PASSIVE ULTRASOUND PATCH FOR MONITORING JOINT CREPITUS

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INTRODUCTION

Arthritis Research UK states that 8.75 million people in the UK have sought treatment for osteoarthritis (OA). An early and reliable detection system for OA has clear potential to save large amounts of money on expensive diagnostic tools, such as MRI and x-ray, and greatly improve the lifestyle and health of patients.

When human joints develop OA, they can make audible grating or clicking noises during regular movement, indicating friction between bone and cartilage (Crepitus). This generally occurs during later stages of the disease, when it is too late to t to arrest further disease development [1]. Interestingly, joints and bones with earlier onset of the disease can also emit noise; however, this is confined to higher, non-audible frequencies.

In OA patients or people who have had joint trauma and are susceptible to early onset OA, being able to detect this noise, for example in joints with small cartilage lesions or instabilities, would allow for a much earlier stage detection (for example, in a GP surgery or even in self-monitoring linked to a mobile or tablet app), without expensive imaging costs and expertise. This would allow earlier intervention when the inflammatory and degenerative cascade processes have not fully developed. The technology to detect these signals is established in materials testing under the name of "Acoustic Emission" (AE). Biomedical research applications exist, but OA studies are limited.

METHODS

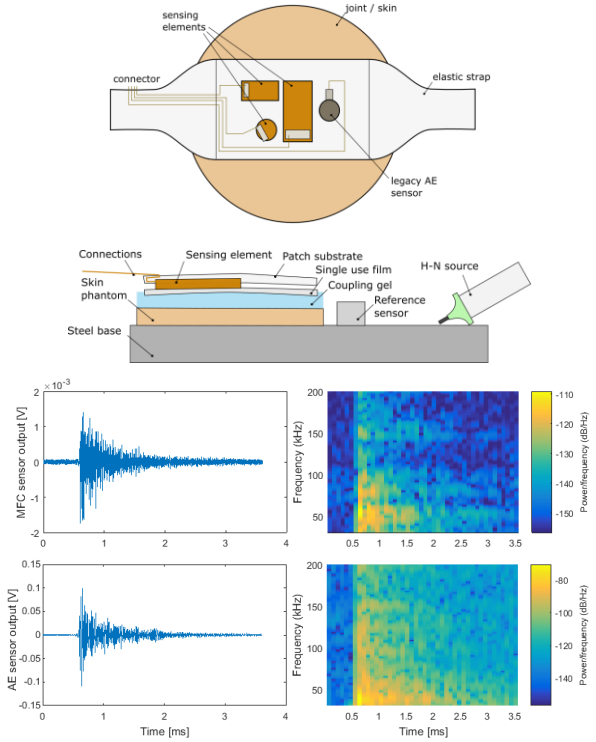

Figure 1: (a) design of the patch and experimental setup; (b) waveforms from MFC sensor (top) and legacy AE sensor (below), and their spectrograms (right).

The developed device consists of a flexible support that conforms to the patient's joint (Figure 1(a)). On the prototype patch, different transducers are mounted: one traditional AE sensor, with a bandwidth between 70kHz – 500kHz, a set of Macro Fiber Composite (MFC) sensors with different shapes and a Lead Zirconate Titanate (PZT) sensor.

To test the different sensors, a set of skin phantoms have been produced according to [2]. The phantoms are coupled to a steel block on which another sensor is mounted. Artificial AE signals are generated using a Hsu-Nielsen source; the performance of different sensors is then evaluated on different phantom thicknesses (1, 2, 5, 10 and 20mm). A sterile film is placed between the skin phantom and the sensor patch to simulate the operating conditions of the final device.

RESULTS AND DISCUSSION

An initial test to verify the output of the MFC sensors was performed. A MFC sensor and an AE sensor were bonded to a steel base using ultrasound grease. 10 calibration signals were generated around the sensors using a H-N calibration source. An example is shown in Figure 1(b).

The average measured Signal to Noise Ratio (SNR) for the MFC sensor was 24dB, whereas the average AE sensor SNR was around 40dB. According to [3], an OA knee releases AE with a recorded amplitude of $90dB_{AE}$ during a simple non-loaded movement (the reference being 1µV, and the H-N source 100dB or 100mV). The MFC sensor during the test outputted an average amplitude of $63dB_{AE}$ or 1.5mV. Assuming a proportional ratio between the calibration signal and the OA signal, it is reasonable to expect the OA signal as recorded by the MFC to be in the range of $53dB_{AE}$ or 0.45mV. This leaves a very good margin above the noise measured during the test and demonstrates the feasibility of using flat sensors for biomedical AE measurements. Further tests will be performed with different thickness skin phantoms in order to simulate the attenuation due to human tissues.

CONCLUSIONS

Tests performed so far demonstrate that the unamplified output of thin sensors can capture the signal amplitudes found in human joints without altering the information contained in the signal. Further tests will be performed to evaluate the effect of soft tissue on the signal propagation.

REFERENCES

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