

Streaming Potentials Measured with an Arthroscopic Medical Device are Reliable Indicators of Biochemical and Biomechanical Properties of Human Articular Cartilage

Garon M¹, Légaré A¹, Quenneville E¹, Sims TJ³, Hollander AP³, Shive MS¹, Restrepo A¹, Buschmann MD²

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First, I want to acknowledge all co-authors at Biosyntech, Ecole Polytechnique and University of Bristol.

Arthro-BST Intended Use



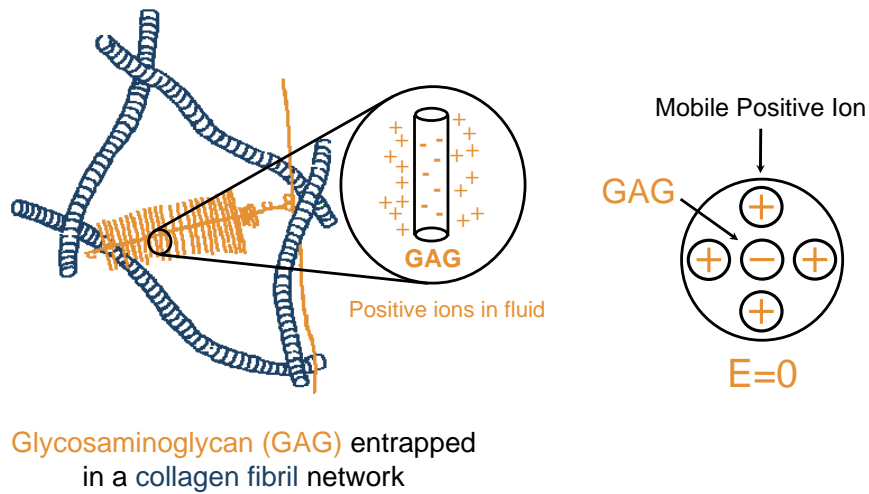
**Quantitative Assessment of
Cartilage Electromechanical
Properties**

**Clinical Arthroscopy
R&D experiments with an open joint**

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Our group developed a new device named Arthro-BST that measures streaming potentials. Its intended use is the quantitative assessment of cartilage electromechanical properties. For example, during clinical arthroscopy or R&D experiments with an open joint.

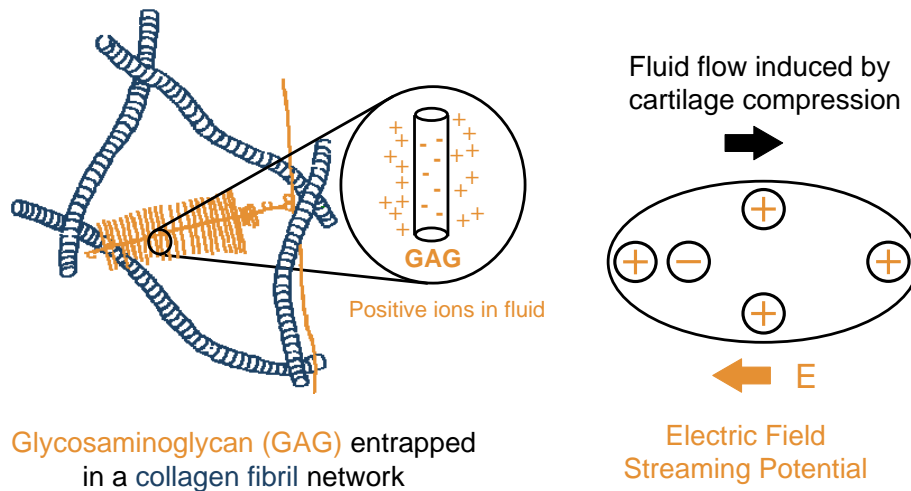
What are Streaming Potentials ?



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So, what is streaming potentials? In cartilage Glycosaminoglycan are entrapped in a collagen fibrils network. Due to the negative charge of GAG, there is an excess of mobile, non-fixed, positive ions in the fluid. Under equilibrium conditions, with no load or fluid flow, these positive charges are symmetrically arranged so that no net macroscopic electric field exists.

