A Pilot Study of Terahertz Pulsed Imaging of Osteoarthritis

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***Abstract*- Terahertz pulsed imaging (TPI) is well suited to biomedical applications due to its non-ionising properties and sensitivity to soft tissues. In this study, we investigate the feasibility to use TPI to quantitatively measure symptoms of osteoarthritis, which is a common form of arthritis, affecting joints such as the knee.**

I. Introduction

Terahertz technology has shown the potential to be applied to a variety of medical applications in recent years. Breast cancer [1] and skin cancer detection [2] with terahertz radiation are the most outstanding examples. In this study, we investigate whether osteoarthritis (OA) could benefit from advancements in terahertz technology. OA is a form of arthritis caused by the breakdown of cartilage. Weight bearing joints such as the knee, hip and spine are most susceptible to this disease. The cartilage and bone layers in a typical knee joint are illustrated in Fig.1a. During the growth of bone tissue, mineralization takes place progressively closer to the junction of hyaline cartilage and subchondral bone and it results at a layer of calcified cartilage with a tidemark separation. The hyaline cartilage deteriorates and becomes thinner in OA knee joints as shown on Fig.1b.

X-ray imaging is a common technique for non-invasive clinical diagnosis, however, it employs ionizing radiation and is not able to detect the early stages of OA. Therefore, in this paper, we launch a pilot study to explore the potential to use TPI as a non-ionizing diagnosis tool to detect OA.

II. Experimental Methods And Results

The system used for this study was a TPI™ Imaga 1000 (TeraView Ltd.) in which the optical setup is described by Pickwell et al in reference [3]. OA samples were harvested from excised rabbit femoral knee joints. One of the rabbit legs is immobilized by an aluminium splint for establishing the OA symptom [4,5] and another leg is used for a control sample. The samples were formalin fixed after excision and then imaged in reflection geometry by placing them on top of the quartz window of the system.

Typical impulse functions from a control sample and OA sample are illustrated on Fig.2a and Fig.2b respectively. We see a peak leading a trough with 3.69ps separation in the control sample. In contrast, two peaks with 1.08ps apart are found on the OA sample. The first peaks of both waveforms are the reflection from the quartz/sample interface. The trough in Fig. 2a and the second peak in Fig. 2b represent the reflections within samples due to the change of refractive index. The optical delay between peak and peak/trough is dependent on the thickness of the tissue and its refractive index.

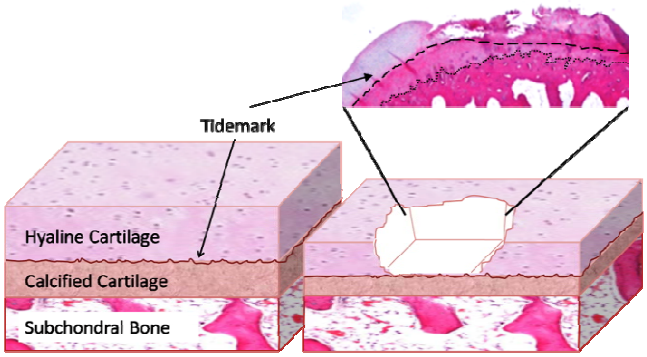

Figure 1a: Schematic diagram of cartilage/bone structure in a healthy femoral condyle.

Figure 1b: Schematic diagram of an OA femoral condyle.

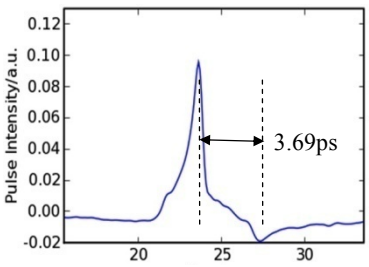

Figure 2a: A typical THz impulse function of control sample.

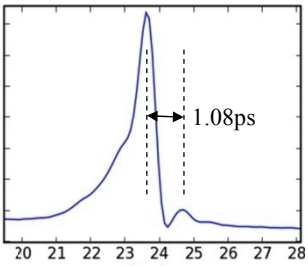

Figure 2b: A typical THz impulse function of osteoarthritis sample.

