Complete 360° circumferential gonioscopic optical coherence tomography imaging of the iridocorneal angle

Ryan P. McNabb,1,2,* Pratap Challa,1 Anthony N. Kuo,1 and Joseph A. Izatt1,2

1 Department of Ophthalmology, Duke University Medical Center, Durham, NC 27710 USA
2 Department of Biomedical Engineering, Duke University, Durham, NC 27708 USA
ryan.mcnabb@duke.edu

Abstract: Clinically, gonioscopy is used to provide en face views of the ocular angle. The angle has been imaged with optical coherence tomography (OCT) through the corneoscleral limbus but is currently unable to image the angle from within the ocular anterior chamber. We developed a novel gonioscopic OCT system that images the angle circumferentially from inside the eye through a custom, radially symmetric, gonioscopic contact lens. We present, to our knowledge, the first 360° circumferential volumes (two normal subjects, two subjects with pathology) of peripheral iris and iridocorneal angle structures obtained via an internal approach not typically available in the clinic.

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The iridocorneal angle (ICA) is the circumferential region of the eye where the base of the iris joins the peripheral cornea. Aqueous drainage from the eye occurs through the ICA region, and hence the ICA is an important anatomic region for understanding diseases affected by changes in intraocular fluid drainage such as glaucoma. Optical coherence tomography (OCT) – which has seen widespread diagnostic use within ophthalmology [1–4] – offers the potential to help physicians and scientists visualize pathologic changes in the ICA. However, optical imaging of the ICA is a challenging optical engineering problem. Due to the high angle of incidence required and the large index of refraction difference between air and cornea \( (n_{\text{air}} = 1.000 \text{ and } n_{\text{cornea}} = 1.376) \) [5, 6] resulting in total internal reflection, the angle is generally optically inaccessible when viewed directly through the cornea. Previously, external imaging through the corneoscleral limbus with OCT has been used to image the angle and related internal structures [3, 7–15] using conventional anterior segment OCT systems. Two scanning methods are typically utilized. The first is similar to conventional anterior segment OCT where the axis of the scanner and eye are generally aligned, with the focus of the system limited to or including the ICA [3, 9, 10, 13]. Localized B-scans, localized volumes or volumes of the entire anterior segment can be obtained with this technique. The meridional scan pattern introduced in this paper could also be applied utilizing this imaging technique to shorten volume acquisition time if the ICA is the primary region of interest though this has not been done yet to our knowledge. A second external
approach to imaging the ICA currently requires either the OCT scanner or the subject to be oriented such that the corneoscleral limbus is orthogonal to the optical axis of the scanner to maximize OCT signal strength [7, 8, 10–12, 14, 15]. By positioning the limbus nearly orthogonal to the imaging system’s optical axis, OCT images are limited to individual B-scans or volumes restricted to that small, local region. To view the entire limbus and corresponding circumferential extent of the ICA, multiple repositioning and acquisitions would need to be performed.

Conventional clinical gonioscopy permits optical viewing of the ICA by effectively removing the refractive interface between cornea and air through the use of a special contact lens on the eye [16]. Indirect gonioscopy contacts typically consist of an optically flat front entrance surface, one or more angled mirror facets, and a concave exit surface that optically couples to the subject’s cornea [16, 17]. The ICA may then be viewed directly through each of the mirror facets. Combining a scanning imaging technique such as OCT or multiphoton microscopy [18] with either a direct or indirect gonioscopic contact lens (or gono lens) [16, 17] would eliminate the need to image through the corneoscleral limbus but would still be limited to imaging only B-Scans or locally restricted volumes, similar to the current external imaging technique [12, 14]. Additionally, without incorporating a gonioscopic contact lens physically into the OCT system, aligning the entire optical system (independent OCT, gonioscopic lens, and the subject’s eye) becomes practically much more difficult. To address these limitations, we developed a custom, radially symmetric gonioscopic contact lens coupled with OCT to image the ICA which allowed for clinically accessible 360° imaging of the ICA within a single OCT volume.

2. Optical design concept for 360° gonioscopic contact

Our design concept for circumferential gonioscopic OCT imaging builds upon a conventional gonioscopic contact lens, illustrated in a 2D slice in the sagittal plane in Fig. 1. In the Figure, a chief ray (red lines) propagates parallel to the optical axis (yellow dashed line) and reflects from one of the mirror facets (grey gradient) of the contact.

