Corneal Ablation Process Monitoring

Alessio Poretti

Supervisors: Prof. Christoph Meier, MSc Viktor Ruff
Institutions: Bern University of Applied Sciences, Institute for Human Centered Engineering
Ziemer Ophthalmic Systems AG
Examiners: Prof. Christoph Meier, MSc Dominik Inniger

Introduction

Uncorrected refractive errors are the second leading cause of blindness after cataracts [1]. Laser use has helped improve the outcome of refractive surgery and accelerate healing. Lasers and devices to perform this procedure are constantly evolving and improving. During the development phase of a new ablation device, ex vivo experiments are often performed on enucleated porcine eyes to model and optimize the treatment process before treating patients. However, accurate characterization of the ablated volume in tissue remains a difficult task. Manipulations, motion artifacts, internal stresses of the cornea, changes in hydration, or thermal effects may alter the ablated geometry and affect the outcome assessment. The aim of the present work is to develop a high-resolution spectral-domain optical coherence tomography (SD-OCT) device to precisely measure the ablated volume without affecting the path of the ablation laser.

Materials and Methods

For this purpose, a high-resolution SD-OCT was built and calibrated. The measuring head was tilted by 20° to allow the acquisition laterally to the surgical laser. Due to the unique design of the measuring head, the resulting 3-dimensional volume had to be corrected for rotation and non-telecentric scanning. The pre-operative corneal surface topography was then segmented, corrected for distortions, and compared to the postoperative cornea.

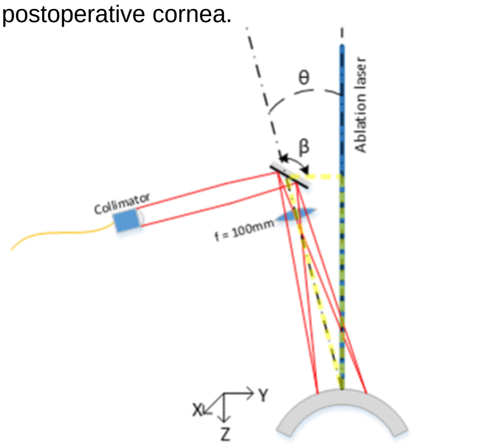

Fig. 1 Design of the tilted scanning head, composed of a collimator, 2-axis scanner, and objective lens. Red lines indicate the measuring laser path. Note that the scanning head does not interfere with the ablation laser path (blue line).

Results

The developed OCT device boasts an axial resolution of 1.6um and a lateral resolution of 44um. A crater was engraved on a PMMA sample and measured with an industrial-grade confocal microscope (CM) and a white-light interferometer (WLI). OCT-CM and OCT-WLI comparison indicate a root mean squared error (RMSE) of 22um and 40um respectively, comparable to a RMSE between the two certified devices of 29um.

Different geometries for myopia and hyperopia correction were ablated on PMMA samples and porcine eyes, and the resulting volume was quantitatively evaluated.

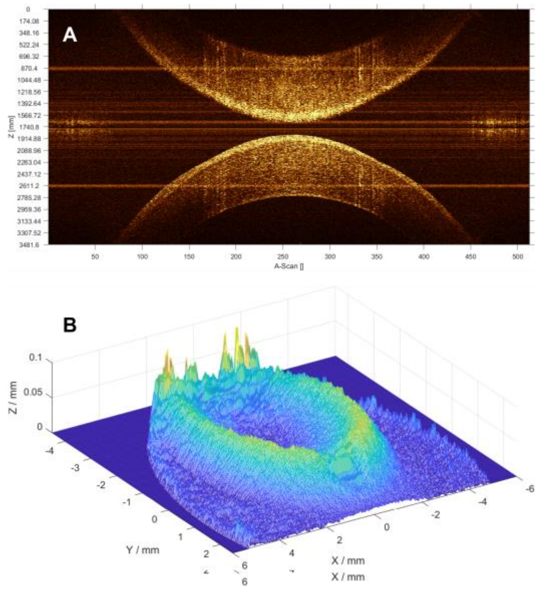

Fig. 2 A) Raw B-scan of a porcine eye after hyperopia correction. B) Resulting ablated volume on the same eye.

Discussion

The theoretical resolution is affected by the tilted acquisition. However, the built device is installed rapidly on a surgical laser for refractive surgery, delivering reliable measurement of an ablated volume without altering the result through sample manipulations.

References

[1] Bourne, R. R. A et al. (2013). Causes of vision loss worldwide, 1990-2010: a systematic analysis. The Lancet. Global Health, 1(6)