Histology was performed on both OA and control samples after our measurement and the results are illustrated in Fig. 3a and Fig. 3b respectively. Three different layers: hyaline cartilage, calcified cartilage and subchondral bone which are separated by the black line (indicating the tidemark) and the blue line are shown on the histology. Intact layers can be found in the control sample whereas an obvious degeneration of cartilage is formed on OA sample. According to the histology, the combine cartilage thickness (both hyaline cartilage and calcified cartilage) of the control sample ranges from about 530µm to 930µm. Comparatively, in the OA sample, the cartilage thickness is only 400µm within the damaged area. It is much thinner than that of the control sample. Hence, the THz result showing that the peak-to-peak optical delay in OA sample is shorter than that of control sample is coherent with the thinner cartilage tissue found in OA histology, compared to the control sample.

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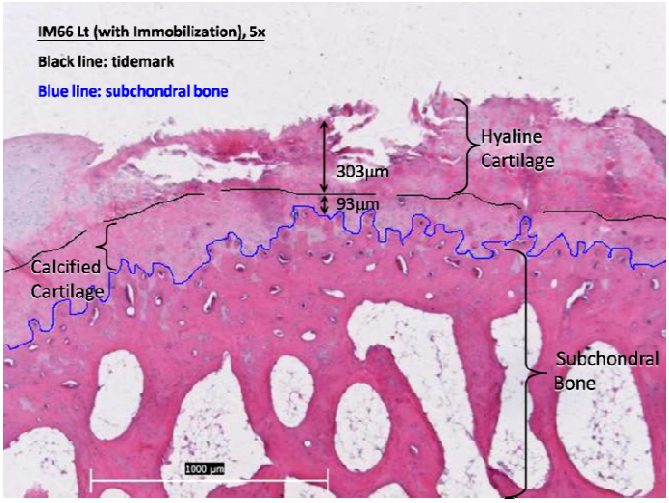

Figure 3a: Histology of the sample IM66's left femoral condyle with OA symptom.

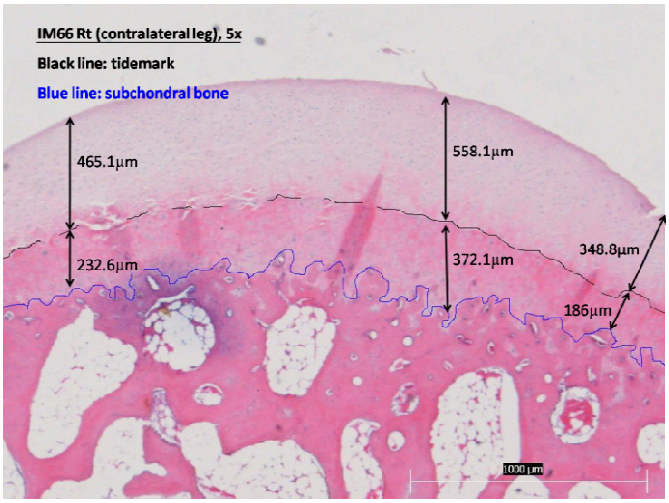

Figure 3b: Histology of the control sample IM66's right femoral condyle.

According to our system, an optical delay of 1ps in air would correspond to around 170µm in depth. As biomedical tissue should have a greater refractive index than unity, the correspondence depth to 1ps should be lower than 170µm. According to this scale, 3.69ps optical delay in the control sample can be due to not more than 627µm thickness in tissue. Given that we see a trough in the control sample, we deduce that the reflection is due to the calcified cartilage/bone interface. It is hard to confirm which part of our measurement can match with the histology with the current system. But we will continue the study by measuring the samples with handheld THz probe. It should be much helpful to match the THz response to its histology.

III. Conclusions

In this study we examine the differences between the THz impulse functions of normal and OA samples and relate our findings to the histology results of the samples. The shorter optical delay found in OA samples is consistent with thinner cartilage found in the histology. Our next step will be to investigate the THz features of OA using a handheld THz probe.

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