Background

Articular cartilage (AC) covers the ends of long bones (Fig 1).

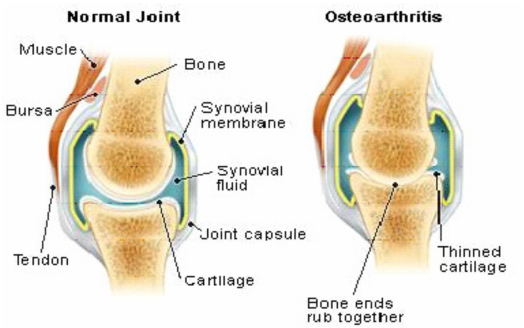

Figure 1: A normal joint showing the position of AC lining the bones and an osteoarthritic joint showing degenerated AC and subsequent bone position[1].

Currently, the biomechanical properties of AC are analysed by a materials testing machine using explanted cartilage[2]. This is highly invasive, time consuming and not reflective of the in vivo environment.

Stiffness is a mechanical property suitable for quantifying AC degeneration[3].

Project Aims

To develop a system that can be used in vivo to determine the biomechanical properties of articular cartilage (AC) for evaluation of degenerative states. Initially, this system will be used in sheep models for quantitative analysis of AC degeneration induced from orthopaedic implants.

Future Directions

The prototype needs to be tested on cartilage samples as the intended application is for quantitative analysis of cartilage degeneration induced from orthopaedic implants in sheep models. It is also anticipated that this device will be modified and further developed for clinical use to determine the integrity of AC in a joint during arthroscopy procedures.

Conclusion

This prototype provides feedback relating to the biomechanical properties of the test sample. However, the repeatability and sensitivity of the device needs improvement prior to in vivo application.

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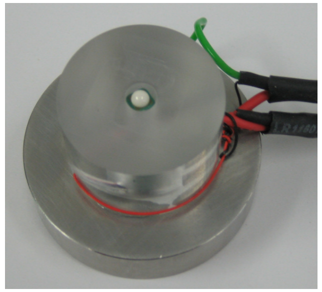
References

1. Shiel, W (2007) *Osteoarthritis*. [Online] URL: www.medicinenet.com/osteoarthritis.article.htm
2. Reece G & Hern C (2006) *A device to measure articular cartilage stiffness*. Honours thesis, Flinders University, Adelaide, SA.
3. Lyyra Y, Jurvelin J, Pitkanen P, Vaatainen U & Kiviranta. Indentation instrument for the measurement of cartilage stiffness under arthroscopic control. *Med Eng Phys* 1995; 17:395-399.

An Instrument to Measure Articular Cartilage Stiffness



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Indentation Device Design

We have previously described an indentation device and control system capable of dynamic indentation[2] (Fig 2). A rigid indenter compresses the surface of a test material under a controlled load. Stiffness is represented by analysing the resultant displacement.

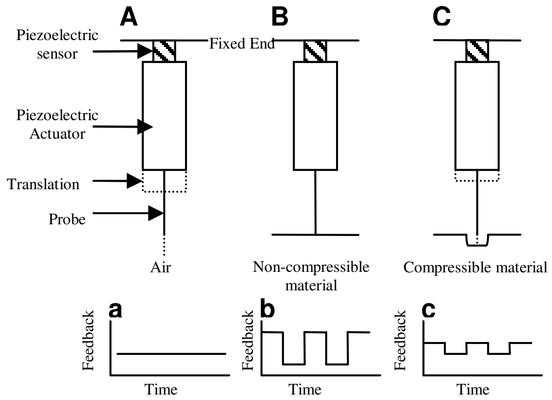

Figure 2: Concept of operation in air (A) and with a non-compressible (B) and compressible (C) material.

Further development was needed to validate the prototype and optimize the hardware components.

The piezoelectric elements were tested without a probe to evaluate the interaction between these elements (Fig3).

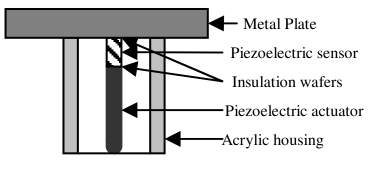

Figure 3: Cross section of the construction of the piezoelectric elements.

Method

Polyurethane samples of known hardness values (40A, 55A, 80A, 95A) were used as test materials.

Samples were tested once consecutively with the developed indentation device and then repeated to yield 5 tests for each sample.

This set of tests was repeated each day for 3 consecutive days resulting in 15 tests for each sample.

Results

The sensor feedback showed increasing amplitude as the hardness of the samples increased (Fig 4) validating the initial concept shown in Figure 2.

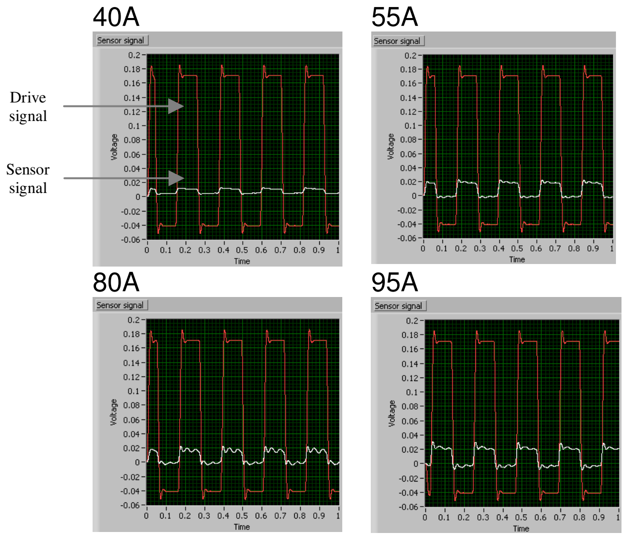

Figure 4: Drive (largest amplitude) and resultant sensor signals for the test samples.

Testing the device on three consecutive days revealed inconsistency between the system responses from each test (Fig 5).

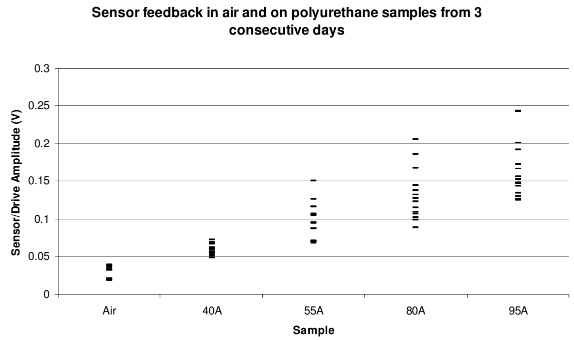

Figure 5: Sensor feedback obtained on 3 consecutive days.

The 80A sample produced the largest variance with system responses ±25.02% from the mean whilst the 40A sample had the smallest variance with sensor feedback ±11.42% from the mean.

This variance was most likely generated from the interaction between the piezoelectric actuator and sensor as well as from temperature variations.

Next Prototype

The device repeatability and sensitivity needs improvement so that the prototype can detect discrete levels of stiffness. Modifications to develop a self-sensing actuation system have been recommended to address the identified issues of the variable interaction between the piezoelectric elements as well as temperature compensation.