Computational Comparison of Tibial Tuberosity Anteromedialization vs. MPFL Reconstruction for Patellofemoral Instability

John J. Elias[1], Andrew J. Cosgarea[2]
[1]Medical Education and Research Institute of Colorado, Colorado Springs, CO; [2]Orthopaedic Surgery, Johns Hopkins University, Baltimore, MD
elias@meric.info

Introduction: Surgical treatment is commonly required to treat lateral patellar instability. Trochlear dysplasia complicates the choice of an appropriate surgical treatment method due to decreased articular resistance to lateral patellar subluxation. Reconstruction of the medial patellofemoral ligament (MPFL) and anteromedialization (AMZ) of the tibial tuberosity are two popular surgical options. MPFL reconstruction is performed using a graft stiffer than the native MPFL to resist the lateral force applied to the patella by the quadriceps muscles and the patella tendon. Tibial tuberosity AMZ is performed to reorient the patella tendon, which reduces the lateral force acting on the patella and patellofemoral compression. The hypothesis of the current study is that, for patients with trochlear dysplasia, tibial tuberosity AMZ is more effective at decreasing the lateral force acting on the patella and unloading lateral cartilage than MPFL reconstruction.

Materials and Methods: Following IRB approval, two computational models were developed to represent dysplastic (sulcus angle > 140°) knees that had experienced multiple instability episodes. For each knee, MRI images of the extended and flexed knee were obtained to create representations of the bones and cartilage and characterize patellofemoral alignment with the knee flexed, respectively. Passive knee flexion was simulated for the pre- and post-operative conditions. Pre-operative kinematics were based on the measured patellofemoral alignment. The patella was assumed to be centered within the trochlear groove following MPFL reconstruction and tibial tuberosity AMZ (Fig. 1).

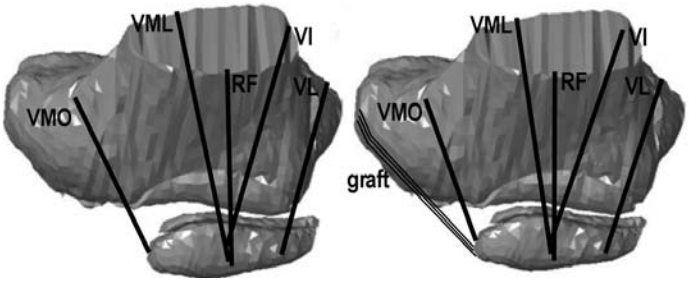

Fig. 1: A knee in the pre-operative condition and after simulated MPFL reconstruction.

Force vectors representing the quadriceps muscles and the patella tendon applied a constant 30 N-m extension moment. For AMZ, the tibial tuberosity was anteriorized and medialized by 7 mm in each direction. An MPFL graft was represented by three springs between the medial epicondyle of the femur and the medial edge of the patella. For one simulation, the resting length of the graft was chosen to maintain tension at all flexion angles. For another simulation, the resting length was chosen to cap the tension at 20 N. In the absence of tension, the condition following MPFL reconstruction was identical to the pre-operative condition. The properties of the graft were based on dual strand semitendinosus tendon grafts [1].

At each flexion angle, the resultant force and moment applied to the patella by the quadriceps muscles, the patella tendon and the graft (if present) were calculated. The patellofemoral force and pressure distributions were quantified using the discrete element analysis technique, as described previously [2]. Cartilage was represented by a surface of springs midway between the cartilage on the patella and the femur. Translation and rotation of the patella with respect to the trochlear groove minimized the total potential energy stored within the springs representing the cartilage and the graft. The percentage of the total compression applied to the lateral cartilage and the maximum pressure were calculated for each simulation.

Results: Tibial tuberosity AMZ decreased all components of the resultant force and moment acting on the patella. Anteriorizing the tibial tuberosity increased the quadriceps moment arm, decreasing the total joint reaction force. Medializing the tibial tuberosity further decreased the lateral force acting on the patella and the moments acting to tilt the patella laterally and rotate the distal patella laterally. The changes in the resultant force and moment led to relatively large post-operative decreases in the lateral force percentage and maximum pressure (Figs. 2, 3).

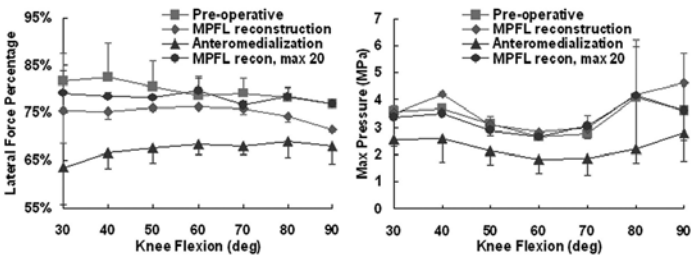

Fig. 2: Lateral force percentage (left) and maximum pressure (right) for all four conditions.

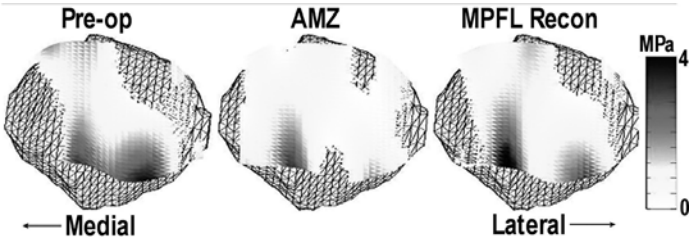

Fig. 3: Pressure distribution for one knee at 40° for pre-operative condition, AMZ and MPFL reconstruction with tension at all angles.

MPFL reconstruction had less influence on the resultant force and moment acting on the patella. With tension at all flexion angles, tension values as large as 30 N were recorded at low flexion angles. When graft tension was limited, the graft was unloaded at multiple flexion angles in deeper flexion. Due to the primarily posterior orientation of the graft, the graft primarily decreased the tilt moment acting on the patella. With tension at all flexion angles, the lateral tilt moment became a medial tilt for most flexion angles. MPFL reconstruction produced relatively little change in the lateral force percentage and maximum pressure, especially when the graft tension was limited. The maximum pressure increased at some positions when tension was applied at all flexion angles due to a pressure increase within the medial cartilage.

Discussion: Based on limited data, for patients with trochlear dysplasia, AMZ is more effective than MPFL reconstruction at unloading lateral cartilage due to decreases in the lateral force acting on the patella and the joint compression. Reducing the lateral force also helps constrain lateral subluxation. The data also indicates that, due to variations in graft length during flexion, MPFL reconstruction performed to improve alignment at all flexion angles can increase the pressure applied to medial cartilage. In order to avoid increasing the medial pressure, the graft will be lax at some flexion angles. The number of models was limited due to the limited number of patients meeting the inclusion criteria.

References: 1. Ciccone et al. J Bone Joint Surg Am 88:1071-8, 2006.
2. Elias et al. 53rd ORS Meeting, p. 94, 2007.

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