Using this cross-sectional model as a starting point for OCT gonioscopy, only a single radial location in the iridocorneal angle would be imaged. By simply rotating the entire profile around the optical axis, a 3D structure is created and a complete 360° ring of locations could potentially be imaged. In this case, the mirror surface becomes frustoconical in shape (Fig. 2). However, the simplified model in Fig. 1 only considers the chief optical ray. In OCT a group of rays is delivered, and because of the frustoconical shape of the model (linear in one cross-section and circular in the orthogonal cross-section), significant astigmatism is introduced, thus preventing proper focus. Figure 2 illustrates the introduction of this astigmatism using a Zemax (Radiant Zemax, LLC; Redmond, WA) model where a collimated set of rays was reflected from the frustoconical mirror and focuses in the tangential but not the sagittal dimension. Conventional indirect gonioscopy does not suffer from this astigmatism because imaging is performed utilizing either a single or multiple flat mirror facets instead of a single curved frustoconical mirror.
To further explain, consider the simple scenario of a concave cylindrical mirror (circular in cross-section). If a collimated beam of rays were incident on this concave cylindrical mirror at an angle oblique to the axis of the cylindrical curvature, the beam would focus only in a single lateral dimension. Likewise, the conically shaped mirror as shown in Fig. 2 will only focus in a single (tangential) dimension. Additionally, the radius of the mirror changes as a function of position along the optical axis with a larger radius at the wider entrance and a smaller radius at the narrower cornea interface. Because of this changing radius of curvature, the focal length changes depending on where the beam is reflecting. The ultimate result is a mirror that introduces tangential astigmatism that is axially symmetric around the contact and varies along a given radius away from the optical axis.

One potential approach to correct for this complex astigmatism would be to introduce a second, refractive element in series with the frustoconical mirror to add focusing power in the sagittal dimension. This yields a toroidal lens as shown in Fig. 3, which illustrates how this can achieve a focused point of light with no astigmatism at the image plane. One significant
limitation of this design approach, however, is that while both the frustoconical mirror and toroidal lens focus light to the same image plane, they each do so over different focal lengths and thus through-focus astigmatism is still present within the system.

A further improvement can be made by replacing the frustoconical mirror and toroidal lens combination with a single curved surface, a paraboloid mirror as shown in Fig. 4. This design shifts all of the optical power in the sagittal plane to the mirrored surface, thus matching the focal lengths in both sagittal and tangential dimensions, thus reducing through-focus astigmatism. It should be noted that for all design concepts, collimated light entering into the curved surface is focused at a distance of one focal length of the curved surface.
Notice that the light is at what would be the center of contact lens and would not reach the desired image plane of the iridocorneal angle. In the methods section we describe that we operate the final gonioscopic lens in a 2F configuration where we are imaging a point in the object plane two focal lengths away from the mirror (the focal plane of telecentric lenses) to the image plane (the iridocorneal angle and the surrounding tissue) which is another two focal lengths away. This optical design concept is meant as an illustration of how a curved mirror focuses light and the design considerations that need to be made when transitioning from a flat surface to the curved surface basis ultimately utilized, however, it is not the final optical design. This paraboloid mirror approach is the design basis for the contact lens implemented for the circumferential GOCT system described in this work.

3. Methods

3.1 Optical system

All OCT volumes were acquired using a swept source OCT (SSOCT) system with $\lambda = 1050\text{nm}$, $\Delta \lambda = 100\text{nm}$, SNR = 99.6dB @ 100 kHz A-scan rate (Axsun Technologies, Inc.) (Fig. 5). A custom sample arm (Fig. 6(A)) was mounted on a modified slit-lamp base with a chin and forehead rest for subject stability. The sample arm consisted of a collimator, X-Y scanning galvanometers split with a 4F telescope, a telecentric lens system, and a custom gonioscopic contact that imaged the telecentric image plane to the ICA.

The collimator consisted of three 12.7mm diameter achromatic doublets and were optimized to provide minimal spherical and chromatic aberration with a beam diameter of 3.2mm. The collimated beam was reflected off the first scanning galvanometer mirror to a 4F telescope. The 4F telescope consisted of two pairs of opposing 25.4mm diameter achromatic doublets to image the first scanning galvanometer onto the second orthogonally scanning galvanometer mirror. Each pair of achromatic lenses had a back focal length of 71mm. The entire scanning system was optimized to eliminate field distortions introduced by conventional offset X-Y galvanometer scanning systems, to provide collimated light following the scanning system, and to minimize additional optical aberrations. A telecentric lens system consisting of three 50.8mm diameter achromatic doublets focused light following the scanning system. The lens system had a back focal length of 117mm and was optimized to provide a telecentric imaging over a 25.4mm diameter region at the focal point. The gonioscopic OCT contact lens, in a 2F configuration, imaged the telecentric focal plane to the ICA of the phantom or subject (Fig. 6(E)). The cornea used for optical modeling was based on the Goncharov and Dainty eye model [19]. Dispersion mismatch between reference and sample arms was corrected in real-time in software to each A-scan.

