Streaming Potential-Based Arthroscopic Device Discerns Topographical Differences in Cartilage Covered vs. Not Covered by Meniscus in Ovine Stifle Joints

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Introduction

- Animal models of osteoarthritis are used for understanding disease progression[1,2] and are essential for assessing potential new therapies[3]
- Ovine models, such as the lateral meniscectomy model, are of interest because meniscectomy models often follow a disease progression similar to that in humans, and joint size is sufficient for multiple analyses of cartilage including biomechanical, biochemical & histological evaluations[1,2,3]
- Current evaluation methods do not allow for non-destructive, sequential, quantitative assessment of cartilage function
- We have used a new arthroscopic device, the Arthro-BST™, to non-destructively evaluate cartilage at multiple positions in ovine knee (stifle) joints

Hypotheses

- User-independent evaluation of cartilage properties related to electromechanical function is possible with the Arthro-BST™
- Differences in electromechanical properties in normal ovine cartilage in regions of the tibial plateau covered and not covered by meniscus can be assessed non-destructively using the Arthro-BST™

Materials & Methods

A pair of stifle joints obtained from a 6 year old female sheep

43 positions assigned on the tibial plateau & femoral condyles using a digital camera & software

Streaming potentials measured during indentation, w/Arthro-BST™, & used to calculate the Quantitative Parameter (QP). Performed by 5 users making 3 measurements at each position

Fig.1: Arthro-BST™

Fig.2: Mach-1™ Mechanical Tester

4 mm diameter osteochondral cores harvested from 11 locations of the original 43 using a drill w/ hollow bit

Cartilage thickness measured optically w/a stereomicroscope & software

Unconfined compression testing using Mach-1™ Mechanical Tester: contact with cartilage surface, then 5 ramps of 2% amplitude applied at 0.4%/s. Between ramps, load decayed until 0.01g/min

Data analysis: fibril modulus (Ef), matrix modulus (Em), and permeability (k) obtained with Fibril-network-reinforced biphasic model [4]. Statistical comparisons with a one-way ANOVA and Fisher's LSD. Since the condyles articulate over the meniscus & tibial plateau, all measures of the femoral condyles were analyzed as one group.

What are Streaming Potentials?

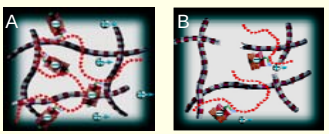

Fig. 3: Normal (A) and Osteoarthritic (B) cartilage

- During cartilage compression, positive mobile ions in the interstitial fluid are displaced relative to the fixed negatively charged proteoglycan molecules, which are entrapped in the collagen network (Fig. 3A)
- In osteoarthritic cartilage (Fig. 3B), the collagen network is degraded and there is a loss of proteoglycans, leading to abnormal streaming potentials

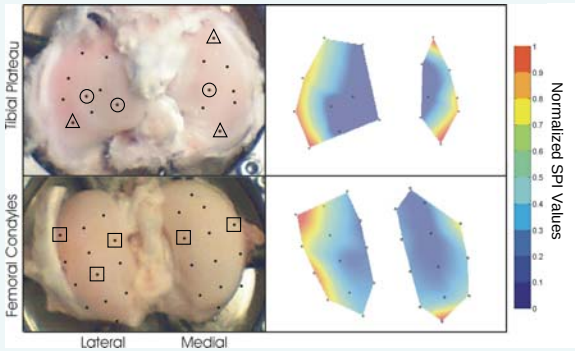

Fig. 4: Position assignment and topographical maps of Streaming Potential Integral (SPI) values, where SPI is shown as a percentage of the highest value (i.e. 1) on each joint surface. Each data point is an average of 15 individual measurements.

	Tibial Plateau		Femoral Condyles
	Covered	Uncovered	
SPI (mV*mm^3)	24.2 ± 4.4*	1.0 ± 0.2*	12.5 ± 7.7
Thickness (mm)	0.27 ± 0.05*	1.01 ± 0.20*+	0.57 ± 0.20+
Em (MPa)	0.2 ± 0.09	0.2 ± 0.1	0.5 ± 0.1
Ef (MPa)	7.8 ± 3.2	6.1 ± 2.8	12.0 ± 2.4
k (mm^4/Ns)	0.015 ± 0.014	0.0134 ± 0.010	0.0013 ± 0.0006
	(n=3)	(n=3)	(n=5)

Table 1: Streaming Potential Integral (SPI), cartilage thickness, matrix modulus (Em), fibril modulus (Ef) and permeability (k) on the tibial plateau covered by meniscus (Δ), uncovered by meniscus (o) and on the femoral condyles (□). *+ indicate ($p<0.05$). All values are mean ± SEM.

Results

- Topographical patterns (Fig. 4) were consistent among users, with a high reliability as determined by the Intraclass Correlation Coefficient[5] of 0.64
- Values of Streaming Potential Integral & cartilage thickness depend on location and meniscal coverage. A larger sample size could make differences in cartilage mechanical properties due to location more apparent (Table 1)

Discussion & Conclusions

- Some variability among users could be attributed to user-specific differences in positioning the device on the relatively small cartilage surfaces and the broad range of mechanical properties and cartilage thickness observed on these joint surfaces (Table 1)
- The mechanical properties measured in this study are consistent with mechanical measurements of cartilage on human tibial plateau, where thinner, stiffer cartilage was found in regions beneath the meniscus[6]
- Cartilage SPI maps, generated with the Arthro-BST™, were related to meniscal coverage in the sheep stifle
- In future studies, additional parameters such as water content & collagen cross-links will be assessed to further describe the relationship between SPI and cartilage functional mechanical properties

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References: **[1]** Little *et al. J Rheumatol* 24:2199-209, 1997 **[2]** Appleyard *et al. Osteoarthritis Cart* 11:65-77, 2003 **[3]** Hoemann *et al. J Bone Joint Surg Am.* 87:2671-86, 2005 **[4]** Soulhat *et al. J Biomech Eng* 121:340-7, 1999 **[5]** Shrout *et al. Psychological Bulletin* 86:420-8, 1979 **[6]** Thambyah *et al.* Osteoarthritis Cart 14:580-8, 2006