Diagnosis of Corneal Diseases Using Corneal Microlayer Thickness Maps

Amr Elsawy 1, 2, Mohamed Abou Shousha 2 and Mohamed Abdel-Mottaleb 1

1Electrical and Computer Engineering, University of Miami, Coral Gables, FL, USA
2Ophthalmology, Bascom Palmer Eye Institute, Miami, FL, USA


Cornea

Cornea is the transparent part at the front of the eye that covers the pupil, the iris and the anterior chamber. The cornea has six microlayer boundaries: the air-epithelial boundary (EP), the basal-epithelial boundary (BS), the epithelium-Bowman’s boundary (BW), the Bowman’s stroma boundary (ST), the Descemet’s membrane (DM) and the endothelium-aqueous boundary (EN) (Fig. 1a). Optical Coherence Tomography (OCT) is used for imaging the cornea and the corneal microlayer boundaries can be seen (Fig. 1b).

Figure 1: Cornea

Earlier detection of corneal diseases helps to treat these diseases and prevents them from progression to corneal blindness. Examples of corneal diseases are keratoconus, Fuchs dystrophy and corneal graft rejection. Keratoconus is a progressive thinning of the cornea. It affects 1 every 2,000 Americans. LASIK refractive surgery may cause ectasia similar to it. It causes thinning and bulging of the middle of the cornea (Fig. 2a). This causes double or blurred vision, nearsightedness and astigmatism (Fig. 3). Earlier, it can be treated with glasses or contact lenses. Later, it requires crossing-limbal surgery, intrastromal corneal rings or corneal transplant. Fuchs’ dystrophy disease progresses slowly and it is more common in women. It causes vision to gradually worsen over years without noticing until the age of 50s or 60s. It affects 4.5% among patients over 50s and 10.5% of patients over 60s [1]. Fuchs’ dystrophy is caused by the gradual deterioration of cells in the corneal endothelium which causes fluid to build up within the cornea. The cornea swells and becomes cloudy (Fig. 2b) and vision becomes blurred. Earlier, the swelling is reduced with drops or contact lenses. Later, the eye may need a corneal transplant. Corneal graft rejection happens when the immune system of the host does not accept the transplant. Earlier detection of the rejection is crucial to save the graft otherwise it will fail. The rejected graft appears cloudy and it causes redness and itchiness of the eye (Fig. 2c).

Figure 2: Corneal Diseases

Methods

Averaging OCT images have inherent speckle and background noise. We use cross-correlation [7] and outer corneal boundaries for registration and averaging.

Visualization Segmentation is the detection of the 2D curves that represent the corneal microlayer boundaries in each OCT image (Fig. 5c). We use several methods for the detection of the corneal microlayer boundaries including graph theory, polynomial model, RANSAC method and Hough Transform [8, 9]. These methods segment the six corneal microlayer boundaries.

Figure 3: Simulated vision of moon for a keratoconus patient

Figure 4: OCT images of corneal diseases

Diagnosis of Corneal Diseases

Measuring the thickness of corneal microlayers in vivo has proven to be valuable for the diagnosis of corneal diseases. For example, thinning of Bowman’s microlayer has been shown to be an accurate sign for the diagnosis of keratoconus [2, 3]. Also, thickening of the endothelial/Descemet’s microlayers has been shown to be an effective method for the early diagnosis of corneal graft rejection and Fuchs dystrophy [4, 5, 6].

Figure 5: Averaging and segmentation

Conclusion

Our work has medical significance by providing new measures for earlier detection of corneal diseases and algorithmic significance by proposing new methods for visualizing and segmenting OCT images that segments more corneal microlayer boundaries.

References


Figure 6: Reconstruction and thickness measurement


Support:
- NEI core center grant (P30 EY014801):Code F (Financial Support)
- NEI K23 award (K23EY026118):Code F (Financial Support)
- Research to Prevent Blindness (RPB): Code F (Financial Support)