Fig. 5. Gonioscopic OCT system schematic.
The design concept for the gonioscopic contact described above was implemented and optimized in Zemax. As a result of optimization, a low refractive power toroidal lens was added to the anterior surface of the gonio lens to correct for aberrations introduced by scanning across the paraboloidal mirror. The contact lens was manufactured via diamond turning from a single block of Zeonex E48R, an acrylic-like polymer (Figs. 6(B), 6(C), and 6(D)). The front toroidal refractive surface was described by an aspheric annulus with an anti-reflective coating at the design wavelengths (Fig. 6(F)). The paraboloid portion of the contact (Fig. 6(G)) was coated with a silver reflective surface and a SiO$_2$ protective layer. After receipt from the manufacturer, this region was also coated with polytetrafluoroethylene (PTFE – i.e. Teflon) to protect the silver and SiO$_2$ surface from alcohol disinfection wipes.
used when imaging patients. The final region consisted of a second, steeper frustoconical section designed to better accommodate the contact-subject interface. This region terminated in a concave corneal interface with a radius of curvature of 7.85mm.

The entire OCT sample arm was designed to achieve a 23.9µm FWHM sagittal spot size and 28µm FWHM tangential spot size at the angle (Fig. 7) of the Goncharov and Dainty model eye [19]. This corresponds to at least 30 lp/mm at 10% contrast for both dimensions. This optical resolution was chosen given the desire for at least a 2mm depth of focus in tissue and the source wavelength of ~1050nm. Optical performance was verified by imaging 1951 USAF test target resolution bars embedded within the angle of a custom anterior segment phantom.

![Graphs showing PSF and MTF data at the iridocorneal angle from Zemax optical model.](image)

Two OCT scan patterns were utilized to illustrate the ICA imaging potential of the novel gonioscopic lens. The first was a custom meridional waveform applied to the galvanometers allowing for complete circumferential coverage of the ICA or a subsector thereof, as
illustrated in Fig. 8(A). Each B-scan consisted of 500 A-scans along a meridional cross-
section of the angle. B-scans were taken at 1° increments to generate circumferential volumes. 
The total acquisition time for this pattern was 1.8 seconds (Fig. 8(B)). The second scan 
pattern was a conventional radial scan across the entire contact. Each B-scan consisted of 
1500 A-scans along a meridional cross section of the contact. B-scans were again taken at 1° 
increments. Total acquisition time for this pattern was 5.4 seconds. The second method was 
less efficient from a data and acquisition time standpoint but provided for easier operator 
alignment of the patient. This scan pattern allowed the operator to more easily correct for any 
tilt or decentration present within the OCT B-scan between opposing angles along a meridian. 
Additionally, an iris camera was utilized to align and monitor coupling between the contact 
and subject cornea through the middle of the aspheric annulus of the contact. The eye was 
illuminated for iris camera imaging using a low-power near-infrared LED ring illuminator.

![Gonioscopic Meridional Scan Pattern](image)

**Fig. 8.** A) Example annular meridional scan pattern with 5° separation between B-scans for visualization clarity. Arbitrary angular spacing is allowed due to the continuous 360° gonioscopic contact lens. B) Conventional OCT images orient A-scans top to bottom with scan direction progressing left to right. Here an illustrative OCT B-scan (from subject shown in Figs. 12 and 13), obtained using the gonioscopic meridional scan pattern, is shown in the conventional OCT image orientation. This results in a novel view of the ocular anterior chamber with A-scans aligned nearly parallel to the iris.

### 3.2 Phantom design

A non-biological phantom that mimicked the human anterior segment was developed to allow 
testing of the 360° imaging and optical resolution measurements. The requirements for this 
phantom were to provide a solid and realistic corneal interface as well as an “iridocorneal 
angle” with quantifiable image features for resolution testing. To achieve this, we modified a 
Barron artificial anterior chamber which is conventionally used for mounting donor corneas ex vivo. At one portion of its periphery we affixed a section of a USAF 1951 paper test chart (Newport, Inc.). The portion mounted only contained elements from group 1. As these targets 
were much larger than the desired spot size, we used the bars to calibrate the scan range of the 
system and used the derivative of an image of the edge of a bar to estimate lateral resolution.

