Utilization of Anterior Segment Ocular Coherence Tomography to Automate the Design of the Back Surface of Scleral Lenses

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Abstract

Ocular Coherence Tomographer (OCT) systems collect and measure the light backscattered by the surface and sub-surface features located along the path of the probe. The backscattered light and a reference light beam form an interference pattern that is Fourier transformed to produce a 1-D depth profile. 2-D and 3-D images are obtained by scanning the OCT light probe across the surface of the sample while collecting the measured A-Scans into datasets. Corneal scans have been limited to single 16mm slices in large part due to micro and macro eye movements. This pilot study looked at a novel approach to controlling the motion artifacts in large diameter ocular surface OCT scans enabling the construction of eye surface topography with micron level accuracy.

An off the shelf Thorlabs OCT was configured to scan the eye surface in radial segments of 23mm. Each segment contained 1000 axial scans and were completed at two-degree intervals across the ocular surface totaling 180,000 data points. Through a proprietary program the motion artifacts were removed, and a complete profile of the ocular surface was constructed. This profile was utilized to design the back surface of a 15.6 Onefit MED scleral contact lens. The landing angles were matched for each of the four principal meridians determined by the slope data for each meridian. The lens vault was calculated based upon the expected lens position and the height of the corneal apex. Lenses were manufactured for ten eyes relying solely on the profile obtained by the Thorlab OCT. Each eye was observed with bio-microscopy to evaluate the landing zone for compression and impingement. OCT was then performed with the manufactured lens in place and the fluid reservoir depth was observed in the central and peripheral corneas with the corresponding OCT image.

No conjunctival impingement or compression was observed in any of the 10 fitted eyes with bio-microscopy. Of the 10 eyes one central fluid reservoir (FR) was measured unacceptably shallow at 110 um. The other 9 FR's all fell between 200 and 275 microns. Peripheral fluid reservoir was not measured by caliper but was observed to be at least 50um in all 10 eyes.

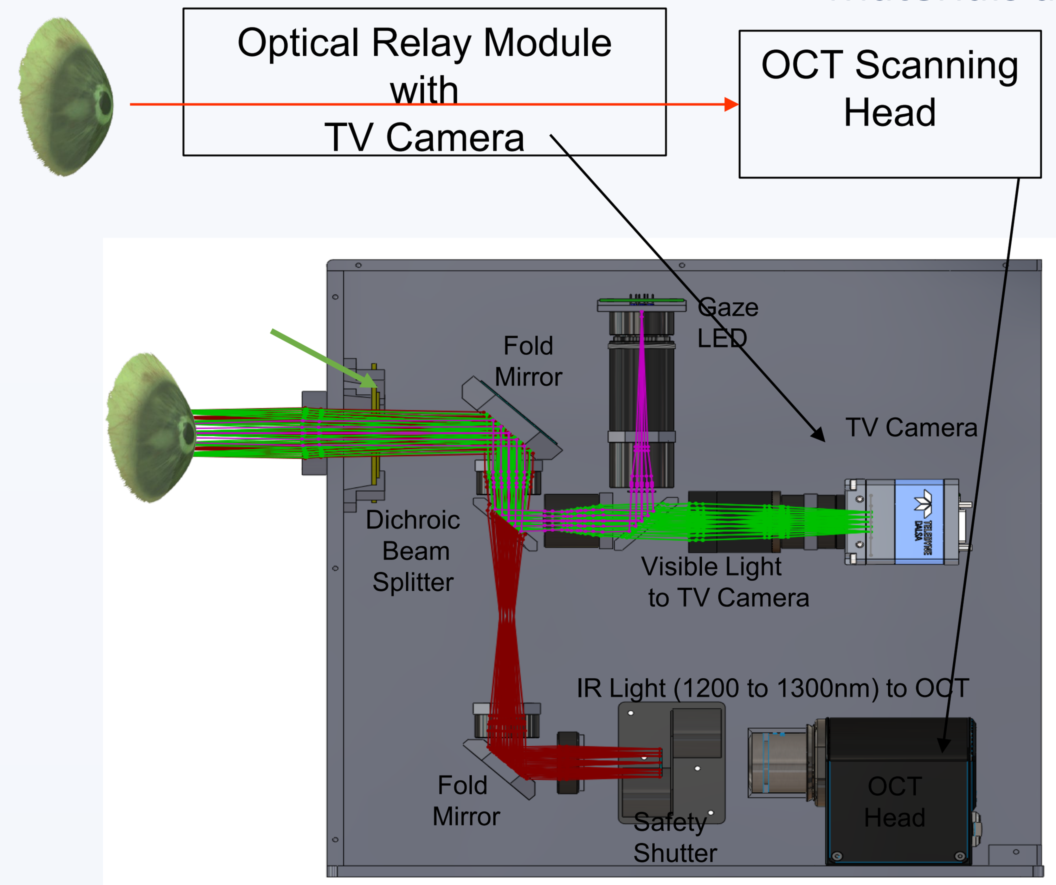
Objective

To determine the feasibility of utilizing a large diameter anterior Ocular Coherence Tomography (OCT) to profile the eye surface in order to empirically design the back surface of scleral lenses in human subjects.

