• STREAMING POTENTIAL-BASED ARTHROSCOPIC DEVICE DISCERNS TOPOGRAPHICAL DIFFERENCES IN CARTILAGE COVERED AND UNCOVERED BY MENISCUS IN OVINE STIFLE JOINTS

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Introduction: Animal models of Osteoarthritis (OA) are invaluable for understanding disease progression and assessing potential treatments. The ovine lateral meniscectomy model follows disease progression similar to that observed in humans, where at 6 months post-meniscectomy, cartilage in the lateral femorotibial compartment displays focal lesions and loss of proteoglycan, leading to cartilage erosion [1,2]. This OA model is advantageous because joint size is sufficient for multiple analyses of cartilage including biomechanical, biochemical and histological evaluations, and minimally invasive arthroscopic surgery is feasible. However, current methods do not allow for non-destructive sequential assessment of cartilage function that would be greatly beneficial in this and other models, where initial degeneration is focal and then radiates outwards to involve more of the articular surface. The objectives of this study were to determine the feasibility of using a new arthroscopic instrument to evaluate cartilage properties at multiple locations in ovine knee (stifle) joints and to obtain intrinsic cartilage mechanical properties for normal ovine tissue in regions covered and uncovered by meniscus. To achieve these goals we used a device (Arthro-BST™**) for cartilage evaluation that measures electric potentials generated during cartilage compression. An array of microelectrodes on a hemispherical indenter is lightly compressed against articular cartilage and a parameter known as the Streaming Potential Integral (SPI) is computed that reflects cartilage health and function. This device has permitted non-destructive and rapid evaluation of cartilage in large joints such as the equine stifle [3] and bovine shoulder [4], however smaller joints with thinner cartilage such as that of sheep have not yet been assessed.

Methods: Both sheep stifle joints (6-year old) with no indications of joint pathology were collected immediately following euthanasia and frozen at -80˚C until testing. The tibial plateau and femoral condyles were separated and secured in custom built fixtures and joint surfaces were hydrated with PBS throughout testing. 17 positions on the tibial plateau and 26 positions on the femoral condyles were identified on the joint surfaces using a digital camera and software. The Arthro-BST™** device was used to compress cartilage at each position and this was performed by five users who made three measurements at each position. Following this, 4 mm diameter osteochondral cores were harvested from a subset of 12 positions using a drill bit designed to minimize tissue damage (Straumann Medical, Switzerland). Each osteochondral core was reduced in length using a dental saw to remove all but a 1-2 mm thick layer of bone beneath the cartilage and then was reduced to a 3 mm diameter with a biopsy punch. Cartilage thickness was measured optically using a stereomicroscope. Each sample was tested in unconfined compression geometry using a Mach-1™ Mechanical Tester**. Five compression ramps of 2% amplitude were applied at a rate of 0.4% per second. Between ramps, the cartilage was allowed to relax until the load decay was 0.01 g/min. The fibril-network-reinforced biphasic model was fit to the data to obtain fibril modulus (Ef) and matrix modulus (Em) and permeability (k) [5].

Results: The SPI patterns for each joint surface were consistent among all 5 users and the values (n=15) for each position were averaged and combined into 2-dimensional contour plots [6] to illustrate topographical differences (Fig 1). Reliability among users was found to be high according to the calculated Intraclass Correlation Coefficient [7] of 0.64. Cartilage thickness and intrinsic mechanical properties were found to depend strongly on site location and on whether cartilage was covered versus uncovered by meniscus (Table 1). By comparing with one-way ANOVA followed by Fisher's LSD, we found significant differences ($p < 0.05$) between the regions covered versus uncovered by the meniscus(*) on the tibial plateau, as well as between the uncovered tibial plateau and the femoral condyles($^+$). Correlation analyses further identified relationships between SPI and cartilage thickness, as well as between permeability and fibril modulus (data not shown).

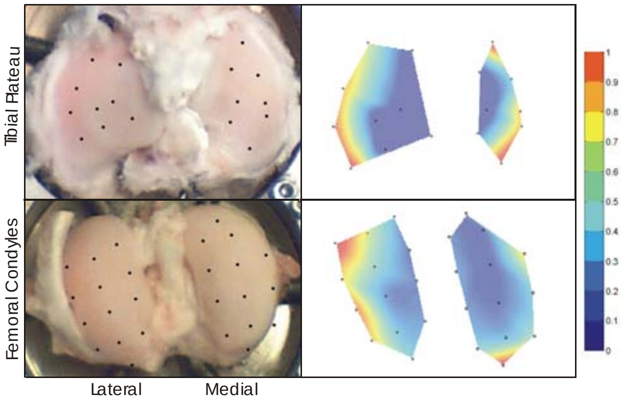

Figure 1: Topographical maps of SPI values. Data normalized to the highest value on each joint surface. Each data point is an average of 15 individual measurements.

	Tibial Plateau		Femoral Condyles
	Covered	Uncovered	
SPI (mV*mm^3)	22.2 ± 3.7*	1.0 ± 0.2*	12.5 ± 7.7
Thickness (mm)	0.22 ± 0.06*	1.01 ± 0.20*$^+$	0.57 ± 0.20$^+$
Em (MPa)	4.0 ± 3.8	0.2 ± 0.1	0.5 ± 0.1
Ef (MPa)	5.9 ± 3.0	6.1 ± 2.8	12.0 ± 2.4
k (mm^4/N.s)	0.012 ± 0.011	0.0134 ± 0.010	0.0013 ± 0.0006

*$^+$differences using a one-way ANOVA followed by Fisher's LSD

Table 1: SPI, thickness and intrinsic properties of cartilage on the tibial plateau covered by meniscus (n=4), uncovered by meniscus (n=3), and on the femoral condyles (n=5). All values are mean ± SEM.

Discussion: The device described here for measuring streaming potentials was found suitable for evaluating articular cartilage in the ovine stifle joint. This joint is considerably smaller than joints previously assessed using this device [3,4], and the cartilage thinner (Table 1), yet it reliably discerned topographical differences in cartilage at multiple positions on the tibial plateau and femoral condyles. The pattern of SPI values was also consistent among all 5 users with the greatest SPI values observed at the periphery of the joint surfaces and decreasing to a minimum towards the centre of the joint (Fig 1). The ovine stifle joint revealed a very broad range of mechanical properties and cartilage thickness (Table 1) suggesting that observed variability among users could be partly attributed to differences between users in positioning the device on the relatively small cartilage surfaces. In this study we found significant differences in cartilage properties (SPI) from regions covered versus uncovered by meniscus. Our findings are consistent with mechanical measurements of human tibial plateau cartilage where thinner, stiffer cartilage was found in regions beneath the meniscus [8]. These results point to a significant dependency of articular cartilage function on the proximity of the meniscus probably due to the role of the meniscus in weight bearing and kinematics [9]. In summary, reproducible topographic patterns of cartilage SPI maps and their relationship to meniscus coverage in sheep joints demonstrate the utility of the Arthro-BST™ device to map the development and progression of focal lesions in ovine models of osteoarthritis.

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