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Indirect gonioscopy system for imaging iridocorneal angle of eye

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ABSTRACT

Current clinical optical imaging systems do not provide sufficient structural information of trabecular meshwork (TM) in the iridocorneal angle (ICA) of the eye due to their low resolution. Increase in the intraocular pressure (IOP) can occur due to the abnormalities in TM, which could subsequently lead to glaucoma. Here, we present an indirect gonioscopy based imaging probe with significantly improved visualization of structures in the ICA including TM region, compared to the currently available tools. Imaging quality of the developed system was tested in porcine samples. Improved direct high quality visualization of the TM region through this system can be used for Laser trabeculoplasty, which is a primary treatment of glaucoma. This system is expected to be used complementary to angle photography and gonioscopy.

Keywords: Trabecular meshwork, Gonioscopy, Ocular imaging, Iridocorneal angle, Laser trabeculoplasty.

1. INTRODUCTION

Optics and photonics engineering play a very vital role in the areas such as imaging[1-6] and translational medicine[7-12]. In recent years, specifically in vision science there have been many advanced medical diagnosis tests for a variety of ocular diseases. However, early clinical evaluation for permanent blindness causing disease such as glaucoma is still challenging since each of the imaging techniques involves testing or assessment of totally different parameters/information. For example, tonometry, is used for checking the inner eye pressure[13]; gonioscopy, which is checking the angle in the eye where the iris meets the cornea[14], ophthalmoscopy, which is checking the shape and color of the optic nerve[15]; pachymetry, which is checking the thickness of the cornea[16] *etc.* Therefore, ophthalmologist needs multiple tests for diagnosis. This would lengthen the process of diagnosis and the waiting time for the patients who need an immediate eye treatment. Due to this issue, ophthalmologists always demand a better equipment and testing methods to provide a fast and accurate diagnosis for the patient.

In glaucoma patients, the assessment of trabecular meshwork (TM) in the iridocorneal angle (ICA) of the eye is known to have potential early diagnostic value. This is because TM controls the aqueous humor flow rate in the eye, any abnormalities in the TM can vary the intraocular pressure (IOP) which could subsequently lead to glaucoma. These abnormalities include marked loss of TM cells, fusion and thickening of the trabecular lamellae and deposition of sheath-derived plaques in comparison to age-matched normals. For this reason, direct high quality visualization and assessment of the TM is very critical for the diagnosis of glaucoma. However current imaging techniques which include gonioscopic angle examination, EyeCam[17], optical coherence tomography (OCT)[18], Scheimpflug imaging (Pentacam-Scheimpflug)[19], ultrasound biomicroscopy (UBM)[20] and Orbscan scanning slit topography[21] do not have the spatial resolution sufficient enough to resolve TM structures.

In this article, we demonstrate an indirect gonioscopy system for imaging iridocorneal angle of eye. We have presented the optical configuration and using Zemax software optical ray tracing and PSF grid measurements were performed. As initial result, an example of porcine angle photographed with the system is shown in this study. We have further illustrated the concept of modifying this system to perform for laser trabeculoplasty.

2. RESULTS AND DISCUSSION

2.1 Optical configuration

Figure 1 shows the schematic of the basic optical configuration of the proposed indirect gonioscope system. In Figure 1, L1 is the objective lens (Thorlabs - LA1951 - A (Focal length = 25 mm); L2 is the tube lens (Hikari tube lens, focal length = 140.8mm); L3 is the convex lens, focusing lens (F = 50mm); L4 is the axicon lens (Thorlabs - AX255-A, 5.0°); C is the CCD and G is Goniotomy lens (Hoskins – Barkan). The L3 lens is kept 5cm separated from the back focal point of the tube lens. Though there is reduction in brightness, the axicon lens helps to further reduce the overall PSF and thus improve resolution. The developed system's lateral resolution is 3 microns.

Figure 1. Schematic of the optical configuration.

