ACL Reconstruction Using a Short Hamstring Graft and Tape Locking Screw: A Biomechanical Study

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Disclosures:

Introduction: Anterior cruciate ligament (ACL) reconstruction is one of the most widely performed orthopaedic procedures in developed counties. Reconstruction using autograft soft tissue such as hamstring tendon has been the preferred choice by many for its superior strength and less donor-site morbidity over the bone-tendon-bone graft. Fixation of soft tissue graft, however, has been less than optimal, and there is some evidence to suggest it affects the function of the reconstructed knee. A newly developed soft tissue reconstruction technique using tape locking screw fixation (TLS) has demonstrated improved fixation properties in preliminary tests and good outcomes in the initial clinical application [1]. There has been no report of biomechanical assessment of this new approach. The objectives of this study are to evaluate knee joint biomechanical behaviors after quadrupled soft tissue ACL reconstruction using TLS fixation method, and compare it with the traditional Endobutton technique in match-pair cadaver model. Modifications were also made to the TLS technique to further improve its fixation strength. The modified technique was evaluated with additional cadaver testing.

Methods: Five pairs of fresh frozen cadaveric knee joints were procured from musculoskeletally normal donors (mean age: 56yrs, range: 48-63yrs), and randomly assigned to receive TLS technique (TLS) on one knee and Endobutton technique (Endo) on the matching knee. An additional nine fresh frozen knee joints were obtained from five donors (mean age: 52yrs, range 44-58yrs) in the second phase of the study and were assigned to modified TLS technique (mod_TLS). All specimens were stored at -30°C and thawed overnight in room temperature for the procedure. After the procedure, specimens were stored at -30°C again until the day of testing. Hamstring tendon autograft was harvested for the procedure. Prior to graft placement, four radiopaque markers were sewed into the looped graft to facilitate the measurement of graft-tunnel motion. Bone tunnels were drilled at the femoral and tibial insertions of the transected ACL. Two of the markers were placed in the locations corresponding to proximal and distal quarters of the femoral tunnel, and another two were placed in the corresponding tibial tunnel. For TLS group, 10x20mm locking screw was used in the femoral side and 10x25mm on the tibial side. For mod_TLS group, two modifications were made to all nine specimens: 1) a larger diameter (12x20mm) locking screw was used on the tibial side, and 2) once tibial TLS was in place, the two tape ends were looped over a metallic button and tied together with a triple knot.

All biomechanical tests were performed at room temperature using a servo-hydraulic loading frame (MTS 809, Eden Prairie, MN). The reconstructed knee specimen was mounted into a set of custom-made apparatus that allowed adjustment of the knee flexion angle. The specimen was moistened with saline solution during mounting and testing. Three sets of test were completed: 1) Graft-tunnel motion: With the ACL-reconstructed knee placed in 60° of flexion and neutral rotation, anterior pulling loads of 33 N, 67 N, and 100 N were applied to the tibia sequentially. A portable x-ray machine was set up to take lateral radiographs of the knee. The x-ray cassette was aligned parallel to the femoral bone tunnel, and the gantry of the machine was adjusted so that the x-ray beam was perpendicular to the cassette. The positions of cassette holder and the gantry of the machine remained fixed throughout testing. Five lateral radiographs were taken: 0 N, 33 N, 67 N, 100 N, and 0 N again. Longitudinal migrations of the markers were quantified on the digital images of the radiographs with the aid of imaging software (Image J by NIH, Bethesda, MD). 2) Drawer tests: The drawer tests were performed with the knee in 90° of flexion and neutral rotation. An anterior pulling force up to 50 N was applied to the tibia in three loading-unloading cycles at a rate of 1 mm/sec. All three hysteresis curves were recorded and the third curve was analyzed to quantify the anterior drawer displacement and stiffness. The test was repeated after all soft tissues were dissected leaving only the reconstructed ACL. 3) ACL load-to-failure tests: Tensile failure test of the reconstructed ACL was performed with the knee positioned in neutral flexion in the same adjustable fixtures. Reconstructed ACL was loaded at a rate of 1mm/sec until graft failure or reaching maximum separation of the 30mm. The resulting load-displacement curve was recorded and maximum load was calculated. Specimen was then visually examined for mode of failure.

Results: All specimens showed higher tunnel migrations on the tibial side than on the femoral side. The mean tibial tunnel migration from the Endo group was 27% and 36% higher than the mod_TLS and TLS groups respectively, but neither reached statistical significance. Large inter-specimen variations were observed in both TLS groups. The mean anterior displacement of the mod_TLS was 1.96±0.31mm for ACL only specimens and 1.76±0.30mm for post-operative knee specimens. Compared to the TLS and Endo groups, these represent 25.9% (p<0.015) and 33.4% (p<0.0002) decrease respectively for ACL only specimens, and
35.5% (p<0.006) and 30.7% (p<0.018) decrease for the knees. The mean stiffness derived from the linear region of the anterior drawer test was 34.9±5.9 N/mm for the mod_TLS group, which was significantly higher than the Endo group (28.1±3.0 N/mm, p<0.04) and TLS group (26.3±6.1 N/mm, p<0.02). The mean failure load of the mod_TLS was 668±278N, which was more than two times higher than the Endo group (288±77N, p<0.01) and close to four times higher than the TLS group (136±100N, p<0.002). Large variations in failure load were observed in all three groups. For specimens in TLS and Endo groups, the failure occurred on the tibial side with the graft pulled out of the bone tunnel. Among the nine mod_TLS specimens, one failed as the graft broke; the remaining eight all reached the maximum separation of 30mm.

**Discussion:**
Results from this cadaver study simulating scenarios of immediate post-surgery showed that reconstruction using TLS technique provides comparable joint stability (drawer test) as the traditional Endobutton technique. The TLS group was superior in preventing graft migration within the bone tunnels under moderate level of loading, especially in the tibial side. However, reconstruction using the original TLS technique had much inferior tensile strength with the knee in neutral position. Modifications using larger tibial screw and tying loose ends of the tibial tapes over a button effectively improved the strength of the reconstructed ACL. These modifications also significantly improved joint stability under anterior drawer test over the original TLS and the Endobutton techniques.

**Significance:** Graft fixation is a weak link in ACL reconstruction during the initial post-operative period. It is important for new fixation techniques to be evaluated biomechanically with a clinically relevant cadaver model.

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