Imaging the zonules using OCT with folded obliquely-aligned optics

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PURPOSE

The zonules are the suspensory ligaments that connect the crystalline lens to the ciliary body and are critical for transferring force to the lens during accommodation. Because the zonules are positioned behind the iris, they are difficult to image using slit lamps and optical coherence tomography (OCT) and are therefore usually visualized using a gonioscope that contacts the patient's eye. Here we present a folded optical system that redirects the OCT scanning beam for imaging the zonules without contacting the patient.

METHODS

An add-on lens was designed to redirect the scanning beam from a swept-source OCT system (PLEX® Elite 9000, ZEISS, Dublin, CA) to image the zonules (Figure 1). The add-on system requirements were:

- Field of view (FOV) must be 8.5° before entering eye
- Angle at the patient cornea relative to optical axis must be 70°
- The $1/e^2$ beam diameter at the zonules must be <30µm
- Patient must maintain central fixation
- Maintain the same working distance as posterior segment imaging mode on PLEX
- Optics avoid the center of the FOV, so the iris viewer and internal fixation target in the system can be used.

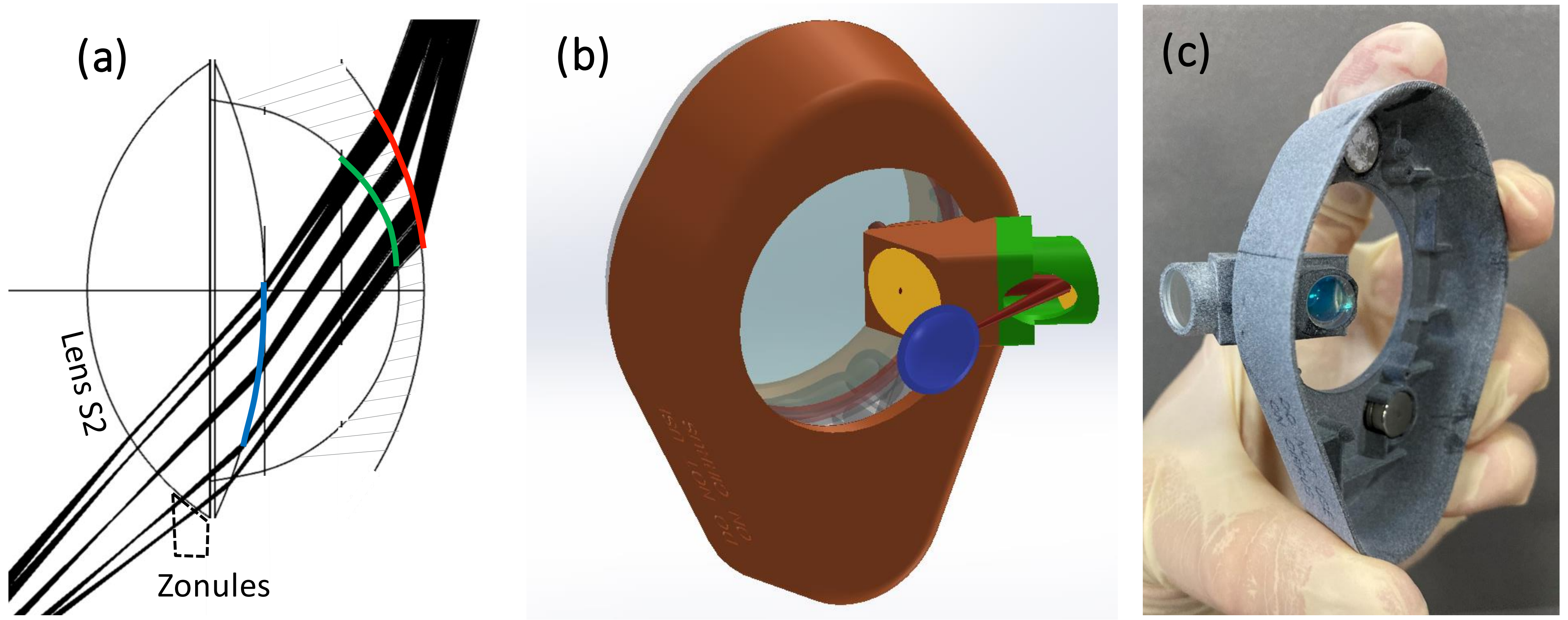

Figure 1. (a) Optical model of test eye with scan over anterior segment. (b) CAD model of the add-on lens. Blue is anterior segment, yellow are mirrors, and orange and green are mounts. (c) Picture of 3D-printed add-on lens prototype.

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RESULTS

The design consists of several off-the-shelf lenses and mirrors folded to redirect obliquely-scanned light into the patient pupil (Figure 2a). The optical performance was evaluated using Zemax. Due to the non-uniform optical pathlength over the scan, the B-scans can be transformed to more closely reflect the anatomical structure of the zonules.