What are Streaming Potentials ?

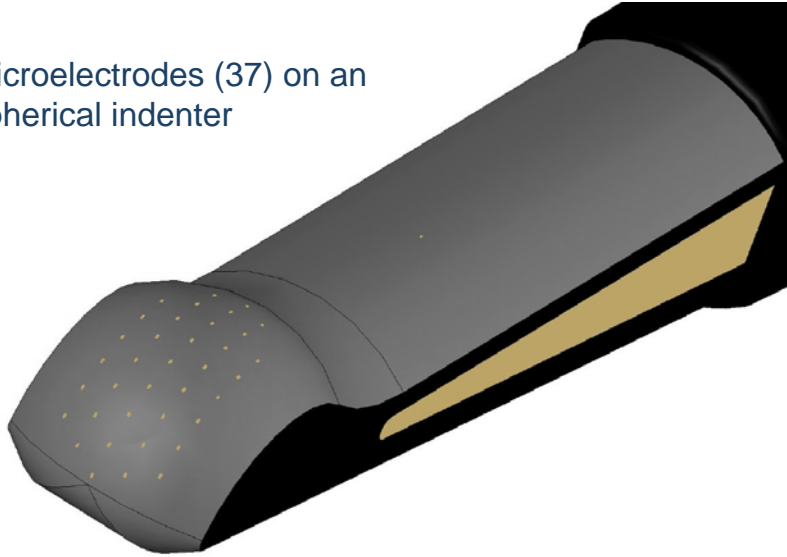


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During fluid flow induced by cartilage compression there is a displacement of positive ions relative to the fixed charge of GAG resulting in an electrical field named streaming potential. You can imagine how streaming potential would be sensitive to GAG content and collagen integrity. A loss of GAG removes the fixed charge and cleavage of collagen network allows GAG to move with the fluid, both reducing streaming potentials.

Arthro-BST Sensor

Microelectrodes (37) on an
spherical indenter



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The sensor of this device has 37 microelectrodes evenly distributed over the surface of a spherical indenter.

Streaming potentials are recorded by every microelectrode when the spherical indenter is manually compressed against the articular cartilage surface

Why a Spherical Indenter ?

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You may ask why a spherical indenter and so many electrodes? During an arthroscopic procedure it is difficult to perfectly align an indenter relative to the cartilage surface.

Why a Spherical Indenter ?

Arthro-BST →



Cartilage →



Streaming Potentials Inside Cartilage

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We overcome this lack of control in the orientation by using a spherical indenter. As long as you are in the spherical region of the indenter the induced streaming potentials are the same within the cartilage and the calculated electromechanical properties will be independent of the orientation.

Proposed Clinical Procedure



1 The sensor is introduced into the knee during arthroscopic procedure

2 Spherical indenter is positioned over the region of interest

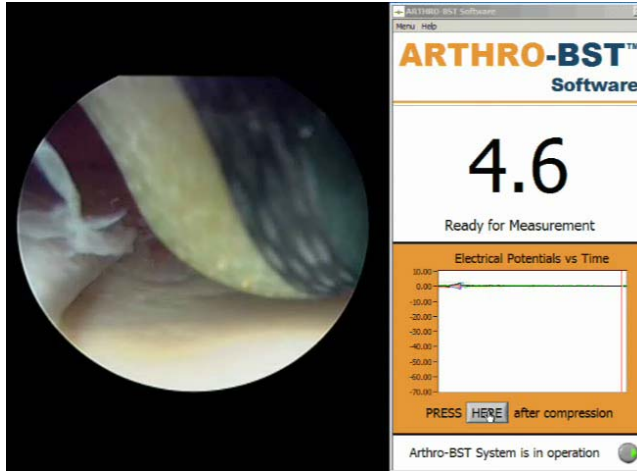
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The proposed clinical procedure to use the device is as follows: First the sensor of the device is introduced into the knee during an arthroscopic procedure. Then, the spherical indenter is positioned over the region of interest.

