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Journal:	*Orthopaedic Research Society*
Abstract ID:	Draft
Presentation Type:	Either Poster or Podium
Categories for Abstract Review:	Tendon/Ligament - Ligament and Tendon Mechanics, Hip & Knee � Disease Process - Joint Mechanics, Hip & Knee � Disease Process - Knee
Keywords for Transactions on DVD-ROM:	Ligament and Tendon Mechanics, Surgical Navigation and Robotics, Joint Mechanics

A Biomechanical Comparison of Two Femoral Fixation Techniques for Single-bundle Anterior Cruciate Ligament Reconstruction: Anatomic Femoral Tunnel versus Over-the-top Fixation

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INTRODUCTION

Anterior cruciate ligament (ACL) reconstruction in skeletally immature patients is a challenging procedure. Regarding the femoral fixation, two techniques are commonly used including the femoral tunnel (FT) technique and the over-the-top (OTT) fixation. OTT fixation, passing the graft over the superomedial border of the lateral femoral condyle, has gained favor as a physeal-sparing technique despite its non-anatomic location, although it is close to the femoral insertion of the anteromedial bundle of the ACL.

The purposes of this study are to compare knee kinematics and the *in situ* force of the graft between using the anatomic FT technique and the OTT fixation for single-bundle ACL reconstruction. It is hypothesized that better biomechanical results would be achieved with the anatomic FT method than with the OTT method since the graft is placed in the anatomic insertion of the ACL.

METHODS

Ten fresh frozen cadaveric knees (mean age 57 years, range 48-65 years) were used in this study. All soft tissue, approximately 10 cm away from the joint line, on both sides were removed to expose the bone while the knee joint was kept intact. The exposed femur and tibia were secured in the cylindrical shaped epoxy compounds (Bondo, Atlanta, GA) for secure mounting in custom-made aluminum fixtures. The femoral side was rigidly fixed to the base of the robotic manipulator, while the tibial side was mounted to the end-effector of the robot through the universal force-moment sensor (UFS).

The robotic manipulator (CASPAR, OrthoMaquet, Rastatt, Germany) is a six-joint serial articulation device which allows 6-degree-of-freedom motion of the knee. The UFS (model 4015, JR3 Inc, Woodland, California) is capable of measuring 3 orthogonal forces and moments with repeatability of 0.2 N and 0.01 Nm respectively. The following external loads were applied to the tibia: 1) a 89 N anterior tibial load at full extension and 15º, 30º, 60º, and 90º of flexion; and 2) a combined rotatory load of 7 Nm valgus torque and 5 Nm internal tibial rotation torque at 15º, and 30º of flexion.

The same loads were applied to the intact knee, the ACL deficient knee and the ACL reconstructed knee. Five-degree-of-freedom kinematics, forces, and moments were recorded. The kinematics of the intact knee were repeated in the ACL deficient knee, and the kinematics of the reconstructed knee were also repeated after graft removal. By the principle of superposition, the vectorial differences are the in situ force of the ACL and the reconstructed graft respectively.(1,2) The testing protocol is demonstrated in Fig. 1.

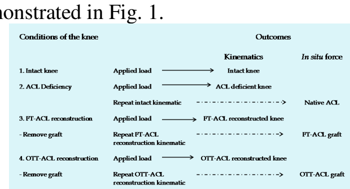

Fig 1 Testing protocol

Arthroscopic ACL reconstruction was performed utilizing a 3-portal technique including anterolateral, anteromedial, and accessory medial portals.(3) Both femoral and tibial footprints were identified and marked with a thermal device. For the anatomic FT technique, 8-mm-diameter tunnels were drilled at the center of femoral and tibial insertion sites. The 8-mm-diameter hamstrings graft was passed and fixed on the femur utilizing an Endobutton CL (Smith and Nephew). On the tibial side, a staple was used for graft fixation at 30º of flexion while a 44 N tension was applied, and augmented by suture to screw post fixation.

For OTT ACL reconstruction, a lateral incision was made over the distal femur and the OTT position was manually palpated. A posterior capsular hole was made at the OTT position by passing the tip of the curved clamp inside-out. The same graft was subsequently passed and fixed to the bicortical screw at the lateral femoral metaphysis via a continuous loop (Smith and Nephew). The graft was then fixed to the proximal tibia in the same fashion as the FT technique.

