Optical Feedback System for Smart Laserosteotome

Figure 1: LIBS (short for Laser-Induced Breakdown Spectroscopy) setup. A high peak power nanosecond Nd:YAG laser pulse is used to create plasma from the specimen. The collected plasma emission is transferred to the spectrometer for spectrochemical analysis (Picture: H. Abbasi).

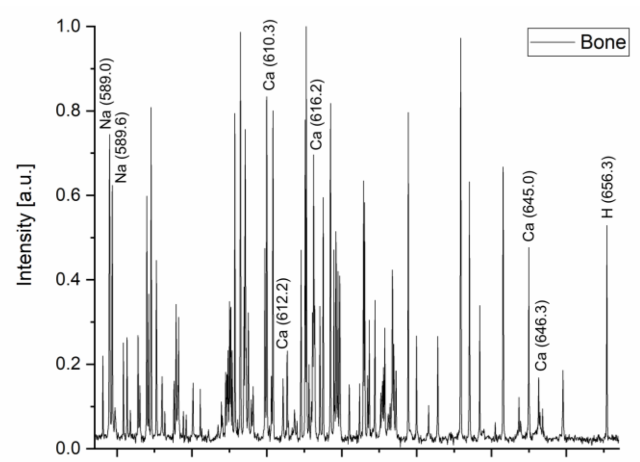

Figure: Typical LIBS spectrum collected from a bone sample. By comparing the wavelength of the observed peaks with reference wavelengths, the presence of specific elements in the material can be concluded (Picture: H. Abbasi).

PhD Thesis by Hamed Abbasi at BLOG.

Compared to traditional mechanical tools for bone cutting (osteotomy), laser offers several benefits, including functional cutting geometry (high axial and lateral resolution), contactless interaction, reduced trauma, and, subsequently, accelerated healing. Lack of real-time feedback about the type of tissue being cut risks iatrogenic damage due to body/laser movement or any other unexpected error. Therefore, real-time feedback during laserosteotomy is essential in order to avoid damage to adjacent soft tissues. Equally vital is the ability to monitor laser-induced thermal damage in order to control the irrigation system used for rehydrating and cooling down the tissue during laserosteotomy. Laser-induced thermal damage (e.g., carbonization) can slow down the cutting procedure and prolong the healing process. Therefore, an optical feedback mechanism based on laser-induced breakdown spectroscopy (LIBS) was developed to serve as a powerful label-free method for elemental analysis.

For this purpose, a custom-made, high-resolution, broadband Echelle spectrometer with high optical throughput was developed. The portable LIBS system, coupled with multivariate spectrochemical analysis, was able to differentiate bone from its surrounding soft tissue and to detect laser-induced thermal damage — both with high accuracy in a single-shot measurement without any sample preparation. The feedback system was integrated into an efficient bone cutting system and was tested in a real-time closed-loop manner, to stop the ablation laser in situ when it encountered the adjacent soft tissues that should be preserved. In the end, the system was miniaturized by delivering the high peak power laser beam through a highly flexible bend-insensitive fiber system with a tiny half-ball lens at the tip, suitable for intraoperative tissue characterization in a minimally invasive endoscopic procedure.

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References:
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