Augmentation of ACL Repair With Scaffold Assisted ALL Reconstruction Normalizes Knee Kinematics in a Cadaveric Model

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INTRODUCTION: Primary ACL repair has re-emerged as a viable option for select injuries, particularly proximal tears and femoral avulsions with good tissue quality. Compared with reconstruction, repair preserves native ligament tissue and proprioception, avoids graft harvest morbidity, and is less invasive, yet residual instability remains a concern. Concomitant anterolateral ligament (ALL) injury is common in ACL tears, and the ALL plays a critical role in resisting tibial internal rotation. Combined ACL–ALL procedures have therefore been developed to improve rotatory stability and reduce failure rates. In parallel, orthobiologics and biologic scaffolds are increasingly applied to enhance the biological environment for healing. A porous collagen–PLLA scaffold with load-sharing strength and capacity for tissue ingrowth, has been described in various orthopedic applications, but biomechanical data supporting its use in ACL repair are lacking. This study investigates the time-zero biomechanical effect of incorporating the scaffold-assisted graft into a combined ACL repair and ALL reconstruction construct.

METHODS: Eight matched pairs cadaveric knees (5F;3M) were prepared with femoral and tibial diaphyses sectioned 20 cm from the joint line; distal tibiae were potted in custom aluminum jigs using two-part epoxy and a 12-mm hex screw for torque application. Specimens underwent sequential testing in ACL/ALL-deficient, ACL repair, and ACL repair with scaffold-assisted ALL reconstruction states. Kinematics were assessed at 0°, 30°, 60°, and 90° of flexion under standardized loads: 100 N anterior translation, 5 Nm varus/valgus (25 N applied 20 cm from the joint line), and 5 Nm internal/external rotation. Loads were applied using a handheld electronic load cell (Omega 661.09B) and torque wrench, with motion captured via an Optotrak Certus optical tracking system, Figure 1. Surgical Technique: A medial parapatellar arthrotomy was performed, and the ACL was sectioned proximally while the ALL was transected in its midsubstance through a lateral approach. For ACL repair, two UHMWPE braided sutures were placed through the ligament stump, and a femoral tunnel was created at the native origin using an outside-in guide and flip cutter. The sutures were shuttled through the tunnel and tied over a cortical button to restore ligament continuity. For scaffold-assisted augmentation with ALL reconstruction, the scaffold was passed with the repair sutures into the femoral tunnel and secured over the cortical button. The free end was routed laterally and fixed at the tibial ALL insertion with an interference screw, creating a continuous construct that reinforced the ACL repair and reconstructed the ALL, Figure 2.

RESULTS SECTION: ACL repair alone failed to restore normal anterior translation and rotational stability, with significant residual increases in anterior load, internal rotation, and external rotation across flexion angles. In contrast, scaffold -assisted ALL reconstruction restored knee kinematics to native levels, showing no significant differences from the native state across all angles and load types. Compared with repair alone, the scaffold-assisted construct significantly reduced anterior translation at all flexion angles ($p = 0.048$–0.008), normalized external rotation at 30°, 60°, and 90° ($p = 0.019, 0.001, 0.014$), and restored internal rotation at 30°, 60°, and 90° ($p = 0.032, 0.003, 0.007$). Valgus stability showed modest improvement at 0° ($p = 0.035$), while varus stability was unaffected, Figure 3.

DISCUSSION: ACL repair alone failed to restore normal anterior displacement or rotational stability, with significant increases in anterior translation and both internal and external rotation across flexion angles compared to the native state. In contrast, ACL repair with scaffold-assisted ALL reconstruction eliminated these differences, showing no significant deviation from native kinematics for all motions and flexion angles tested. Varus stability was unaffected across groups, while valgus stability showed a small but statistically significant difference at 0° in the control group, which was not present with the scaffold-assisted construct. These results demonstrate that the addition of scaffold-assisted graft not only restores native-level stability in anterior and rotational planes but also avoids the residual laxity seen with repair alone. This suggests a potential advantage of scaffold-assisted graft in providing mechanical reinforcement while serving as a biologically active scaffold to support tissue healing. Limitations of this cadaveric model include the absence of muscular stabilization and differences from clinical surgical techniques, underscoring the need for in-vivo studies to assess biologic integration, durability, and long-term outcomes.

SIGNIFICANCE/CLINICAL RELEVANCE: Scaffold-assisted ALL reconstruction enhances ACL repair by restoring native knee kinematics and providing combined mechanical and biologic augmentation. This approach may reduce failure rates and improve long-term outcomes, supporting broader adoption of ACL preservation strategies.

ACKNOWLEDGEMENT: ConMed for study funding

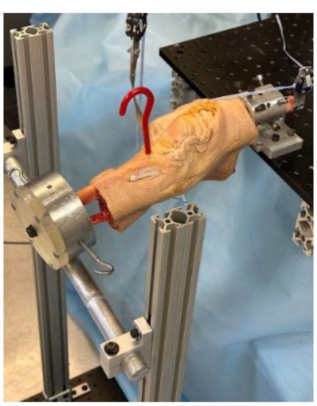

Figure1. Biomechanical test setup. Cadaveric knees were sectioned 20 cm from the joint line, tibia potted in custom jigs, and tested under anterior (100 N), varus/valgus (5 Nm), and internal/external rotation (5 Nm) loads, with motion capture marker placed on the femur and tibia.

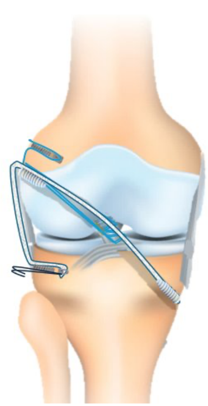

Figure 2. Scaffold-assisted augmentation with ALL reconstruction. The scaffold was passed with repair sutures into the femoral tunnel, secured over a cortical button, and fixed at the tibial ALL insertion with an interference screw to create a continuous reinforcing construct.

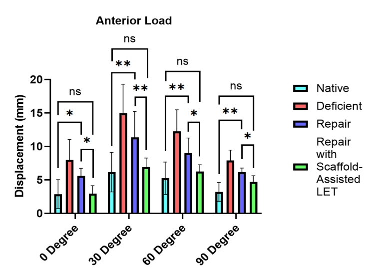

Figure 3. Anterior displacement under 100 N load at 0°, 30°, 60°, and 90° of flexion. The ACL/ALL-deficient state showed significantly greater displacement than all other groups. Scaffold -assisted ALL reconstruction reduced displacement to native levels across angles. *$p < 0.05$; **$p < 0.01$; ns = not significant.