INTRODUCTION:
Biomechanical studies have determined that double-bundle ACL reconstruction (DB-ACLR), as compared to single-bundle (SB-ACLR), more closely mimics the axial rotation [internal-external (IE) rotation] laxity of the ACL-intact knee [1]. However, these studies are typically performed without a tibiofemoral (TF) compressive load applied across the joint, a load which is present in most activities of daily living. Furthermore, there have been no studies to show that the TF compressive stresses, an important variable because ACL reconstruction has been linked to the risk for early OA, are more closely restored with DB-ACLR as compared to SB-ACLR. The objective of this in vitro study was to compare the TF kinematics and TF compressive stresses during a simulated squatting activity. Squatting was selected because it has been shown to produce relatively high strains on the ACL and high joint contact stresses [2]. We hypothesized that knee kinematics (anterior-posterior (AP) translation, IE rotation) and the TF compressive stresses of the DB-ACLR were closer to those of the ACL-intact knee when compared to SB-ACLR.

METHODS:
12 matched pairs of fresh frozen cadaver knees [9 female; 3 male; mean age=58 (range 16-80)] with no evidence of knee pathology were utilized. The specimens consisted of the distal third of the femur and the proximal two thirds of the tibia. Threaded rods were cemented into the intramedullary canals of the femur and tibia so that they could be attached to the loading fixture that simulates squatting activity. The rods were supported by universal joints to represent the hip and ankle joints [3]. The ankle joint was permitted to translate vertically along the rail of the loading fixture to allow the knee to course through flexion-extension. Knee extension was induced by a servomotor that loaded the quadriceps tendon, while a static 70 N TF compressive load and a 22 N hamstring force were applied. The Optotrak Image Analysis System (Northern Digital; Waterloo, Ontario) was used to track the position of the tibia with respect to the femur in 6 DOF. A joint coordinate system was used to describe knee kinematics [4]. Thin-film pressure sensors (K-scan 4000; Tekscan Inc, South Boston, MA) were used to simultaneously measure the TF compressive stresses in both compartments of the knee. The sensors were inserted underneath the menisci and secured into place with sutures [5].

Simulated squats were performed in the ACL intact joint. The ACL was then transected and either a SB- or DB-ACLR was performed (randomized within each knee pair). Graft tunnels were located with the ACL insertion sites. For the SB-ACLR, two doubled-over semitendinosus grafts were placed within a single tibial and femoral bone tunnel. For the DB-ACLR, each tendon was doubled-over and each one placed in the two tibial and femoral tunnels. The simulated squats were then repeated in the ACL reconstructed knees.

For each outcome measure (AP translation, IE rotation, and TF contact stress), a 2-factor repeated measures ANOVA was used to test for differences between the surgical procedures with respect to the mean change from intact state. Within-subject factors were surgical procedure (SB- vs DB-), and knee flexion angle (0° to 100°).

RESULTS:
AP translation values for the SB- and DB-ACLR procedures were dependent on the knee flexion angle with the tibia shifting posterior as the knee was extended (p=0.02). No significant differences were detected between the SB- and DB-ACLR knees (p=0.37). When compared to the ACL-intact state, the shift was significantly greater than the ACL-intact condition from 40° to 0° of flexion for both procedures (p=0.05).

IE rotation was dependent on the knee flexion angle (p=0.001). The screw home mechanism was preserved in both the SB- and DB-ACLR knees as the knee was extended (Fig. 1). There were no significant differences between the two ACLR techniques (p=0.68). When compared to the ACL-intact state, the DB-ACLR was significantly different from normal only at 0° of extension (p=0.035), while the SB-ACLR was significantly different from 20° to 0° (p=0.05).

There were no significant differences in the TF contact stresses between the SB- and DB-ACLR procedures (p=0.74) (Fig. 2). When compared to the ACL-intact condition, the compressive stresses of the DB-ACLR were slightly lower from 60° to 80° (p=0.05), while the SB-ACLR was only different at 80°.

DISCUSSION:
The joint kinematics of the SB- and DB-ACLR procedures were similar during squatting. Although slight differences relative to the ACL-intact knee were detected at 0° of flexion for the DB-ACLR and between 0° and 20° for SB-ACLR, the mean differences were very small (<1°). Furthermore, no significant differences were found in the joint compressive stresses. These data imply that either procedure would produce comparable results at the time of surgery after graft fixation. The advantage of the ex-vivo squatting fixture is that it enabled us to evaluate the surgical procedures during a common activity of daily living, and to directly measure the TF compressive stresses, which is currently not possible in vivo. However data acquired from a cadaver only provides baseline data of joint function and does not account for changes that may occur with graft healing.

REFERENCES:

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