Proposed Clinical Procedure

3 Cartilage is compressed and induced streaming potentials are recorded

4 A parameter representative of the electromechanical properties of the cartilage is displayed



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Cartilage is compressed by the device sensor and the induced streaming potentials are recorded. Finally, the streaming potentials, that we can see over here, are analyzed and a parameter representative of the electromechanical properties of the cartilage is displayed.

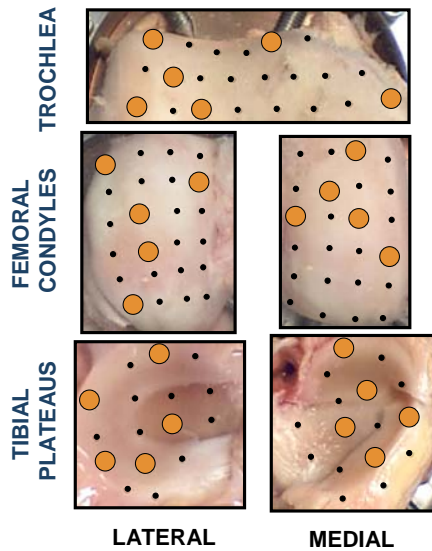
Objectives

- Evaluate the reliability of the Arthro-BST among different users.
- Obtain streaming potential maps of human knee cartilage.
- Correlate Arthro-BST to biochemical and biomechanical properties of human cartilage.

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The objectives of this study were to Evaluate the reliability of the Arthro-BST among different users. Obtain streaming potential maps of human knee cartilage. And, correlate Arthro-BST to biochemical and biomechanical properties of human cartilage.

Methods – Human Samples



102 positions

5 users - 3 mappings

26 cartilage disks tested in unconfined compression

**Equilibrium Modulus
Fibril Modulus
Hydraulic Permeability**

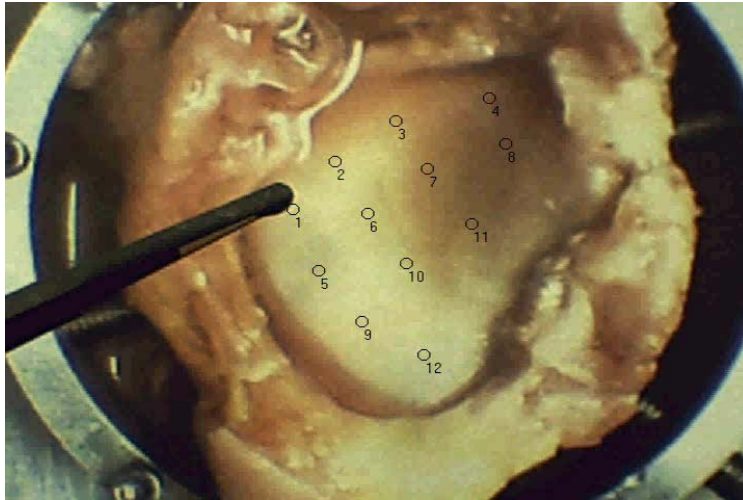
**Collagen Content
Mature and Immature
Collagen Crosslink**

**Intraclass Correlation
Coefficient**

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102 positions were tested with the device during an open joint experiment on trochlea, femoral condyles and tibial plateaus of one human knee. Five users performed 3 consecutive mappings. Then, 26 cartilage disks were then isolated and tested in unconfined compression to obtain the equilibrium modulus, the fibril modulus and the hydraulic permeability. Cartilage disks were also analyzed for the contents of collagen and both mature and immature collagen crosslinks. Finally, the intraclass correlation coefficient was used to assess the reliability of the device among different users.