Figure 2. Illustration of the optical simulation using Zemax. (a) Ray trace (b) Illustration of the three points source shifted in height by 10 μm .

2.2 Optical simulation and PSF grid measurement

Figure 2a shows the optical ray trace of light from the iridocorneal angle via gonio lens into the camera. The ray trace was performed for system optimization. For the eye model Zemax simulation and the design parameters were chosen from the

studies reported by Herbert *et al*[22]. The optical simulation of Goniotomy lens is done using the design specifications of Hoskins-Barkan lens.

Figure 3. Illustration of PSF grid measurements. (Blue: $\lambda = 486$ nm; green: $\lambda = 588$ nm; red: $\lambda = 656$ nm).

Further with PSF grid measurements, we illustrate the position of the captured optical signals which fall on the detector changes with different point source height. Figure 2b illustrate the ray trace of three different point source separated by 10 μ m height each. When the point source is shifted 10 μ m away, there would be 92-147 μ m shift from the centered point source, 92 μ m for $\lambda = 486$ nm, 147 μ m for $\lambda = 588$ nm & 131 μ m for $\lambda = 656$ nm respectively. For the point source shifted by 20 μ m away, there would be 194-261 μ m shifted from the result of centered point source, 194 μ m for $\lambda = 486$ nm, 257 μ m for $\lambda = 588$ nm & 261 μ m for $\lambda = 656$ nm. This difference happens due to the impact of the geometry of the gonio lens.

2.3 Proof of concept

Figure 4. Illustration of optical setup using axicon lens.

As first experimental demonstration, we have imaged porcine eye using the newly developed probe (Figure 4). (Enucleated porcine eyes were obtained from abattoir). To provide lubrication and to reduce refractive index mismatch, a thin layer of ophthalmic gel (Vidisc Gel, Bausch & Lomb, NY, USA) was applied between the eye and gonio lens before the image capture. The details in the region of iridocorneal angle has been resolved and clearly visualized. However, we are further optimizing the imaging system to improve resolution. Better visibility of the iridocorneal angle region greatly improved the efficiency of the laser trabeculoplasty treatment for glaucoma. For this reason, in our future work we will be modifying

our system to perform both angle photography and laser trabeculoplasty. The conceptual optical configuration of laser trabeculoplasty is shown in Figure 5.

Figure 5. Conceptual diagram of our system modified with laser trabeculoplasty. (M is scanning mirror arm, B is a beam splitter).

3 CONCLUSION

In this paper, we have demonstrated an indirect gonioscopy based imaging probe with significantly improved visualization of structures in the ICA compared to the state of the art equipment's. The conceptual idea of modifying this system to perform laser trabeculoplasty is also illustrated. It is expected that this proposed concept and system pay way for better angle assessment and laser assisted treatment of glaucoma in the near future.

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REFERENCES

- [1] E. Betzig, G. H. Patterson, R. Sougrat *et al.*, "Imaging intracellular fluorescent proteins at nanometer resolution," *Science*, 313(5793), 1642-1645 (2006).
- [2] U. Dinish, Z. Chao, L. Seah *et al.*, "Formulation and implementation of a phase-resolved fluorescence technique for latent-fingerprint imaging: theoretical and experimental analysis," *Applied optics*, 44(3), 297-304 (2005).
- [3] P. M. Sandeep, S. W. B. Rajeev, M. Sheeba *et al.*, "Laser induced fluorescence based optical fiber probe for analyzing bacteria," *Laser Physics Letters*, 4(8), 611-615 (2007).
- [4] M. E. Gosnell, A. G. Anwer, S. B. Mahbub *et al.*, "Quantitative non-invasive cell characterisation and discrimination based on multispectral autofluorescence features," *Scientific Reports*, 6, 23453 (2016).
- [5] N. Sujatha, V. Murukeshan, L. Ong *et al.*, "An all fiber optic system modeling for the gastrointestinal endoscopy: design concepts and fluorescent analysis," *Optics communications*, 219(1), 71-79 (2003).

