A Finite Element Analysis of Femoral Anterior Cruciate Ligament Reconstruction Graft Placement

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Disclosures:

Introduction: Femoral ACL tunnel malposition is related to clinical instability and graft failure. Given the prevalence of ACL reconstruction, there is a paucity of studies employing finite element analysis. While graft placement has been studied clinically and experimentally, quantitative information regarding differences in local biomechanics as a function of femoral graft placement has not been systematically evaluated. We hypothesize that simulated graft placement anterior to the anatomic footprint will result in pathologic knee biomechanics.

Methods: An established non-linear contact finite element model (1) used to evaluate 25 different tunnel loci representing primary ACL reconstructions; the first represented the center of the femoral anatomic footprint and loci diverged by 2.5mm increments in 8 directions relative to the roof of the notch: anterior, anterior/superior, superior, posterior/superior, posterior, posterior/inferior, inferior, anterior/inferior. A simulated Lachman maneuver was utilized to assess knee joint laxity, meniscal stress, in situ graft loading, and peak articular cartilage contact pressure for each of the tunnel positions.

Results: Significant increased anterior tibial translation during Lachman testing was observed when the femoral graft was moved anterior, anterior/inferior, and posterior/inferior relative to the anatomic footprint. Cartilage contact pressure (MPa) and peak von Mises stress at the medial and lateral menisci increased significantly when the femoral graft was moved anterior and anterior/inferior. Peak von Mises stress in the ACL grafts significantly increased as a function of graft position when moving posterior (120%) and posterior/inferior (144%).

Discussion: Femoral ACL graft malposition significantly affects local knee biomechanics. With regard to anterior tibial translation, there appears to be more tolerance/forgiveness when the graft is placed superiorly, superior/posterior or posterior with respect to the anatomic footprint. Conversely, simulated ACL grafts experience higher von Mises stress when placed too far posteriorly or posterior/inferior. Graft malposition is least forgiving when placed anterior or anterior/inferior to the anatomic footprint, and most forgiving when placed posterior to posterior/superior with regard to simulated Lachman testing. Given modern trends towards anatomic reconstruction and moving grafts inferior and posterior, this data suggests excessive posterior/inferior graft placement may subject grafts to significantly higher stresses.

Significance: Femoral ACL graft malposition is biomechanically least forgiving anterior/inferior to the anatomic footprint; current trends towards low and posterior placement may subject grafts high stress.

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Peak von Mises (\(vM\)) stress at the ACL graft (MPs)

Figure: Peak von Mises (\(vM\)) stress at the ACL graft observed in various femoral tunnel placements displayed topically in response to simulated Lachman testing. Relative to the notch angle, increased Peak von Mises stress in the ACL grafts observed moving posterior and posterior/inferior relative to the anatomic footprint.
Anterior Tibial Translation (millimeters)

Figure: Anterior tibial translation (mm) of various femoral tunnel placements displayed topically in response to simulated Lachman testing. Relative to the notch angle, increased translation is observed when the graft is moved anterior, anterior/inferior, and posterior/inferior relative to the anatomical footprint.
Cartilage Contact Pressure (MPa)

Figure: Posterior view of the femur. Articular cartilage contact pressure observed during simulated Lachman as a function of various femoral tunnel placements. Relative to the notch angle, increased cartilage contact pressures were observed when graft placements were anterior to the anatomic footprint.