Limbus Detection using Ultrawide-field Optical Coherence Tomography (OCT)

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Introduction

Demarcating the position of the corneoscleral limbus is important for fitting scleral lenses. Appropriate limbal clearance is essential to reduce lens decentration, conjunctival prolapse, stem cell breakdown, tear reservoir debris, and discomfort.[1,2] Traditionally, horizontal visible iris diameter or white-to-white have been used to determine the location of the limbal zone. However, the topographical transition between cornea and sclera does not correspond with the white-to-white diameter.[3,4] Since the posterior surface of a scleral lens has vault the cornea and the limbus while landing on the sclera, the limbus measured as the topographic change between cornea and sclera compared to other subjective measurements may better assist us in designing a well fitted scleral lens to ensure good vision, comfort and ocular health compared to the white-to-white.

Objective: Develop an automatic method to demarcate the topographical limbus using Optical coherence tomography (OCT)

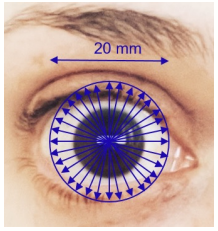

Figure 1. Scan pattern used to image the corneoscleral profile.

Methods

Measurement:

An ultrahigh-speed (325 kHz) and ultra-wide swept-source OCT was used to image the entire anterior segment of 17 eyes. The axial resolution is 8.8 µm in tissue. A scan pattern was designed consisting in 16 radial scans of 20 mm width that was centered at the pupil center (Fig. 1). Each eye was measured three times to evaluate the repeatability by means of the within-subjects standard deviation (SD).

Limbus Detection:

For each meridian, the 2nd central moment of the OCT axial signal was projected along the transverse dimension. The transition from clear cornea to white sclera and iris edges were identified as sharp transitions. To locate the external topographic limbus (ETL), the corneal surface was fitted with a 4th order polynomial and the scleral surface was fitted with a 2nd degree polynomial. The intersection of the two fitted curves determined the ETL (Fig. 2). The ETL positions of 16 meridians were combined to obtain a 3D limbal representation (Fig 3). Along the transversal direction the limbus was modelled with a best-fit ellipse. Along the axial direction the limbus was fitted with a plane.

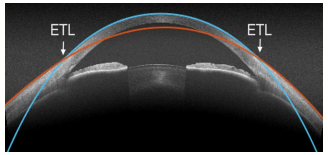

Figure 2. Corneal surface fitted with 4th degree polynomial (blue line) and scleral surface fitted with 2nd degree polynomial. The intersection of both fittings is the external topographic limbus (ETL, white arrows).

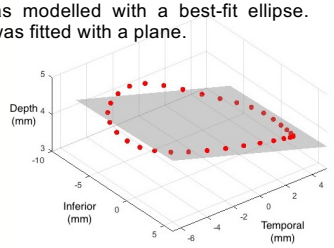

Figure 3. 3D topographic profile of the limbus. The limbal points (red points) is combined to obtain the best-fit plane of the limbus (gray plane).

Results

Best Fit Limbal Ellipse Semi-Length Axes (mm)		
	Mean ± SD	Pooled SD
Major (a)	6.45 ± 0.21	0.10
Minor (b)	5.99 ± 0.28	0.13
Ratio (a/b)	1.07 ± 0.05	0.02

- The limbus has toricity as it deviates from the best-fit plane (Fig. 3)
- The ETL ellipse was significantly longer along the horizontal direction (12.73 mm) compared to the vertical (12.19 mm) (linear-mixed model, p = 0.003).
- The mean orientation of the major axis was 1 ± 20 degrees.

Conclusions

- Limbus identification with the proposed method is repeatable and can provide 3D topographic information of the limbus.
- The limbal shape is not circular, but wider in the horizontal dimension compared to vertical dimension.
- For patients with an oval shaped limbus, new scleral lens designs with an internal oval trend may improve scleral lens fitting.
- In the future, OCT may provide scleral lens fitters a non-invasive, effective and efficient way to trouble shoot scleral lens complications in clinic.

References

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Supported by the NIH, (Bethesda, MD) (grants no.: R01EY028755, R01EY029023 and P30EY010572) and an unrestricted grant from Research to Prevent Blindness

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