For the phantom cornea, we utilized a 500µm thick flat sheet of cellulose formed into a 
corneal shape. This was done by mounting a cut 30mm square of cellulose sheet between two 
aluminum plates which had a central 20mm region removed allowing direct access to the 
clamped cellulose. Heat was applied to soften the cellulose then a 15.8mm diameter ball 
bearing was pressed into one side of the cellulose creating a bearing shaped dome. This size 
was chosen to closely match a typical corneal radius of curvature. The entire mount was 
allowed to cool and in the process the cellulose retained the smooth dome shape imparted by 
the ball bearing. Once cooled, the cellulose was removed from the mount and cut to fit the
artificial anterior chamber mount. The periphery of the cut cellulose was sanded to mimic the scattering effects of the sclera while leaving the central region of the dome optically clear.

The cellulose “cornea” was secured in the artificial anterior chamber in the same fashion as a donor cornea. The chamber was then filled with saline solution and sealed. The result was a portable, fluid-filled, non-biological phantom for pre-clinical testing of imaging performance and protocols.

3.3 Subject imaging

All human subject research was approved by the Duke University Medical Center Institutional Review Board. Prior to imaging, informed consent was received for all subjects after explanation of the possible consequences and nature of the study. All portions of this research followed the tenants of the Declaration of Helsinki. Two healthy volunteers were recruited from the Duke Eye Center. Prior to imaging, a topical anesthetic (proparacaine HCl, 0.5%) and gel lubricating drops (Systane Gel Drops, Alcon Novartis) were administered to both eyes of the subject. When the gonioscopic OCT system was aligned and in contact with the subject, we acquired either repeated B-scans at a single location or complete circumferential volumes as described above. Two additional subjects with pathology were also consented and imaged. The first subject was also imaged with a standard commercial anterior segment 1310nm OCT system for comparison (Visante, Carl-Zeiss Meditec, Inc.). The second subject had previously undergone trabecular canaloplasty where a suture is threaded through the Schlemm’s canal and pulled inward to open the outflow pathway for treatment of glaucoma [20–22].

4. Results

4.1 System validation

The constructed gonioscopic OCT system was paired with the artificial anterior segment phantom to test optical performance. Optical power prior to the contact was measured to be 1.7mW and was within the ANSI limit for 1050nm light. The SSOCT system sensitivity was measured by replacing the gonioscopic lens with a mirror and attenuating neutral density filter. The peak sensitivity was 99.6 dB and the z6dB range was 3.23mm. The sensitivity fall-off plot is shown in Fig. 9. Figure 10 shows an OCT summed voxel projection (SVP) of the 1951 USAF target within the phantom. From the target image, a lateral resolution of 24µm was measured using the edge response function method described above.

Fig. 9. SSOCT system sensitivity fall-off plot measured before the gonioscopic contact lens.
Figure 11 shows a representative B-scan from 20 averaged B-scans and an *en face* SVP that shows the full 360° circumferential view of the artificial anterior chamber. The representative B-scan was rotated such that the DC of the OCT signal is on the left side of the image. Vertical streaks within the image are artifacts due to constant frequency noise which were not completely removed in post-processing. The structure in the upper right portion of the B-scan image was part of the chamber clamping apparatus. An SVP was acquired by taking a 1000 A-scan by 1000 B-scan raster volume over the entire contact. Compared to circumferential scanning, this scan pattern was inefficient for patient imaging but did provide a complete *en face* view of the gonioscopic contact showing both usable and unusable imaging areas.

4.2 *In vivo* human imaging

Two healthy volunteers without known ocular pathology other than refractive error were consented and enrolled for imaging. We acquired 360° circumferential volumes in 1.8 seconds per volume in both subjects. Each volume consisted of 500 A-scans per B-scan and 360 B-scans per volume (or one B-scan every 1°). The gonioscopic lens also allowed for arbitrary angular divisions. In one subject, B-scans from four distinct sectors of the anterior chamber, taken from a single volume acquisition, are depicted in Fig. 12. Figure 13(A) is a representative rendering of an OCT volume from the same subject showing the angle from a similar perspective as in Fig. 12. Note the iris extends completely to the iridocorneal angle without loss of signal with fine iris processes readily apparent. Figure 13(B) provides a 180° perspective of the ICA in a different region within the eye than what was shown in Fig. 13(A). Figure 14 depicts four 180° slices (superior, inferior, temporal and nasal views) from a single
360° volume from a separate subject. Because the optical system comes in contact with the subject, motion is reduced thus image registration was not required.

