VML/RF). Loading cables connected to dead weights over pulleys were clamped to the muscles at their insertion sites on the quadriceps tendon. An extension moment of approximately 30 N-m was applied while representing a normal quadriceps force distribution, a weak VMO and a VMO with delayed activation. Previously published muscle extension moments for patients with pain and normal subjects [1, 2] were input into a computational model [3] to determine the forces applied through each muscle. For the normal quadriceps force distribution, 420 N, 116 N, and 60 N were applied through the VI/VML/RF, the VL and the VMO, respectively. For the weak VMO, the applied forces were 432 N, 127 N and 27 N, respectively. The delayed activation case used the same forces as the weak case, except with no force applied by the VMO. All tests were performed with the cartilage intact, with a 12 mm diameter lesion at the center of the lateral facet, with the lateral lesion filled with silicone, and with a 12 mm diameter lesion at the center of the medial facet.

Patellofemoral forces and pressures were measured with a calibrated sensor (I-Scan, Tekscan, Boston, MA), which was inserted into the joint. For each test, the position of the patellar ridge was identified on the sensor. The maximum lateral and medial pressure and the percentage of the total compressive force applied to the lateral cartilage were quantified. For assessing the influence of lesions, the intact case was treated as the control for the lateral lesion, and the case with silicone within the lateral lesion was treated as the control for the medial lesion. At each flexion angle, a two level repeated measures ANOVA showed if creating a lesion or varying the loading condition significantly (p < 0.05) influenced the output. A Student-Newman-Keuls post-hoc test was used for comparisons between individual loading conditions.

RESULTS
Increasing the force applied by the VMO reduced the load carried by the lateral cartilage. The lateral force percentage decreased significantly with each increase in the VMO force at each flexion angle for all cartilage conditions (Fig. 1). Increasing the VMO force decreased the maximum lateral pressure (Fig. 2) and increased the maximum medial pressure (Fig. 3), with significant differences noted at each flexion angle. Creating a lateral lesion significantly increased the maximum lateral pressure at 60° and 80°, but creating a medial lesion did not significantly increase the maximum medial pressure. A medial lesion did not significantly increase the maximum medial pressure due to the majority of compression being applied to the lateral cartilage, indicating that improving VMO function is beneficial even in the presence of a medial lesion. For patients with lateral malalignment, and particularly those with a lateral lesion, improving VMO function could relieve symptoms.

DISCUSSION
The results indicate that eliminating VMO weakness and a delay in VMO activation can reduce pressure applied to lateral cartilage. As the VMO force was increased, the increase in the maximum medial pressure was more consistent than the decrease in the maximum lateral pressure due to an accompanying slight increase in the total joint compression. Creating a lateral lesion increased the maximum lateral pressure at 60° and 80°. At 40°, the area of contact tended to be distal to the lesion. When the lateral pressure was elevated due to the presence of a lesion, increasing the VMO force tended to cause a larger decrease in the maximum lateral pressure. A medial lesion did not significantly increase the maximum medial pressure due to the majority of compression being applied to the lateral cartilage, indicating that improving VMO function is beneficial even in the presence of a medial lesion. For patients with lateral malalignment, and particularly those with a lateral lesion, improving VMO function could relieve symptoms.

REFERENCES

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