Knee Kinematics of Meniscal suture spacing influences biomechanics of meniscal repairA BiomechaCombined ACLR and Anterolateral Reinforcement using Iliotibial Band Autograft nical Study of Combined ACLR and Anterolateral Reinforcement using an Iliotibial Band Autograft

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INTRODUCTION: TAn alternative anatomic ACL reconstruction (ACLR) combinesprises combined ACLR and anterolateral reinforcement using an iliotibial band (ITB) autograft (SATURN). The aim of this study is to evaluate the effects of this technique on knee kinematics in the ACL injured knee. here is a widespread consensus that preserving the meniscus is preferable to meniscectomy to prevent the onset of degenerative changes in the knee.[1] Several meniscal repair techniques have been described to achieve this, with suture placement playing a crucial role in repair biomechanics. Longitudinal vertical meniscus tears are common in clinical practice and are considered the standard indication for meniscus healing.[2] The ideal distance for placing two consecutive meniscus sutures is not well described in literature.Despite this, the best suture spacing for an effective repair remains uncertain. This study aimed to determine the optimal distance between meniscus sutures that minimizesminimises the tear gap in a vertical longitudinal tear. We hypothesized that larger distances between sutures would result in more significant displacements than smaller distances between sutures.

METHODS: With Institutional approval (Committee for Oversight of Research and Clinical Training Involving Decedents), ten unpaired fresh-frozen human cadaveric knees (mean age: 40.6 years) were tested using a robotic system under three loads: (a) an 89N anterior tibial translation (ATT) load, (b) a 5 Nm internal rotation (IR) tibial torque, and (c) simulated pivot shift (PS) loading as a combined 7 Nm valgus moment followed by a 5 Nm internal rotation. In this ACLR, with the knee flexed at 80°, -the ITB autograft, (8mm (n=6), 9 mm (n=4)), was passed over the lateral collateral ligament (LCL), and for lateral reinforcement procedure was performed with the knee flexed to 80° of flexion, and was inserted inwards throughfrom the outside of the femoral tunnel which was created just posterior and proximal of lateral epicondyle. The graft was fixed in this tunnel with an interference screw- underwhile applying 80 N of tension and fixed with an interference screw. Inside the joint tThen graft was then passed through the tibial tunnel and fixed 80 N tension at 20° of flexion. Data was acquired for the intact, ACL-deficient (ACL-DEF), and the ACLR (SATURN) state. -Pairwise T-tests with Bonferroni correction hadwere used with significance set at $p<0.05$. After removing the meniscus roots, of 50 bovine medial and lateral menisci, the remaining meniscus was cut radially into two (anterior and posterior) samples. In each sample, a full longitudinal meniscal tear was created 5mm from the peripheral meniscal rim using a no. 15 blade. The tears were repaired using two 2-0 braided sutures (Ultrabraid, Smith&Nephew) with vertical mattress sutures 3mm from the torn edge with five different suture spacings: 3, 5, 7, 9, and 11mm. The sutures were tensioned to 30 N using a tensiometer and securely tied to the meniscus base with a sliding knot. Additionally, to prevent slippage, five alternating half-hitch simple knots were performed. To allow for radial loading of the repair, three #5 braided polyester loading sutures were placed at the peripheral meniscal rim, spaced equally at intervals of 10mm, starting from the center of the sample (Fig. 1). Each sample underwent 5-20 N (combined suture load) for 1000 cycles at a crosshead speed of 75 mm/min using a material testing machine. The tear opening gap at the 1000th cycle was measured using a digital image correlation system. An ANOVA test with a Bonferroni correction was performed to determine differences in displacement between groups at the 1000th cycle.