To test the add-on lens, we imaged a zonules phantom consisting of tape intended to mimic the suspensory ligament in a test eye (Figure 2b-c), as well as the zonules in one healthy volunteer (Figure 2d-e). In both cases, the zonules were successfully imaged.

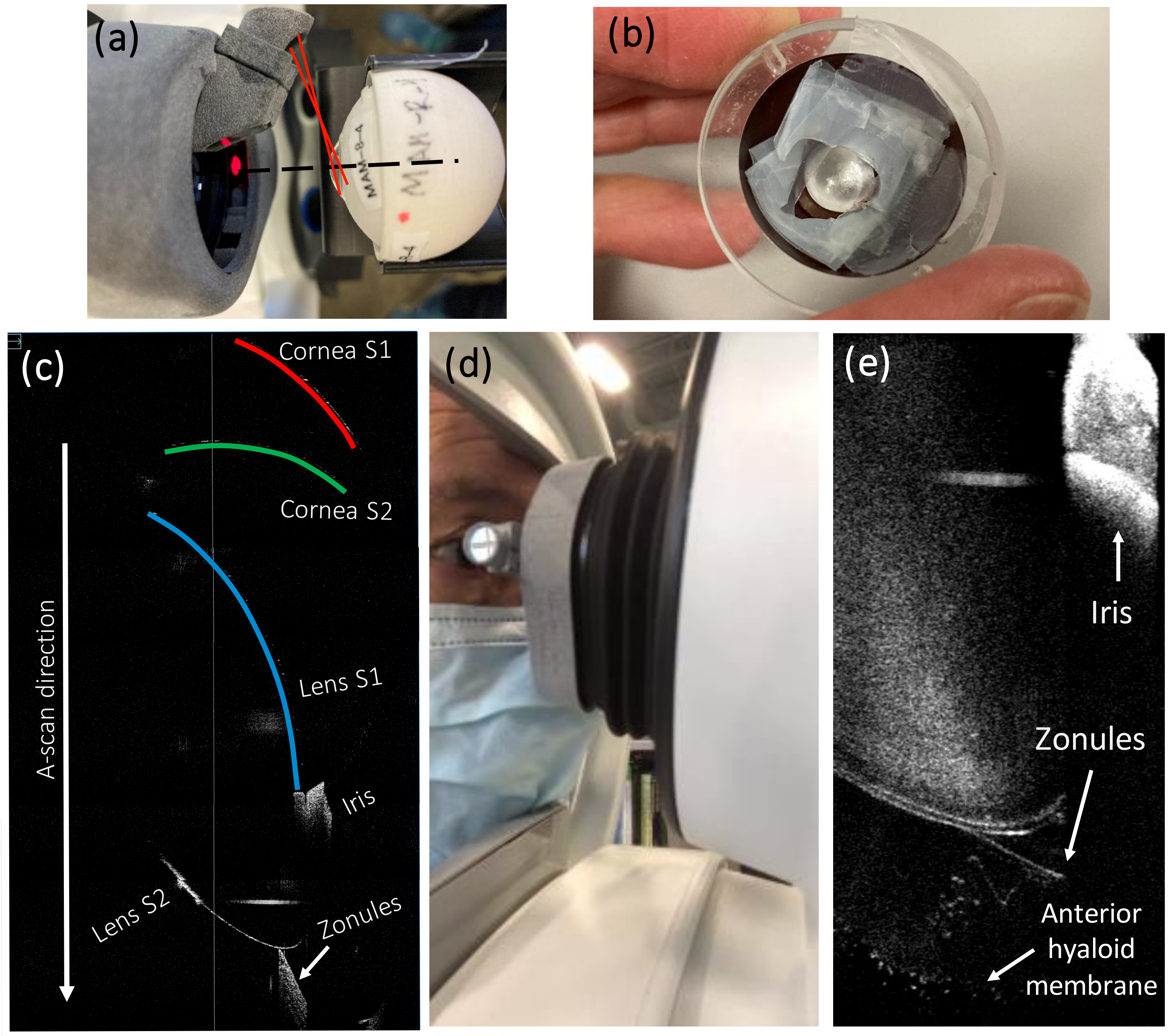

Figure 2. (a) Top view of add-on lens system for zonules imaging. Red lines indicate chief rays over maximum size of scan. (b) Test eye with zonules phantom. (c) Four stitched B-scans of test eye imaged with add-on lens. Surfaces are labelled in relation to model in Figure 1(a). (d) Subject getting imaged with add-on lens. (e) B-scan of human zonules imaged with add-on lens.

CONCLUSION

Our proposed system enables non-contact OCT imaging of the zonules and can potentially be used to determine when modified surgical procedures may be needed for intraocular lens implantation. Instead of directing fixation at extreme angles, the add-on successfully imaged the zonules while the subject maintained central fixation. Future designs will aim to increase imaging coverage to include the full circumference of the crystalline lens.