Statistical analysis for differences in kinematic data and *in situ* force at each flexion angle was performed using Friedman test, followed by post hoc analysis to compare differences between each pair-wise comparison using Wilcoxon signed ranks test.

RESULTS

Anterior tibial load: Anterior tibial translation (ATT) of both FT and OTT ACL reconstructions were not significantly different from the intact knee at each flexion angle. There were also no significant differences between ATT of both techniques at every testing angle. (Fig 2) *In situ* force of the native ACL varied from 67.5 ± 2.8 N at 15º of flexion to 75.6 ± 6.7 N at 90º of flexion. At full extension, OTT ACL graft had significantly higher *in situ* force than the native ACL ($p=0.013$). *In situ* forces of both reconstructions, FT and OTT, were significantly greater than the native ACL at 15º of flexion ($p=0.017$ and $p<0.01$ respectively) and were significantly lower than the native ACL at 60º and 90º of flexion ($p<0.01$). No significant difference of the *in situ* forces between FT and OTT techniques at each testing angle. (Fig 3)

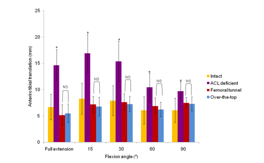

Fig 2 ATT under a 89 N anterior tibial load (mean ± SD; * significant difference compared with the intact knee, p<0.05; NS non-significant difference between FT and OTT technique, p>0.05)

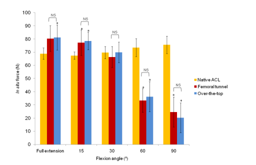

Fig 3 *In situ* force of the native ACL and the ACL reconstructed graft in response to a 89 N anterior tibial load (mean ± SD; * significant difference compared with the intact knee, p<0.05; NS non-significant difference between FT and OTT technique, p>0.05)

Combined rotatory load: Coupled ATT of the ACL deficient knee, the FT ACL reconstructed knee, and the OTT ACL reconstructed knee were not significant different from the intact knee. Coupled ATT of the FT method was not significantly different from the OTT method. (Fig 4) FT ACL graft had significantly lower *in situ* force than the native ACL at 15º of flexion ($p<0.01$). Whereas, the OTT ACL graft had significant lower *in situ* force than the native ACL at 15º and 30º of flexion ($p<0.01$ and $p=0.013$ respectively), and also had significant lower *in situ* force than the FT ACL graft at 30º of flexion ($p<0.01$). (Fig 5)

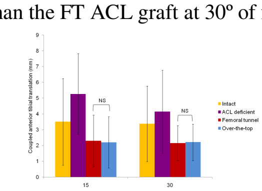

Fig 4 Coupled ATT under a combined rotatory load(mean ± SD; NS non-significant difference between FT and OTT technique, p>0.05)

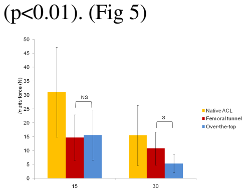

Fig 5 *In situ* force of the native ACL and the ACL reconstructed graft in response to a combined rotatory load (mean ± SD; * significant difference compared with the intact knee, p<0.05; S significant difference between FT and OTT technique, p<0.05; NS non-significant difference between FT and OTT technique, p>0.05)

DISCUSSION

This study revealed that both ACL reconstruction techniques, FT and OTT, can restore knee kinematics in response to an anterior tibial load and a combined rotatory load. Under an anterior tibial load, the *in situ* force of the ACL graft reconstructed with both techniques was found to decrease with an increasing flexion angle, and was significantly lower than the native ACL at 60º and 90º of flexion. The *in situ* force of the ACL graft reconstructed with OTT technique was comparable to FT technique except for the force in response to a combined rotatory load at 30º of flexion. The limitation of this study is that it is a time-zero study that does not take into consideration the effect of graft healing and graft stretching over time.

ACKNOWLEDGEMENT

The support of the Albert B. Ferguson, Jr. MD Orthopaedic Fund of The Pittsburgh Foundation is gratefully acknowledged. The authors thank Chad A. Hume for his technical assistance.

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