Parameters affecting ultrafast laser microsurgery of sub-epithelial voids for scar treatment in vocal folds

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Abstract: Towards developing a new method for restoring tissue viscoelasticity in scarred vocal folds, we previously proposed to localize biomaterials within sub-epithelial voids ablated using ultrafast laser pulses. The clinical implementation of this method necessitates the quantification of the laser parameters for ablating scarred tissue. Here, we present a comprehensive study of these parameters including ablation threshold and bubble lifetime in healthy and scarred tissues. We also present a new method for extracting tissue-specific ablation threshold and scattering lengths of different tissue layers. This method involves finding the ablation threshold at multiple depths and solving the equations based on Beer's Law of light attenuation for each depth to estimate the unknown parameters. Measured threshold fluences were 1.75 J/cm^2 for vocal folds and 0.5 J/cm^2 for cheek pouches for 3-ps, 776-nm laser pulses. Scarred pouches exhibited 30% lower threshold than healthy pouches, possibly due to the degraded mechanical properties of scarred collagen during wound healing. The analysis of tissue architecture indicated a direct correlation between the ablation threshold and tissue tensile strength and that the bubble lifetime is inversely related to tissue stiffness. Overall, this study sheds light on the required laser parameters for successful implementation of ultrafast laser ablation for phonosurgery.

Keywords: ultrafast lasers, ablation of tissue, endoscopic imaging, nonlinear microscopy, multi-photon processes, laser-induced damage, vocal fold scarring, scarring, tensile strength of tissue, mechanical properties of tissue.