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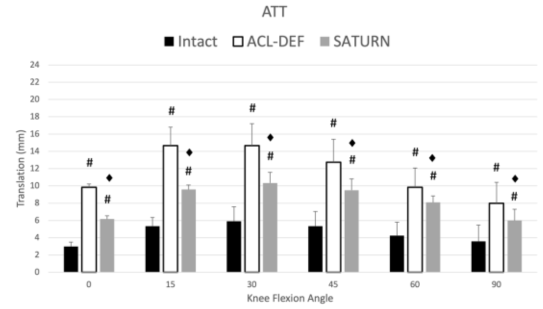
RESULTS SECTION: In response to ATT loading, a statistically significant decrease in ATT was observed at all knee flexion angles between the ACL-DEF and ACLR states (Fig. 1), however, ACLR did not restore the intact knee ATT. While there was a statistically significant difference in IR between the intact and ACLR states at 0° of knee flexion, no statistically significant difference was found between the ACLR and intact states at other flexion angles (Fig. 1). In response to simulated PS load, while higher tibial displacement was detected in the ACLR state compared to the intact state at 0° and 15° of flexion (Fig. 2), no statistically significant difference was found between the states at 30° of flexion (Fig. 2)..The mean ± standard deviation of the tear gap for each repair spacing is given in Figure 2. Groups with suture distances of 3mm, 5mm, and 7mm demonstrated significantly smaller displacements (1.6 ± 0.3mm; 1.9 7 ± 0.5mm; 1.7 ± 0.5mm, resp.) compared to the groups with suture distances of 9mm and 11mm (2.47±0.41mm; 2.7±0.67mm), respectively. The group with suture distances of 7mm demonstrated significant smaller displacement (1.7 ± 0.5) compared to the group with suture distances 11mm. Displacement among suture distances of 3mm, 5mm, and 7mm exhibited no significant differences. Similarly, no significant difference in displacement between groups of 9mm and 11mm was observed. Failure mode did not correlate with suture distance. Sutures broke in 7667.6% (3825/5037) and cut through the meniscus tissue in 229.7% (111/5037), while a combination of one suture breakage and one tissue transection was observed in 2.7% (1/5037).

DISCUSSION: TIn this cadaver study the ACLR did not restore intact ACL ATT, which is not uncommon with ACLR, but it did improveimprovement both to internal rotationIR and simulated pivot shiftPS displacements.he main finding of this study is that meniscal repairs with a suture distance greater than 11 9mm demonstrated significantly higher opening displacements under radial load compared to those at 7mm and below and suture distance of 9mm demonstrated significantly higher opening displacements to those at 3 and 5mm. Meniscus sutures are clinically placed at varying distances[3,4], and the optimal spacing remains undetermined. Based on the current data, a suture distance of 9mm or higher appears to result in a larger displacement and potentially hinder the healing of a meniscus tear. Further biological studies are needed to investigate how the gap size of a tear influences its healing process.

SIGNIFICANCE/CLINICAL RELEVANCE: TBased on the results of this cadaver study, this combined ACLR and anterolateral reinforcement method using this novelthe ITB technique as a autograft provides an alternative methodtechnique to improve stability of the ACL-deficient knee.ear gaps with sutures positioned at distances of 7mm or less exhibit greater biomechanical stability compared to sutures at 9mm and beyond. Surgeons may want to consider the data from this study when employing meniscus sutures at a distance of greater than 7mm.



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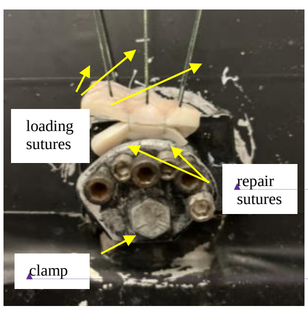

Figure 11: Clamped inner edge of meniscus wedge with three loading sutures placed at the peripheral meniscal rim

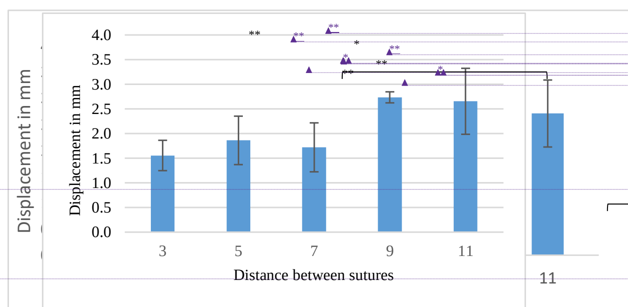

Figure 2 Gap openingp increase from unloadedpreloaded statecondition to 1000th load cycle. The bars show the mean ± standard deviation. * p≤0.05;

Figure 1: ATT under 89 N anterior tibial loading at different flexion angles (# p<.05 vs Intact. ♦p<.05 vs. ACL-DEF).

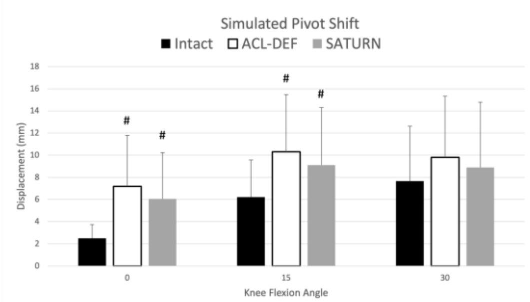

Figure 2: Simulated pivot shift loading (7 Nm valgus & 5 Nm internal moments) at different flexion angles (# p<.05 vs Intact. ♦p<.05 vs. ACL-DEF).

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