

# Mechanical Strain Behavior of the ACL Graft Following Reconstruction: Effects of Femoral Graft Placement

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## Disclosures: N/A

**INTRODUCTION:** Anterior Cruciate Ligament reconstructions (ACLR) are one of the most common Orthopaedic knee surgeries, with approximately 400,000 procedures performed annually in the United States. With respect to graft tunnel(s) location and orientation during ACLR, it is an arthroscopic procedure that heavily relies on the physician's training and experience. A common occurrence is that the graft can be misplaced, potentially causing a reinjury; 1 in 5 patients will retear or reinjure their reconstructed graft, with 22% to 79% of failures associated with improper tunnel placement and failure to recognize associated laxity [2]. A fundamental aspect of the ACL is that it demonstrates isometric motion. In this condition, there is no change in the size or shape of the ligament as the knee undergoes motion around the ACL's center of rotation [3]. The ACL does, however, experience strain during loading, with a peak strain of 13.2%. Thus, there is a direct relationship between graft placement, graft strain, and ACLR success. However, there is limited data correlating these metrics. Therefore, the goal of this study was to use an in silico finite element method to analyze the change in mechanical behavior of ACL grafts as a function of their placement on the Posterior Lateral Condyle (PLC) of the femur. Our overarching goal is to provide surgical guidance on the placement of tunnels.

**METHODS:** A validated finite element (FE) model [4], initially established to study the predictive behavior of knee tissue during exercise, was used. Nodal points (i.e., physical locations) at the tibial and femoral native attachment sites of the ACL, as well as nodal points along the PLC, were chosen to track kinematic motion throughout flexion and extension of the knee. The displacement of these nodal points was then used to calculate the engineering strain that a graft would experience, depending on the location of the femoral attachment point. The ACL strain data, as a function of the femoral attachment point, were compared to the native ACL behavior in the model, using the native ACL's 13±2% strain during flexion and extension as a benchmark [3]. The femoral attachment point was deemed a critical region of interest for these analyses, as it is typically not visible arthroscopically – meaning the surgeon finds this location in a 'blind' method.

**RESULTS:** Two novel algorithms were developed to calculate the associated ACL strain and generate a 3D heat map illustrating the relationships between graft attachment location and strain. The changes in strain ranged from a maximum of a 210% increase in strain (increased stiffness) to a 223.2% decrease in strain (increased laxity), depending on the tibia tunnel location. Interestingly, these significant variances in strain resulted from exceedingly minor changes (>2mm) in the selected attachment site.

**DISCUSSION:** Femoral tunnel placement strongly influences the ACL graft strain behavior. Posterior placement of the graft decreases the strain, resulting in a compression force and loss of initial tension, which leads to increased laxity and instability of the knee. If the graft is placed posterior to the ideal native attachment, it can be initially fixed with appropriate tension. However, because the graft is no longer in its isometric position, it can lose tension when the knee undergoes any flexion-based motion, leading to an increase in instability. Alternatively, the anterior-distal placement increases strain, indicating a rise in tension, which may potentially cause increased stiffness or impingement. This anterior-distal placement is most observed as the patient loses range of motion, typically because the graft is fixed in a degree of flexion. If placed anteriorly, the graft is then too short to maintain the native isometric properties. Both misplacements cause the graft to deviate from the natural behavior of the ACL, possibly contributing to higher retear rates.

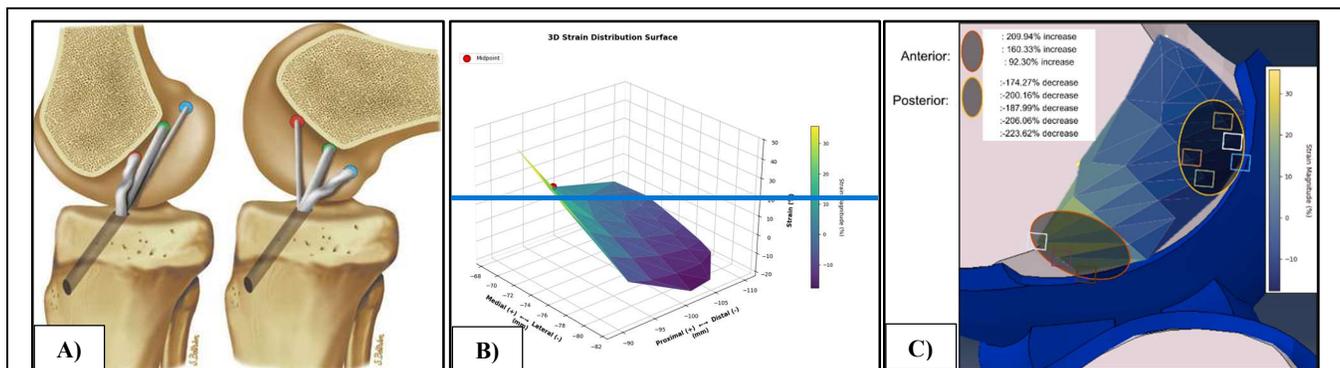
**SIGNIFICANCE/CLINICAL RELEVANCE:** (1-2 sentences): These data clearly demonstrate that small changes in femoral tunnel placement during ACLR result in significantly varied graft strain. Understanding the biomechanical relationship between ACL tissue biomechanics and femoral tunnel placement will enable physicians to select the appropriate femoral attachment for the new ACL graft, thereby improving surgical outcomes.

## REFERENCES:

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## IMAGES AND TABLES:



Figures: **A)** This figure by Bencardino, J. T. et al. [1] demonstrates that graft strain is a direct function of anterior to posterior placement of the ACL graft. **B)** The strain magnitude is shown overlaid on the possible attachment position on the Posterior Lateral Condyle. Two regions of interest have been highlighted (anterior and posterior).