STREAMING POTENTIAL BASED ARTHROSCOPIC INSTRUMENT DISTINGUISHES SITE-SPECIFIC PROPERTIES OF EQUINE ARTICULAR CARTILAGE

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INTRODUCTION: Osteoarthritis (OA) is a joint disorder that leads to the articular cartilage destruction. Since the prevalence of OA increases with age and the average age of the population is increasing, it is projected that the number of people with OA will increase by 57% by 2020 [1]. So far, treatments for OA have focused on pain control. However, new treatments are under development to prevent, delay or even reverse OA. A reproducible technique providing a quantitative assessment of cartilage health is therefore needed to evaluate the efficiency of these treatments. Recently, we applied the principle of spatial resolution of streaming potentials [2] towards an arthroscopic device for the quantitative assessment of cartilage health in vivo (Arthro-BST, Bio Syntech Canada Inc.). This device has 37 microelectrodes evenly distributed over the surface of a 3.5 mm diameter hemispherical indenter. The spherical indenter is manually compressed against articular surface and the induced streaming potentials are recorded. The primary objective of this study was to correlate measurements made by this arthroscopic device with well-known and understood biochemical, biomechanical and geometrical properties. The secondary objective was to compare the biochemical, biomechanical and geometrical properties of different equine stifle joint surfaces.

METHODS: Equine samples. To cover a broad range of material properties, the trochlea, tibial plateaus and femoral condyles were harvested post mortem from both stifle joints of a 16-years-old horse. Samples were kept for up to 6 days in humid chambers at 4°C. The 36 positions tested were evenly distributed over tibial plateau (n=16), femoral condyle (n=11) and trochlea surface (n=9). **Electromechanical manual indentation testing**. Every position was manually compressed with the spherical indenter and the induced streaming potentials were recorded. The different start time of streaming potential signals over the spherical surface allows the accurate determination of compression amplitude, velocity and orientation. All measured streaming potential signals were integrated *(Streaming Potential Integral, SPI)* over the spherical surface when the amplitude of compression was 0.15 mm. **Unconfined compression testing & analysis.** Full thickness 3mm disks were harvested at every position tested in indentation (1-3.4 mm thickness). Unconfined compression tests were performed in PBS with the Mach-1 Mechanical Tester (Bio Syntech Canada Inc.). An initial 5% precompression amplitude was applied followed by 5 stress relaxation ramps of 2% compression amplitude at 0.4%/sec. Data acquisition for each ramp continued until the rate of load decay was less than 0.01g/min. The last stress relaxation ramp was curve fitted in the Laplace domain to the fibril-reinforced biphasic model [3]. The equilibrium modulus (*E33*), the fibril modulus (*Ef*) and the permeability (*k*) were obtained from this curve fit. **Biochemistry, Histology & Immunohistochemistry.** After unconfined test 3mm disks were bisected. One half was fixed in 4% paraformaldehyde, 0.1 M sodium cacodylate for histology. The others half was analyzed for sulfated glycosaminoglycan (GAG) by DMMB. A 6mm outer ring was harvested around the 3mm disk for collagen and collagen cross-linking quantification. **Statistical Analysis**. The correlations between all material properties were assessed by simple linear regression and multiple linear regressions. Results were compared with the two-tailed Welch's test.

RESULTS: Parametric correlations. The SPI had strong correlation with the articular cartilage thickness and the fibril modulus (Figure 1 A&B). Interestingly, no correlation was found between the SPI and the GAG content or the equilibrium modulus. Nevertheless, the equilibrium modulus was strongly correlated to the GAG content (Figure 1C). The permeability was correlated to the fibril modulus (Figure 1D). **Joint surface comparaisons**. There was no significant difference between the properties measured on the femoral condyles and the trochlea. SPI and fibril modulus were however higher on femoral condyles and trochlea compared to the tibial plateau in addition to significantly lower permeability (Table 1).

DISCUSSION: The ability of an arthroscopic instrument to detect site-to-site differences in articular cartilage and to relate its particular diagnostic to well known biomechanical and biochemical indices of cartilage function is critical for its success. Our implementation of a microelectrode array distributed on a spherical surface allows the calculation of a user-independent and orientation independent diagnostic streaming potential integral. We found in this study that this SPI could be related to cartilage thickness and to the fibril modulus of articular cartilage, although apparently not to GAG content in healthy cartilage. It is well establish that GAG content is responsible for articular cartilage equilibrium modulus [4] but in our case we measure the quasi-instantaneous response of articular cartilage that is mainly governed by the fibril modulus [5] and not by the equilibrium modulus. The SPI also clearly demarcated tibial plateau cartilage from condylar and trochlear cartilage thus boding well for its potential to identify degraded cartilage in these latter zones. Studies are ongoing towards following cartilage degradation with this technology in an equine animal model.

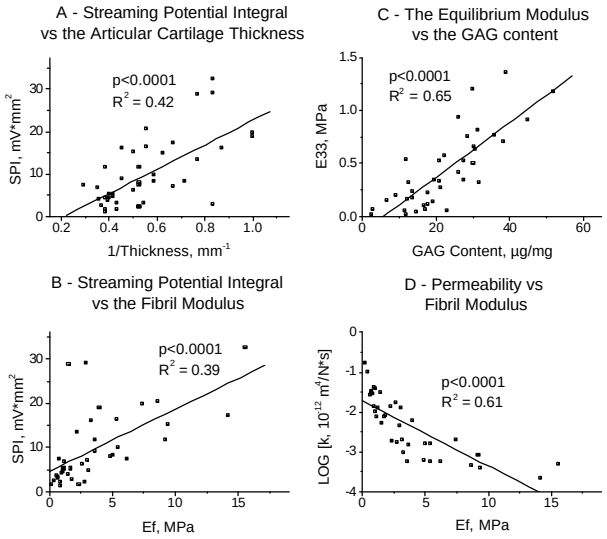

Figure 1 – Parametric correlations

	Tibial Plateau	Femoral Condyle
SPI, mV*mm²	3.8	17.7***
Thickness, mm	2.2	1.5**
Equilibrium Modulus, MPa	0.54	0.55
Fibril Modulus, MPa	1.7	6.3*
Permeability, 10^{-12} m⁴/N*s	0.03	0.003*
GAG content, µg/mg	25	23

Two-tailed Welch's test: *p<0.05, **p<0.01, ***p<0.001

Table 1 - Properties of tibial plateau vs. femoral condyles

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