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A comparison of Anterior Cruciate Ligament graft tunnel orientation: Anatomic vs. transtibial

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Background: Recent Anterior Cruciate Ligament reconstruction techniques have emphasized reproducing the insertion sites of the native Anterior Cruciate Ligament. Anatomic techniques have shown improvements in biomechanical testing, but their superior results have not been shown clinically. The hypothesis of this study is that more oblique tunnels utilized in anatomic reconstructions cause asymmetric loading across the graft.
Methods: Seven cadaver knees were tested in a knee simulator that performed a gait cycle and an anterior–posterior laxity test. Each knee underwent both reconstructions in random order utilizing the same Anterior Cruciate Ligament bone patellar tendon bone graft. Before reconstruction, the graft was split longitudinally and miniature force probes were inserted in the medial and lateral portions.
Findings: During anterior–posterior laxity testing, the transtibial medial bundle averaged 74.8 N compared to 87 N for the anatomic. The lateral bundles averaged 146.2 and 158 N respectively. Both reconstructions exhibited a similar ratio of force distribution between the bundles and there was no statistical difference. The average anterior–posterior motion for the intact knees was 10.8 mm compared to 17.0 mm after the Anterior Cruciate Ligament was sectioned. Anatomic reconstructions had an average of 14.0 mm of laxity compared to 14.9 mm for transtibial reconstructions ($P<0.038$).
Interpretation: Greater obliquity did not lead to an increase in asymmetry of graft loading. The failure of anatomic reconstructions to show clinical improvement over transtibial reconstructions is not due to oblique tunnels causing asymmetric graft loading.

1. Introduction

The goal of every Anterior Cruciate Ligament (ACL) reconstruction is to provide a stable knee that will allow return to previous function and knee kinematics. Previous studies have shown aberrant knee kinematics after reconstruction and long term osteoarthritis continues to be a problem (Logan et al., 2004; McCulloch et al., 2007; Streich et al., 2008). Recently, there is considerable interest in developing and testing more anatomically correct reconstructions with the expectation that this will lead to improvements in outcomes. Single and double bundle techniques have been developed (McCulloch et al., 2007) that more closely reproduce the femoral insertion of the native ACL. Although these techniques have shown some improvements in biomechanical testing (Mae et al., 2001; Yagi et al., 2002), their superior results have yet to be shown clinically (Meredick et al., 2008; Streich et al., 2008), and the ideal location and orientation of bone tunnels in an ACL reconstruction remains controversial. Surgical techniques used to make the femoral tunnel in an anatomic location yield a more oblique tunnel in the coronal plane (Fig. 1). The native ACL insertion is typically too distal on the lateral femoral condyle to be drilled in a transtibial fashion. One hypothesized explanation for the lack of clinical improvement is that the greater tunnel obliquity of these ACL reconstructions may lead to asymmetric loading across the ACL graft.

The goal of this study was to determine if there is a difference between the transtibial reconstruction and a single bundle anatomic reconstruction in term of anterior–posterior (AP) laxity, knee kinematics, and graft loading.

2. Methods

Seven fresh cadaver knees (5 right, 2 left knees; average age 70, range 59 to 77; 2 male, 5 female) were tested in a six degree of freedom knee simulator (Sutton et al., 2010) (Fig. 2) that moved each knee through a standardized gait cycle based on an International Organization for Standardization (ISO) Standard (ISO, 2002) for load-control testing of knee implants. The simulator caused knee flexion–extension while applying axial compressive loads, AP loads, and tibial torques to the knee. To prevent possible overloading of the

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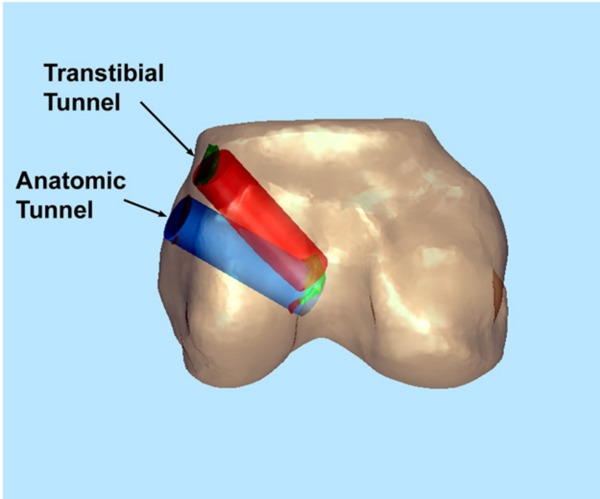

Fig. 1. Three dimensional model of the femoral tunnels taken from a single cadaver specimen.

