OSTEOARTHRITIS (OA) FOLLOWING ANTERIOR CRUCIATE LIGAMENT (ACL) RECONSTRUCTION

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Introduction:
ACL reconstruction surgery is commonly performed to restore knee kinematics and decrease the incidence of post-traumatic OA in the ACL-deficient knee. However, many ACL-reconstructed patients develop OA despite surgery (1). Clinical studies have been limited because sensitive techniques to document the onset and progression of OA remain elusive. The ACL-transection model is commonly used to study OA, but invasive techniques to document the onset and progression of OA remain elusive. Despite surgery (1). Clinical studies have been limited because sensitive techniques to document the onset and progression of OA remain elusive.

The ACL-aggregate modulus, permeability coefficient) provide surrogates for measurements of the articular cartilage material properties (i.e. the ACL-reconstructed knee). The ACL-transection model could also provide a means to evaluate the relationship between ACL reconstruction and post-traumatic OA while controlling confounding variables (i.e. concomitant injuries, time between injury and surgery). The objective of this study was to determine if ACL reconstruction affects the material properties of the articular cartilage of the tibiofemoral joint (e.g. OA).

Methods:
ACL reconstruction surgery was performed in four skeletally mature (4-year old) Nubian goats following an Institutional Review Board approved protocol. Independent blood tests were performed to ensure that they did not carry caprine arthritis encephalitis virus (CAEV), which is known to initiate articular cartilage degeneration. The animals were anesthetized for surgery. A-P laxity of the ACL-intact knee was measured using a custom arthrometer (3). A-P laxity was defined as the amount of anterior tibial translation relative to the femur during the shear load limits of ±60 N while the knee was at 60° flexion. This value was later used to set the pre-tension level on the graft during surgery. The ACL was then excised and reconstructed using a 6-mm wide bone-patellar tendon-bone graft. The graft was positioned anatomically and the proximal end was fixed in the femoral bone tunnel using an interference screw. The distal end of the graft was pre-tensioned to restore A-P laxity of the ACL-intact knee. While maintaining the appropriate graft tension, the bone block was fixed in the tibial tunnel with an interference screw. Five 0.8-mm tantalum beads were inserted in the distal femur and proximal tibia to serve as radiographic landmarks. The incisions were closed. Following surgery, the A-P laxity of the reconstructed knee was measured using Radiostereometry Analysis (RSA) while the animal remained under anesthesia (3). The goats were allowed to run free in their pens for 6-weeks before they underwent euthanasia. Tantalum beads were inserted into the bones of the contra-lateral “control” knee, and A-P laxity measurements were obtained from both knees. The RSA based A-P laxity measurements were documented across the healing period because abnormal knee kinematics is thought to contribute to degenerative joint disease. The hind limbs were then harvested for subsequent post-mortem testing of the tibiofemoral articular cartilage.

The material properties (aggregate modulus and permeability) of the tibial and femoral articular cartilage were measured using the biphasic indentation creep test (4). The tests were performed on the medial and lateral condyles at the centers of the tibiofemoral contact points (with the knee at 60° of flexion). The specimens were immersed in Ringers solution, and a 1.5-mm porous indenter tip was used to indent the tissue. The cartilage thickness was measured with a needle probe. The material properties were calculated from the load-displacement response using the software (“Indenter_I”) developed at Columbia University (4). Data obtained from the medial and lateral sites of each bone were averaged. The material properties between the ACL-reconstructed and ACL-intact knees of the femur and tibia were compared using paired t-tests.

Results:
The aggregate moduli of the articular cartilage of the ACL-reconstructed knee were less than those of the contra-lateral (ACL-intact) knee after 6-weeks of healing (Fig. 1). On average, the aggregate modulus was 25% of the ACL-intact knee. The mean permeability coefficients of the cartilage from the reconstructed knee were approximately 60% greater than the ACL-intact knee (tibia = 1.4 x 10^{-15} m²/Ns; femur = 1.4 x 10^{-15} m²/Ns). There was also visual evidence of articular cartilage wear in the reconstructed knees as compared to the contra-lateral ACL-intact knees. The changes in the material properties occurred in conjunction with an increase in A-P laxity over the healing period. The significance of this relationship remains unknown. Future work will examine this relationship, and will attempt to optimize ACL reconstruction procedures in an effort to minimize articular cartilage degeneration.

Discussion:
The articular cartilage of the reconstructed knee exhibited a decrease in the aggregate modulus and an increase in the permeability. Worsening of the collagen matrix and loss of proteoglycan has been shown to produce lower aggregate modulus values (2). Loss of proteoglycan is also associated with higher permeability values (2). There was also visual evidence of articular cartilage wear in the reconstructed knees as compared to the contra-lateral ACL-intact knees. The changes in the material properties occurred in conjunction with an increase in A-P laxity over the healing period. The significance of this relationship remains unknown. Future work will examine this relationship, and will attempt to optimize ACL reconstruction procedures in an effort to minimize articular cartilage degeneration.

The A-P laxity of the reconstructed knees increased during healing (Fig. 2). Following surgery, the mean A-P laxity of the reconstructed knee was 32% greater than the contra-lateral ACL-intact knee. The laxity of the reconstructed knee increased by 24% during healing.

Fig. 1: The aggregate modulus obtained from the femoral cartilage of the ACL-reconstructed knee was significantly less than those of the ACL-intact knee after 6-weeks of healing. A strong trend was also noted for the tibial surface.

Fig. 2: A-P laxity values increased over time. The solid and dashed lines provide the mean and standard deviation of the contra-lateral ACL-intact knee. Although the A-P laxity values increased with time, the average 6-week value was 39% less than that of the ACL-deficient knee (3).

References:

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