Fig. 12. Averaged B-Scans from four distinct sectors (superior, inferior, temporal and nasal) from a full 360° volume placed such that the anatomical structures are in a conventional orientation. Cornea and sclera are on top, iris is on the bottom and the zero-delay line is to the right. At the base of the angle, the highly scattering trabecular meshwork appears as a hyper-reflective region [3, 7, 9, 10, 13, 15].

Fig. 13. A) Volumetric rendering from a quarter of a 360° circumferential gonioscopic OCT volume from a human subject. Visualizing the volume in 3D shows interesting features. The angle is immediately present as in Fig. 11 but now extends back into the image. The iris extends all the way out to the corneoscleral limbus and iris processes can be seen in detail. B) Another view from the same OCT volume. This 180 degree view shows a different region from the previous image.
A third subject had a lesion near the corneoscleral junction (Fig. 15(B)). The subject was first imaged with a commercial 1310nm wavelength anterior segment system in an attempt to assess the depth of the lesion. The patient was positioned such that the tumor was approximately normal to the optical axis of the system. Despite the typically improved penetration depth of 1310nm light in scattering tissue, the cornea below the tumor was not visible (Fig. 15(A)). We then imaged the same region on the patient with GOCT. By imaging with an internal approach, we were able to visualize the cornea and surrounding anterior chamber. We did not see evidence of the highly scattering tumor infiltrating the corneal stroma (Fig. 15(C)). The images from the GOCT allowed the clinician to conclude that this tumor was not grossly invading the cornea underneath and a superficial excision of the tumor could be undertaken. Subsequent excisional biopsy demonstrated the lesion to be a xanthogranuloma.

A fourth subject had previously undergone trabecular canaloplasty (Fig. 16(A)) for treatment of glaucoma. We imaged the entire 360° iridocorneal angle (Fig. 16(D)) and were able to observe the inward peaking of the trabecular region created by the suture (Fig. 16(B)) and a scleral lake (reservoir) created by the surgeon during the procedure (Fig. 16(C)). The presence of the canalicular suture added during the canaloplasty provides a localizing marker for Schlemm’s canal.
Fig. 15. B-scans from a corneal tumor on Subject 3. A) External B-scan from commercial anterior segment 1310nm OCT system (Visante, Carl-Zeiss Meditec, Inc) with a manufacturer’s reported scan range of 16 mm x 6 mm (lateral x depth). Red box indicates the tumor and region imaged by GOCT. The eyelid is visible on the left side of the image. B) External photograph of corneal tumor. C) GOCT image of the underside of the region of the tumor. The cornea appears grossly normal without evidence of mass infiltration of the tumor.

Fig. 16. Gonioscopic OCT of a patient who had previously undergone canaloplasty – insertion of a circumferential suture into Schlemm’s canal. A) Gonioscopic photograph showing faint blue canalicular suture. B) Representative B scan of suture (hyper-reflective region) causing peaking of the trabecular meshwork region. C) B scan showing the presence of a scleral lake reservoir created as part of the canaloplasty procedure. D) Volume rendering of 180° of the acquired data. The area of the scleral lake is seen and above the iris root, inward peaking of the trabecular region can be seen (arrowheads). (See Media 3 for the full 360° volume).
5. Discussion

We have developed an optical system which images the entire 360° circumferential iridocorneal angle within a single volumetric acquisition using an internal approach. We achieved this through the use of a novel, custom contact lens coupled with a swept source OCT system. The custom contact lens combined a toroidal refractive surface and a paraboloid mirror to allow focusing of the circumferentially scanning beam. We tested optical performance with a USAF 1951 test chart in a custom phantom mimicking the human ocular anterior chamber. Additionally, the system was tested in human subjects, in which we were able to image both normal and subjects with known pathology.

Unlike most ophthalmic implementations of OCT, gonioscopic OCT comes in contact with the subject creating unique challenges. By utilizing local anesthesia and gel lubricating drops, any patient discomfort and need to blink is reduced. Proper imaging required careful alignment of the system in three dimensions with respect to the subject. The use of the iris camera was crucial in this alignment process. Prior to contact, the subject’s eye in the iris image was seen grossly for lateral alignment. When the patient came in contact with the system there was a distinct change in the iris camera image as the contact-cornea interface removed all air between them and was filled with the gel lubricating drops. No further axial translation was required. A contact based system also provided the imaging advantage of reduced patient motion (both axial and lateral) due to mechanical coupling between the subject and the system.