knee ligaments and other soft tissues, 33% of each axial compressive force, AP force and tibial torque specified in the standard were utilized. Free medial–lateral motion and free abduction–adduction were permitted. In addition to moving the knee through 10 repetitive walking gait cycles, the simulator replicated a cyclic AP laxity test at 30° of knee flexion with first a 50 N anterior force and then a 50 N posterior force for 5 repetitions. During the AP laxity test a constant 150 N compressive axial force was applied while free medial–lateral motion, free tibial rotation and free abduction–adduction were permitted. Potting and alignment of each knee in the simulator was done as previously described (Sutton et al., 2010). Optical sensors (NDI Corporation, Ontario, Canada) were mounted directly to the femur and tibia with cortical pins (Fig. 2) and used to measure angular knee kinematics (with an accuracy of <0.1°) while AP displacements (with an accuracy of <0.01 mm) were measured using an integrated displacement transducer connected in parallel to the knee simulator AP actuator. The alignment of the femoral optical sensor defined the knee coordinate system from which knee flexion, tibial rotation and valgus/varus rotations could be measured. The femoral optical sensor was oriented to be parallel to the femoral coronal plane. This was defined while potting each knee by using the femoral epicondylar axes and the long axis of the femur. The femoral sensor flexion–extension axis was aligned to be parallel with the knee flexion–extension axis as determined while potting the knee (Sutton et al., 2010).

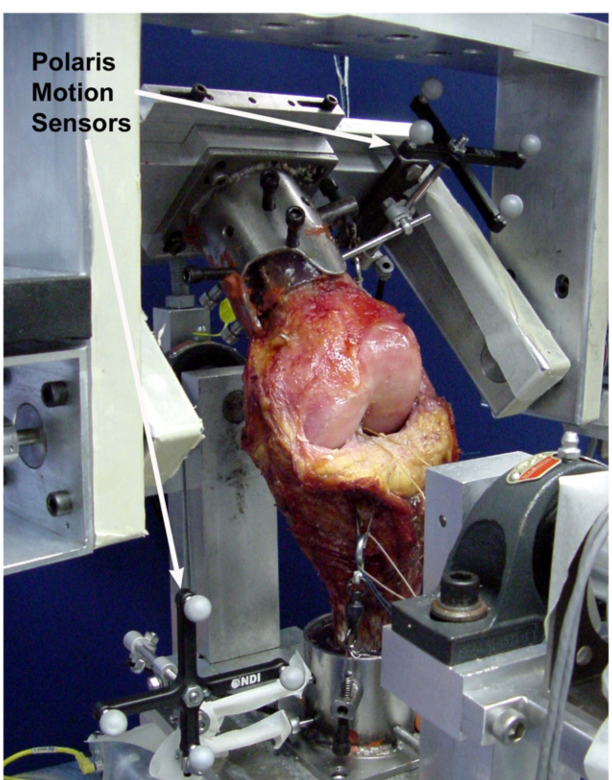

Fig. 2. Knee simulator with cadaver knee flexed showing placement of optical sensors and overall setup.

Each knee underwent both an anatomic (bone tunnel centered at the native femoral ACL attachment) and a standard transtibial reconstruction (Fig. 1) utilizing the same ACL 12 mm diameter bone–patellar tendon–bone graft with 25 mm long bone plugs (Fig. 3). The order of performing the anatomic reconstruction and the transtibial reconstruction was randomly selected for each knee. A new bone–patellar tendon–bone graft was harvested for each knee, but used for both repairs in each knee. The anatomic tunnel starting point was centered between the anteromedial and posteriolateral native bundles on the tibia and the femur, while the transtibial starting point was centered between the bundles on the tibia and the standard over the top position on the femur (7 mm over the top guide). The graft was then inserted with the cortical sides facing posterior. The femoral side was fixed first by tying over a post and the knee was then flexed 10 times while holding tension. The knee was then placed in 20° of flexion and fixed by tying the tibial sutures as tightly as possible. The second reconstruction was performed after filling the femoral tunnel with cement and then redrilling the tunnel. Each knee was tested in the knee simulator with all soft tissues intact, after the ACL was sectioned and after each of these ACL reconstructions. To facilitate performing the reconstructions, the knee was removed from the simulator for each ACL reconstruction.

Prior to the reconstructions, the tendinous portion of the graft was split axially perpendicular to the plane of the cortex and miniature force probes (AIFP force probe, MicroStrain, Inc, Williston, VT, USA) were inserted in the medial and lateral portions of the graft while the bone plugs were kept intact(Fig. 3). These bundles were aligned in the coronal plane to provide the greatest sensitivity for the difference in the coronal obliquity of the tunnels. Thus each force probe independently measured the force in one half of the graft (medial or lateral), while the bone plug on each end was secured as typically performed clinically. Instead of inserting the force probes transverse to the length of the tendon, a longitudinal pocket in the tendon was

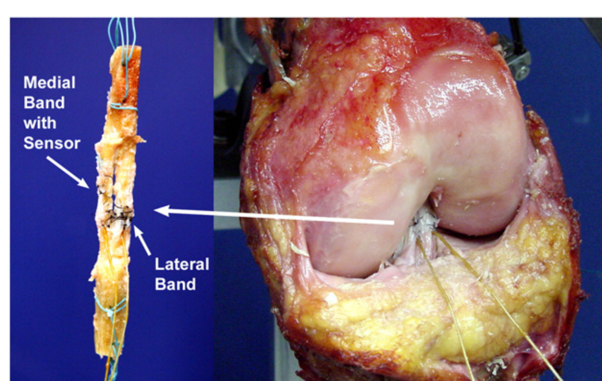

Fig. 3. Placement of tension sensors in medial and lateral bundles of ACL graft and knee shown after implantation.