

ABSTRACT

This dissertation provides a comprehensive investigation on corneal light scattering parameters and the ways of their assessment. Currently used measures seem to be confounded by factors of various nature. Therefore, the superior aim of the work is to create estimators of corneal light scattering parameters that would be independent of confounding factors and will improve diagnostic value of these parameters. As corneal scattering properties are addressed in this work in different points of view, it was necessary to divide the main research part into three projects.

The first project raises the problem of confounding factors observed in Scheimpflug-based corneal densitometry, a clinically used quantity to assess corneal backscatter and, subsequently, health. The research is performed on Scheimpflug images of 141 young and 73 old subjects. Three densitometry parameters were analyzed, which were the mean pixel intensity and the Weibull scale and shape parameters, calculated for the chosen region of interest (ROI). The main confounders have been identified as the eye biometry parameters, namely, anterior chamber depth, pupil size, and central corneal thickness. Also, extensive elaboration on image preprocessing has been performed. The result is an algorithm which successfully compensates densitometry measures for the observed confounding factors.

The second project considers the matter of multilayered structure of the cornea. The purpose was to assess and quantify the influence of the corneal epithelium on the scattering signal corresponding to the corneal stroma. In this case, another imaging technique, optical coherence tomography (OCT) has been utilized. A retrospective data set of 11 porcine OCT images acquired before and after epithelial debridement was analyzed to compare the OCT speckle statistics in the stroma for these two measurement modes. Four measures were considered, which were the shape and scale parameters of the Gamma distribution, the mean pixel intensity and contrast ratio for the given ROI, delineating corneal stroma. The investigation confirmed the significant differences in speckle statistics depending on whether the stroma is measured with or without epithelium. The estimation error of the stromal parameters caused by the presence of epithelium was shown to reach over 20%, depending on the stromal depth.

The last project introduces the concept of creating a digital OCT phantom for the cornea. The primary aim was to simulate corneal stroma OCT B-scan, with close to reality speckle statistics. First, a commonly used Monte Carlo algorithm for simulating photon propagation through tissue and an algorithm for calculating the OCT signal were implemented. Both were adapted for the particular OCT device and adjusted to the optical properties of the cornea. Further, a novel method for in-vivo OCT-based estimation of optical properties (that is, scattering and anisotropy coefficients), currently unresolved for the cornea, was developed. For that, a set of multi-reference B-scans was generated for various values of the input optical parameters, selected on the basis of the information available in the literature on the dissected corneal tissue. Then the estimation method based on statistical matching between simulated and experimental data was designed. The group mean of the scattering coefficient and the scattering anisotropy factor for the porcine stroma were $\bar{\mu}_s = 0.146 \pm 0.020 \text{ mm}^{-1}$ and $\bar{g} = 0.893 \pm 0.021$, respectively.