By optically imaging the ICA from within the anterior chamber this provides the potential to deliver other forms of light to the angle including light from therapeutic lasers. Argon laser trabeculoplasty (ALT) [23] and selective laser trabeculoplasty (SLT) [24] utilize therapeutic lasers to lower intraocular pressure in patients with open-angle glaucoma by delivering thermal energy to the trabecular meshwork. ALT utilizes a continuous wave argon laser to deliver thermal energy to a small spot (~50µm) on the trabecular meshwork [23]. SLT utilizes a 532nm Q-switched Nd:YAG laser to deliver thermal energy to a comparatively larger spot (~400µm) on the trabecular meshwork [24]. Both techniques provide similar reductions in the lowering of intraocular pressure [25] and both techniques utilize an indirect gonioscopic lens to deliver the therapy [23, 24]. While SLT might provide an easier implementation due to its larger spot size, combining either technique with our novel gonioscopic contact instead of currently utilized indirect gonioscopic lenses could provide for real-time OCT guided therapy. A limitation of these therapies and a limitation of our imaging technique is that they are limited in cases of closed or narrow angle glaucoma or other instances where the peripheral iris obfuscates the optical path to the ICA. This can be seen in Fig. 15(C) where the most peripheral section of the iris and a small region of the ICA suffer from diminished signal quality due to being blocked by more central iris processes. Eye color may also play a role in signal quality with Figs. 12 and 13 from a volunteer with light colored irises and Fig. 14 from a volunteer with dark colored irises.

While the GOCT system provided direct optical access to the ICA, the lateral optical resolution of this system as designed was limited to 24 microns. Schlemm’s canal is anatomically about 25 x 100 µm [26] with the narrow edge nearly parallel to our A-scans. This specific anatomic orientation increased the difficulty in using this system to image Schlemm’s canal. A redesign of the imaging optics could potentially allow for improved imaging of both the trabecular meshwork and possibly Schlemm’s canal. This system was designed to have a 2mm depth of focus to accommodate a large portion of the adult population but at a cost of a limited lateral resolution. By adding the ability to move the focus within the ICA, we can redesign the system with improved later resolution even though the depth of focus would decrease (OCT axial resolution remains unchanged as it is dependent on the center wavelength and bandwidth of the source) [27]. Additionally shifting to a lower wavelength would also improve theoretical lateral resolution [27] though the light would experience higher scattering within tissue. Imaging of the posterior cornea is difficult to resolve with our system for a couple of reasons including the low refractive index difference
between cornea and aqueous. Additionally, the image plane of the sample arm is designed to be within the ICA. As you move away from that plane axially (i.e. to the posterior cornea), resolution will decrease resulting in a reduction of image quality. Imaging of the trabecular meshwork could be improved through the use of polarization sensitive OCT [13] though this would require a change in the OCT engine design. Masihzadeh, et al. [18] utilized a direct gonioscopy lens to obtain direct optical access to the ICA in order to perform multiphoton imaging of ex vivo porcine trabecular meshwork. Multiphoton imaging provides high imaging resolution and molecular contrast that is complementary to OCT imaging [28]. Unfortunately the power requirements to utilize multiphoton imaging [18] in vivo are beyond the safe illumination limits for ocular tissue [29]. However, a modified version of the gonioscopic lens presented could potentially provide a useful tool to simplify ex vivo multiphoton imaging studies.

Future improvements to the OCT engine may further improve image quality without changing the sample arm optics. Upgrading the OCT engine to take advantage of coherence revival [30] or utilizing a different swept source with a narrow line width [31] could offer the ability to have ~6mm of imaging depth. Switching to a transmissive reference arm could potentially offer improved interferometer efficiency which may yield improved system sensitivity [31]. The swept laser utilized in this SSOCT implementation had a ~50% duty cycle and may be efficiently buffered to double the imaging rate either reducing subject imaging time or increasing the image sampling density [32].

Conclusion

We present, to our knowledge, the first circumferential, single acquisition 360° circumferential OCT volumes of the peripheral iris and select iridocorneal angle structures in human subjects via an internal approach. We imaged two normal subjects and two subjects with pathology, providing views of the ocular anterior chamber not typically available in the clinic. Imaging of the ICA with this approach produces a circumferential view of the ICA and with further development there is potential for diagnostic and therapeutic studies in glaucoma.

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