- [6] S. M. Perinchery, A. Shinde, and M. V. Matham, "Imaging behind opaque obstacle: a potential method for guided in vitro needle placement," *Biomedical Optics Express*, 7(12), 5308-5324 (2016).
- [7] V. K. Shinoj, V. M. Murukeshan, S. B. Tor *et al.*, "Design, fabrication, and characterization of thermoplastic microlenses for fiber-optic probe imaging," *Applied Optics*, 53(6), 1083-1088 (2014).
- [8] S. M. Perinchery, U. Kuzhiumparambil, S. Vemulpad *et al.*, "The potential of autofluorescence spectroscopy to detect human urinary tract infection," *Talanta*, 82(3), 912-7 (2010).
- [9] S. M. Perinchery, U. Kuzhiumparambil, S. Vemulpad *et al.*, "The influence of indoxyl sulfate and ammonium on the autofluorescence of human urine," *Talanta*, 80(3), 1269-76 (2010).
- [10] S. M. Perinchery, A. Shinde, C. Y. Fu *et al.*, "High resolution iridocorneal angle imaging system by axicon lens assisted gonioscopy," *Scientific Reports*, 6, (2016).
- [11] M. Valiyambath Krishnan, M. Vadakke Matham, S. Krishnan *et al.*, "Red, green, and blue gray-value shift-based approach to whole-field imaging for tissue diagnostics," *J Biomed Opt*, 17(7), 076010 (2012).
- [12] V. K. Shinoj, V. M. Murukeshan, M. Baskaran *et al.*, "Integrated flexible handheld probe for imaging and evaluation of iridocorneal angle," *Journal of Biomedical Optics*, 20(1), 016014-016014 (2015).
- [13] S. Tan, M. Yu, N. Baig *et al.*, "Agreement of patient-measured intraocular pressure using rebound tonometry with Goldmann applanation tonometry (GAT) in glaucoma patients," *Scientific Reports*, 7, 42067 (2017).
- [14] E. L. T. Tay, V. K. Y. Yong, B. A. Lim *et al.*, "Agreement of angle closure assessments between gonioscopy, anterior segment optical coherence tomography and spectral domain optical coherence tomography," *International Journal of Ophthalmology*, 8(2), 342-346 (2015).
- [15] I. H. Yusuf, J. F. Salmon, and C. K. Patel, "Direct ophthalmoscopy should be taught to undergraduate medical students," *Eye*, 29(8), 987-989 (2015).
- [16] S. W. Radford, R. Lim, and J. F. Salmon, "Comparison of Orbscan and Ultrasound pachymetry in the measurement of central corneal thickness," *Eye*, 18(4), 434-436 (0000).
- [17] M. Baskaran, S. A. Perera, M. E. Nongpiur *et al.*, "Angle assessment by EyeCam, goniphotography, and gonioscopy," *Journal of glaucoma*, 21(7), 493-7 (2012).
- [18] R. P. McNabb, P. Challa, A. N. Kuo *et al.*, "Complete 360° circumferential gonioscopic optical coherence tomography imaging of the iridocorneal angle," *Biomedical optics express*, 6(4), 1376-1391 (2015).
- [19] S. D. Smith, K. Singh, S. C. Lin *et al.*, "Evaluation of the anterior chamber angle in glaucoma: a report by the american academy of ophthalmology," *Ophthalmology*, 120(10), 1985-97 (2013).
- [20] H. Ishikawa, and J. S. Schuman, "Anterior segment imaging: ultrasound biomicroscopy," *Ophthalmology Clinics of North America*, 17(1), 7 (2004).
- [21] D. S. Friedman, and M. He, "Anterior chamber angle assessment techniques," *Surv Ophthalmol*, 53(3), 250-73 (2008).
- [22] H. Gross, F. Blechinger, and B. Ahtner, [Handbook of optical systems. Volume 4] Wiley-VCH, Weinheim(2008).