Materials and Methods

Subjects were randomly chosen from patients presenting for routine eye examinations. Ectasia and or severe ocular surface disease were excluded. Subjects ranged in age from 26 to 63, three females and two males made up the gender representation. Scans were taken in primary gaze making use of a fixation target. Lids were separated with two cotton tip applicators to expose the superior and inferior bulbar conjunctival surfaces. Scans were taken in rapid succession with no more than three scans needed to obtain satisfactory images in all 360 degrees. The corneal diameter was defined by the technician with an oval that was placed on the image outlining the very edge of the cornea. The lens placement was assumed to be .5mm temp and inferior to this circle.

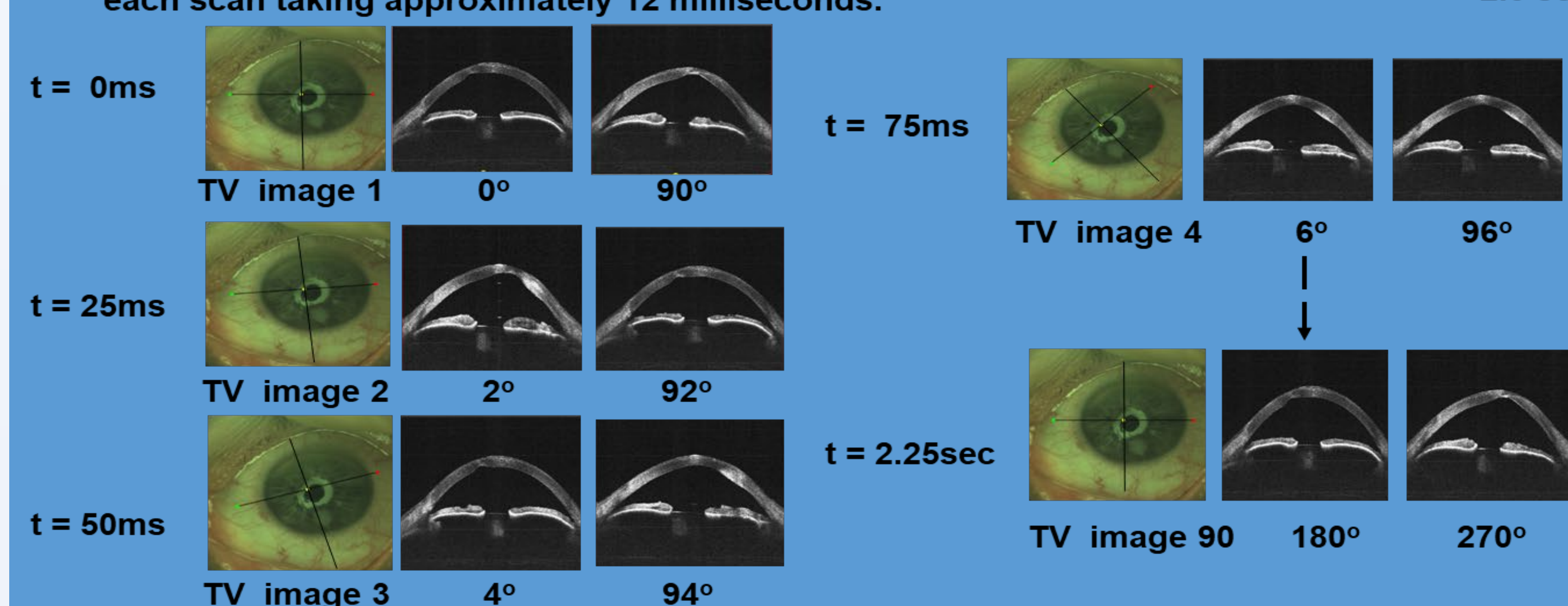
Materials and Methods Cont.



