In-vivo diffuse reflectance for bone boundary detection in orthopedic surgery

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Abstract: Real-time detection of tissue boundaries using diffuse reflectance could help prevent trauma in orthopedic surgery. The aim of this study is to differentiate between four different types of tissue based on results from in-vivo measurements.
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1. Intruduction

Biophotonics is a key enabling technology to fulfil remaining unmet needs of surgical guidance and navigation in a wide range of surgical procedures. Diffuse reflectance spectroscopy (DRS) is a powerful tool to study wavelength-dependent absorption and scattering properties of tissues. DRS can be used to quantify important information relating to physiological properties of the tissue such as chromophore concentration or microstructure and can thus help in identifying the tissue type. For this, there is a need for a thorough understanding of the optical properties of *in vivo* biological tissues and in particular their spectral dependence [1]. Several studies have shown that DRS is a suitable modality for cancer detection, therapeutic monitoring and tissue characterization [2]. Simple, cost-effective and non-invasive DRS techniques can pave the way for the integration of optical spectroscopy directly into surgical tools.

Application of DRS system in orthopedic surgeries, such as intramedullary nailing, could be of particular interest. Tissue identification in addition to tissue boundary detection would help to mitigate the possibility of a potential breach during surgery, thereby greatly reducing the potential risk of postoperative complications due to damage of surrounding tissue. The aim of this study is to evaluate the feasibility of bone tissue identification via DRS to lay the foundation for a real-time feedback control system for surgical guidance during orthopedic procedures.

2. Experimental techniques

Diffuse reflectance spectra of cortical bone, cancellous bone, muscle and lipids were collected (120 spectra) in an *in vivo* pig model within a very wide spectral region covering both the visible and near-infrared regions (350-1850 nm). The measurements were performed using a custom-designed fiber optic probe consisting of two 400 µm core diameter fibers with a NA of 0.5. The first one was coupled to a halogen lamp (Ocean Optics HL-2000), which acted as the optical excitation source, while the latter one, spatially separated by 1.2 mm, was used for collection of the diffused light. Two Ocean Optics spectrometers (QEPro and NIRQuest) were combined to achieve the wide spectral range obtained in these recordings.

3. Results

In order to set the basis for tissue identification, mean diffuse reflectance spectra of four different types of tissue: muscle, lipid, cancellous bone and cortical bone from in vivo pig samples were recorded and analysed. The average spectra in the wavelength range between 350 and 1850 nm investigated in this study are shown in Fig. 1. Due to similarities in the observed curves, advanced methods of multivariate analysis were used to differentiate the spectral features of interest. This information will be implemented in an optical sensorised drill, see Fig. 2 [3].

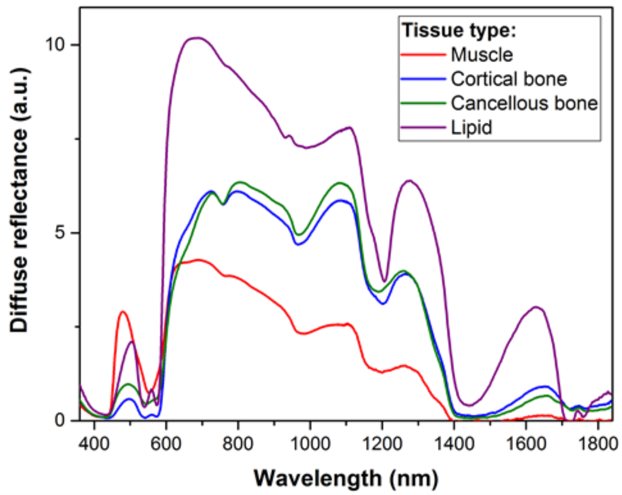

Fig. 1. Sample figure with recorded DR spectra from various tissue types.

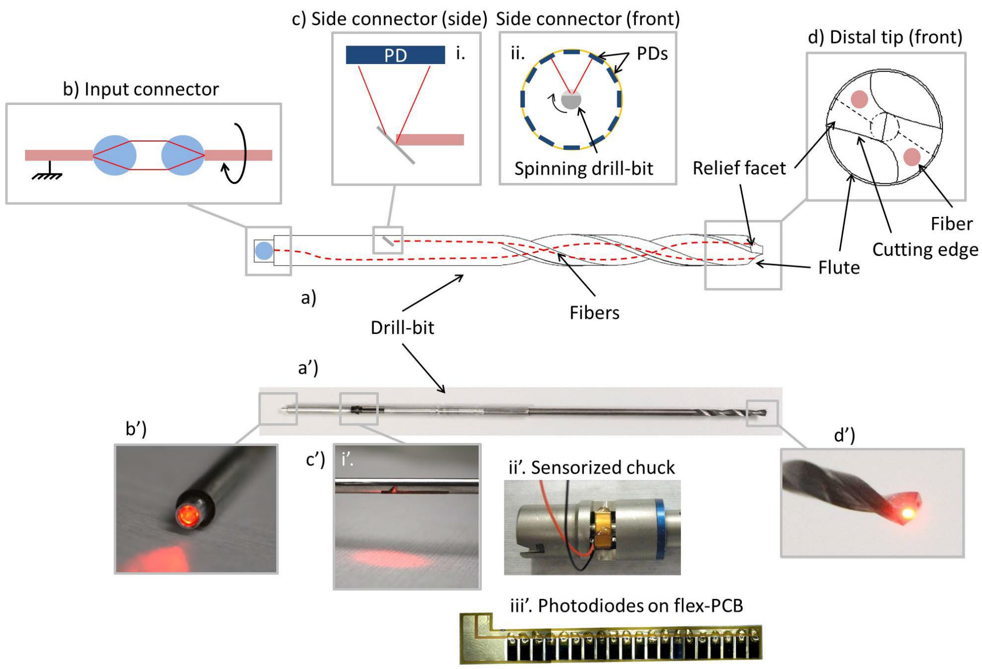

Fig. 2. Illustration how this can be implemented in a drill with optical sensors. [3]

3. Acknowledgements

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4. References

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