Optical Coherence Tomography and Musculoskeletal Disease

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OPTICAL COHERENCE TOMOGRAPHY

A need exists for a new method of high resolution imaging to assess, for example, early osteoarthritis (OA) and guiding tissue engineering. Optical coherence tomography (OCT), the focus of our group, represents a potentially attractive imaging technology for micron scale imaging.[1-3]

STRUCTURAL OCT

OCT is analogous to ultrasound, measuring the intensity of back-reflected infrared light rather than sound. Due to the high speed associated with the propagation of light, the echo delay time can not be measured electronically. Therefore, a technique known as low coherence interferometry, which is not described here, is employed in OCT. With the proper source, resolutions on the order of 2-20 μm are readily achievable. The acquisition rates achieved are in excess of 30 frames per second, and imaging probe size is now under 0.017 inches.[4]

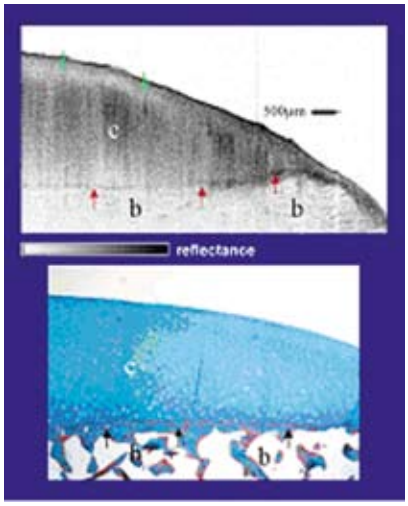

Fig.1:
A human patella is imaged by OCT at 10 μm resolution (Herrmann JM, et al. J Rheumatol 1999;26:627-35).

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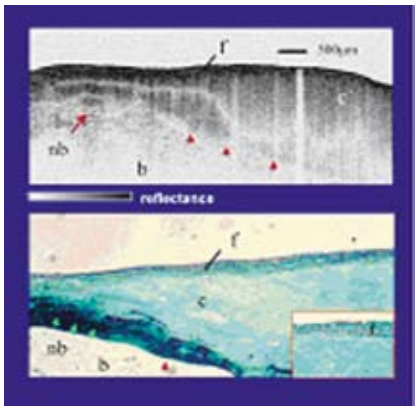
Fig.2:
An OCT image of a diseased osteoarthritic hip and corresponding histology (Herrmann JM, et al. J Rheumatol 1999;26:627-35).



STRUCTURAL IMAGING OF CARTILAGE

Structural imaging has been achieved *in vitro* and *in vivo* of normal and osteoarthritic cartilage, as well as tendon.[5-7] In figure 1, a human patella is imaged by OCT at 10 μm resolution (top picture.)[5] The corresponding histology is shown as well (bottom picture.) It can be seen that a sharp bone-cartilage interface is well defined. In figure 2, a diseased osteoarthritic hip is note where thinning is noted to the left while fibrous scarring is noted on the surface.[5] In vivo structural imaging has also been performed in humans. Figure 3 shows an *in vivo* image of human knee cartilage where the drop areas are noted due to hypercellularity.[7]

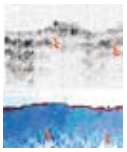


Fig.3: An *in vivo* OCT image of human knee cartilage and corresponding histology (Li XD, et al. Arthritis Res Ther 2005;7: R318-23).

POLARIZATION SENSITIVE OCT

An additional advantage of OCT is the adjuvant technology polarization sensitive OCT (PS-OCT), which measures birefringence.[8] Normal cartilage and tendon contain organized collagen which make it birefringence, presenting as a banding pattern due to the rotation of the back-reflected infrared light. When collagen breaks down, the birefringence is lost. This is seen in figure 4 from an in vivo human knee where birefringence is present on the left, but lost on the right due to early arthritis.[7]

RAT MODELS

Therapeutics often needed to be tested in animal models before they can be used in humans. However, most animal models require large animals and the animals to be sacrificed at various time points. This can be expensive, particularly when

therapeutic compounds are found in only small amounts. We have developed an animal model where rat knee joints are imaged at time 0 and subsequently 20, 30, and 60 days. OA is induced by ligation of the ACL and medial meniscus. Example images are shown in figure 5.[5] Current studies are comparing doxycycline and placebo treatment.

TISSUE ENGINEERING

Tissue engineering (TE) uses a multidisciplinary approach to generate viable tissues from their cellular components by designing matrix/polymer scaffolds, biomolecules and bioreactor cultivation systems to support the *in vitro* formation of tissue constructs that mimic native tissues in structure and function. However, non-destructive methods are specifically needed to be able to provide detailed information on the spatial and temporal changes of different tissue elements in three dimensions, along with the scaffolding architecture, while the tissue is growing and remodeling both *in vitro* and *in vivo*. We have recently developed OCT for the high resolution monitoring of scaffold design as well as tissue growth. This work is currently under submission.

BASIC WORK

The lab spends a considerable amount of effort advancing the engineering and knowledge of OCT physics. This includes the use quantum mechanical OCT for tissue characterization, the use a parallel ultrasound beam to improve resolution, and analysis of classical/quantum noise to improve OCT performance.

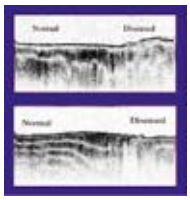


Fig.4:
in vivo OCT images of human knee where birefringence is present on the left, but lost on the right due to early arthritis (Li XD, et al. Arthritis Res Ther 2005;7: R318-23).

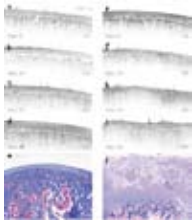


Fig.5:
Representative examples of OCT images of the control and treated femoral condyles of Lewis-Wistar rats, and comparative histology at day 60 (Adams SB, et al. Journal of Orthopaedic Research 2006;24:708-715).

ACKNOWLEDGEMENTS:

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