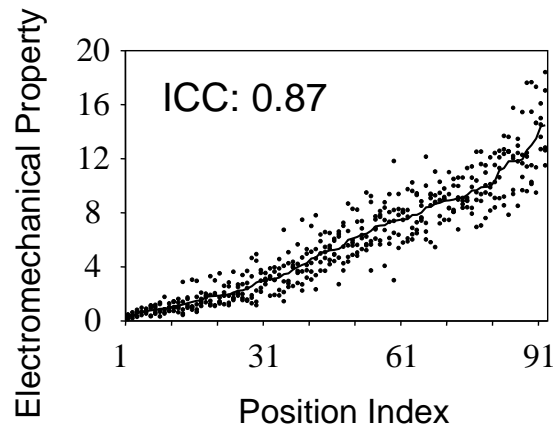
Methods - Mapping Guide



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To make sure that the 5 users test the same sites, custom software was developed to assist in the positioning of Arthro-BST. This software makes it possible to view the surface of a sample with a camera which is positioned above it.

Results - Reliability of the Measurements



Intraclass Correlation Coefficient

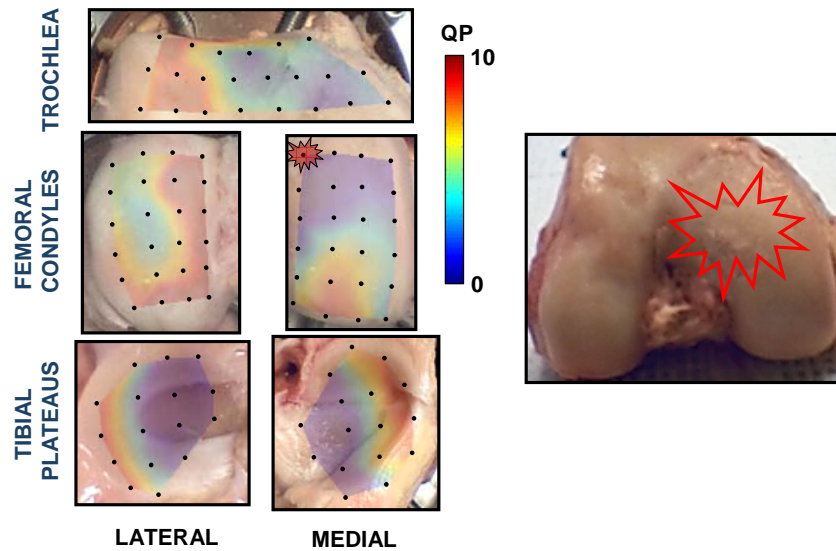
Position explained 87% of the variation measured and that inter-user variability is minimal.

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This figure illustrates the variability between users where measurements are ordered by their average value. The solid line is the average of the five users and the points are individual measurements.

The computed ICC was 0.87 indicating that the position explained 87% of the variation measured and that inter-user variability is minimal.

Results - Streaming Potential Maps



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Here, we shown surface plots of the electromechanical properties overlaid on images of the articular cartilage surfaces. Higher value are represented in red and lower in blue.

The strong dependence of the electromechanical properties of tibial plateaus on proximity to the meniscus is in agreement with an independent study showing lower human cartilage stiffness in regions not covered by the meniscus compared to covered by the meniscus.

We found that the lower values of the electromechanical properties measured on the medial condyle surrounded a visible lesion but extending beyond the visible lesion to possibly indicate the extent of incipient cartilage degeneration.

Streaming Potential Correlates with

- Collagen fibril modulus ($R^2=0.61$, $p<0.05$)
- Collagen content ($R^2=0.45$, $p<0.05$)
- Ratio of mature to immature collagen crosslinks ($R^2=0.38$, $p<0.05$)
- Cartilage thickness ($R^2=0.37$, $p<0.05$)

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The streaming potential obtained with this device correlated positively with cartilage fibril modulus, collagen content and the ratio of mature to immature crosslinks and correlated negatively with cartilage thickness.

Conclusion – Streaming Potential Measurement

- is user independent
- reflects site-to-site variations in cartilage properties
- detects local cartilage degeneration
- correlates with biomechanical and biochemical properties.

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In conclusion, the streaming potential measurement is user independent, reflects site-to-site variations in cartilage properties, can detect local cartilage degeneration and correlates with cartilage biomechanical and biochemical properties.

Financial Support



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Finally, I want to acknowledge these Canadian founding agencies.