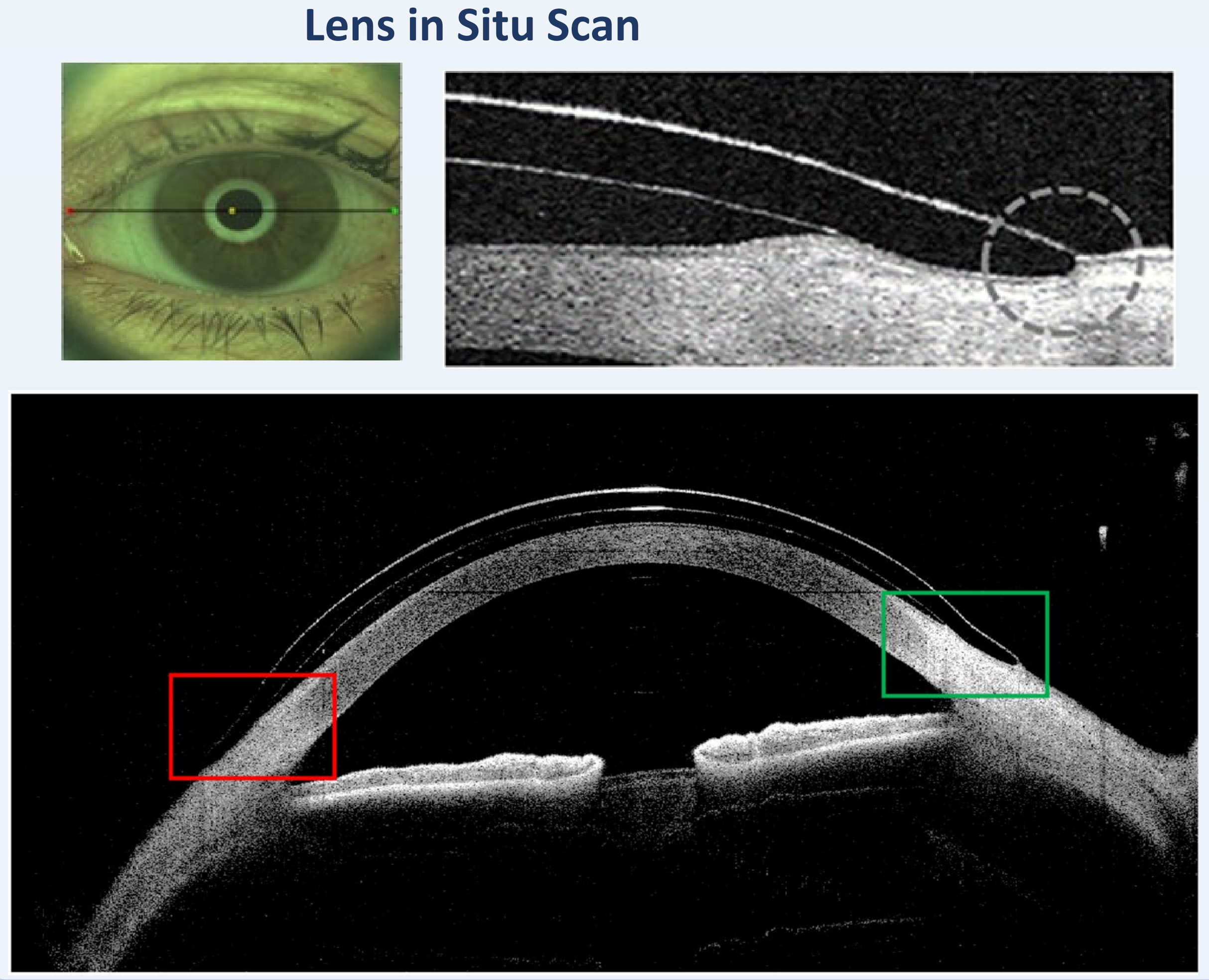
How The System Works – How Motion Is Removed

- The OCT system scans the entire eye from 0 to 360 degrees in approximately 2.5 seconds. The example below if for an injured eye with extensive corneal damage.
- Simultaneously as the eye is scanned by the OCT system, a high frame rate TV camera acquires images of the eye every 25 milliseconds, for a total of 90 images
- Each TV image is accompanied by a set of two orthogonally oriented OCT scans, each scan taking approximately 12 milliseconds.

360° scan in 2.5 seconds



Lens in Situ Scan



Calibration with Known Sphere

Known Sphere Dimensions Radius: 12.500 mm STD: +/- 2.5	Measured Radius	Radius Error	STD	Total Error
Sphere Measured in Static Position	12.506 mm	6 µm	8.1 µm	6 µm +/- 8.1 µm
Continuous XYZ Motion (without XYZ correction)	11.676 mm	824 µm	246 µm	824 µm +/- 246 µm
Continuous XYZ Motion (with XYZ correction)	12.526 mm	26 µm	9.2 µm	26 µm +/- 9.2 µm

Calculating the Lens Back Surface Shape

The slope data for the landing zone was then determined for each of the 180 measured meridians. The flattest meridian indexed the lens so that 3 other meridians were calculated, 90, 180 and 270 degrees respectively from the flat meridian. The slope data for each of these meridians determined the landing zone angles for each. The primary functional sagittal depth (PFSD) of the ocular surface was determined by estimating the diameter of the lens that would first touch the ocular surface. 300 um was then added to the PFSD to determine the vault of the lens to be manufactured. No attempt was made to estimate the power needed to correct for the refractive condition of the subjects. The correct optical power of the devise could be estimated by utilizing the central corneal power data measure by the OCT to estimate the lacrimal lens created by the back surface of the lens but was not attempted in this pilot study.

Conclusions

An off the shelf OCT scanning head was configured to perform large diameter scans of the ocular surface out to 23mm. The EYEDeal Scanning algorithm for motion correction was able to profile the eye surface with enough precision to empirically design the back surface of scleral lenses in human subjects, resulting in no observable compression or impingement in each of the 10 eyes tested. The central FR was measure adequate for 9 of the 10 eyes and fell between 200 and 275um. One FL was deemed inadequate and measured at 110 um. Limbal clearance was not measured by caliper but was deemed adequate with a minimum observed 50 um in all meridians.

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