All-fiber-optic LIBS system for tissue differentiation: A prospect for endoscopic smart laser osteotomy

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Minimally-invasive laser surgeries could benefit from a fiber-optic laser-induced breakdown spectroscopy (FO-LIBS) setup for real-time tissue characterization. In FO-LIBS, the sample receives limited light irradiance due to the fiber's low damage threshold and diminished laser beam quality. Therefore, the plasma created with FO-LIBS is less luminant than that of free-space LIBS. Furthermore, only a small portion of plasma emission can be collected, as the lens's size at the fiber tip is restricted to fit inside the narrow channel of an endoscope. A high optical throughput Echelle spectrometer was developed to compensate for low-intensity light collection with FO-LIBS. The Echelle spectrometer was tested for tissue differentiation when combined with a flexible fiber bundle delivery setup and a small lens at the bundle's tip. The customized FO-LIBS setup, coupled with multivariate data analysis, successfully differentiated bone from surrounding soft tissue (muscle, fat, and bone marrow) with 100% cross-validated (CV) sensitivity and specificity. The CV sensitivity and specificity for differentiation between all tissues were 90.2% and 96.7%, respectively. The results demonstrate, to the best of our knowledge, the first flexible FO-LIBS system, which may provide a further step towards the development of a smart endoscopic laser scalpel.
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