INTRODUCTION: A minimally invasive, hand-held impedance diagnostic device was used to quantify changes in articular cartilage after surgical treatment of chondral defects created in the canine knee joint model. Effects of the procedure on the impedance of both treated and uninvolved tissue were compared. Previous studies have shown electrical impedance to be a sensitive indicator of biochemical composition and tissue integrity. The objectives in this study were (1) to validate the ability of the device to gauge graft repair by comparing impedance measurements with biomechanical measurements and histology, and (2) to quantify the effects of the harvest and graft procedure on the impedance of untreated articulating tissue with comparison to tissue hydration and GAG content. METHODS: Probe manufacture: A 4.5-mm diameter, 10-cm long arthroscopic probe was designed and developed [1,2] to measure the electrical and electromechanical integrity of cartilage at articulating joint surfaces. The four 1.59 mm Ag-AgCl electrodes are placed on the cartilage (Fig. 1) and deliver 10 µA/mm² of sinusoidal current at the tissue surface. Surgical treatment: Autologous articular cartilage was harvested from the trochlear ridge of the left knee of six mature hound dogs. A strip of approximately 20-25 mm by 3-5 mm tissue was removed down to the tidemark. The chondrocytes were extracted and expanded in monolayer up to third passage and then seeded at 1x10^6 cells/disk into EDAC cross-linked, 95% porous, porcine type-II collagen matrices. (Geistlich Biomaterials, Wolhusen, Switzerland). After four weeks the matrices were implanted in partial-thickness 4-mm diameter surgically constructed defects in the proximal and distal patellar groove of the right knees of each dog. The animals were sacrificed sixteen weeks after implantation. This animal experiment was approved by the Brockton/West Roxbury VA Animal Care Committee. Impedance Measurements were made in situ at the two defect sites in the patellar groove and then on adjacent visually normal tissue, as well as at three sites on the distal and lateral patellae (with biomechanical and histological parameters, Fig. 2). The feedback-controlled constant current density was applied at frequencies of 1000, 300, 100 Hz with a penetration depth of 0.7 mm[2]. Tissue impedance was calculated as the measured electrode voltage divided by the driving current, and was normalized to the averaged electrode-electrolyte interfacial impedance. This interfacial impedance was measured in 0.15M phosphate buffer solution at intervals before, during, and after each series of tissue measurements. Mechanical Testing: In situ indentation tests were performed on repair tissue (on bone) from the distal graft and on articular cartilage from the corresponding site in the contralateral joint. Three sequential step displacements to 10, 15, and 20% strain were applied, and the relaxed equilibrium loads recorded. Sinusoidal displacements at 1% strain amplitude were applied in the 1.0 to 0.005 Hz frequency range, superimposed on the 15% static strain, and the resulting loads recorded. The thickness of the cartilage was measured using a needle-ramp method. Histology: Proximal and distal grafts were placed in 10% formalin immediately after specimen procurement. Distal grafts were fixed in formalin immediately after mechanical testing. After fixation, specimens were decalcified in 15% EDTA, dehydrated, and embedded in paraffin. 5 µm sections were stained with Safranin O; semi-quantitative assessment of the degradative changes was made using the Mankin scale. Biochemical Analysis: The articular cartilage was scraped from the surface of the patellae. The samples were weighed wet, lyophilized (48-72 hours), weighed dry, and then digested in 1N HCl. Proteinase K and analyzed for total sulfated glycosaminoglycan (GAG) using the dimethylmethylen blue (DMMB) dye-binding assay with shark chondroitin-6-sulfate as the standard. Tissue hydration was calculated from the wet and dry weights. GAG content was normalized to the wet weight of the undigested tissue. Statistics: Repair tissue in the grafts was compared to adjacent visually normal tissue on the femoral patellar groove. Tissue on the right patellae, articulating against the graft sites, was compared with that on the left patella, articulating against the harvest sites. The Student’s t-test and the Fisher Exact test were used, with the criterion of p<0.05 for significance.

RESULT AND DISCUSSIONS: Repair tissue: The defects were 90-100% filled with repair tissue that was grossly distinct from adjacent uninvolved tissue (Fig. 2). The repair tissue was white in color, but there were visible borders around the defect. Normalized impedance in the graft sites on the femoral patellar groove was significantly less than that in the adjacent the visually-normal tissue (p<0.01, Fig 3). The impedance in the proximal repair tissue was less than in the distal, corresponding with visual inspection at necroscopy, where it was noted that the surface of the proximal repair tissue was slightly uneven while the distal repair tissue was smooth. Histomorphometric evaluation of the tissue in the defects revealed predominately fibrous tissue and fibrocortilage (Fig. 4). In vitro mechanical tests revealed that the distal graft was much less stiff (p<0.01) than the control. Together, these results are consistent with previous studies [1] on normal and moderately degraded human patellar tissue (Collins grade 2), which showed that the degraded tissue had decreased normalized impedance.

Untreated patellar tissue: There were no gross abnormalities distant from the defect and harvest sites at necroscopy. Electrical and biochemical analysis could detect no significant changes between the patellae articulating against the graft and harvest sites. No difference was found in the hydration or GAG% wet weight content of the graft articulating vs. the harvest-articulating patellae tissue. These results suggest that surgically induced tissue repair did not greatly affect the uninvolved tissue in this model.


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