Review: Anterior Segment Optical Coherence Tomography

Laksono Bagus Sasmito[1], Gusbakti Rusip[1], Gede Pardianto[1]*

[1]Faculty of Medicine, Dentistry and Health Science, Universitas Prima Indonesia, indonesia

**email : gusbaktirusip@unprimdn.ac.id*

ABSTRACT

The cornea is a clear and transparent layer that covers the front surface of the eye, playing an important role in protecting the eye and allowing light to enter the eye for sight. As the layer that first receives light, the cornea also functions to refract the light so that it reaches the retina with the right focus, which is then translated by the brain into clear vision. Therefore, the health and integrity of the structures of the cornea are very important for the quality of a person's visual functions.

Keywords: Cornea, OCT, AS-OCT, Phacoemulsification, Corneal Edema

INTRODUCTION

Since the beginning of its development, when this technology was principally applied to study the posterior segment of the eye and especially the macula, optical coherence tomography (OCT) has become an important tool in ophthalmological practice.[1,2] Today, its application, aided by innovations in the application, has enabled the study of the cornea, lens, and, in general, the anterior segment, including the ocular surface and glaucoma, and is now an important element in the diagnosis and guidance of treatment of anterior segment diseases. To date, we have few tools for the anterior segment of the eye beyond slit-lamp biomicroscopy, gonioscopy, and anterior segment photography.[3-5] Confocal microscopy was one such innovation, but it never caught on in wider general clinical applications, despite its scientific merit, because of the small area that can provide information (basically the central cornea), its relative complexity, the need for a skilled observer, the often difficult interpretation, and the need for cooperative patients. In contrast, anterior segment OCT (AS-OCT) has overcome these shortcomings, and any non-expert ophthalmologist or technician can use it easily with basic training.[2,6] In addition, AS-OCT requires minimal cooperation from the patient; fast, non-invasive, and convenient for common applications in often busy anterior segment clinics.[6]

METHODS AND SAMPLES

Data and sample references for this review article processing were collected from recent credible published journals. Every journal is studied thoroughly with a synthesized evidence-based method that maps existing literature on broad topics to identify key concepts.

AS-OCT examination for any corneal disorders

AS-OCT is an ethically safe, non-contact, and non-invasive living histological imaging technique that utilizes infrared light to produce high-resolution images of the anterior segment of the eye, including the cornea, iris, chamber angle, and lens. AS-OCT provides a meticulous observation and examination of those disorders. Early detection and monitoring of the development of these corneal abnormalities is very important to determine the appropriate treatment strategy.[2,6] With the ability of AS-OCT to produce high-resolution imaging, this technology has become an important tool in the diagnosis and monitoring of corneal abnormalities.[6,7] Various disorders or diseases that affect the cornea can have a significant impact on vision. Some of them are:

Keratoconus

This condition occurs when the cornea gradually thins and changes shape to become more cone-like, resulting in vision distortion (**Figure 1**). Keratoconus often develops in adolescence or young adulthood and can cause blurred or ghostly vision, which is difficult to correct with glasses.[8]

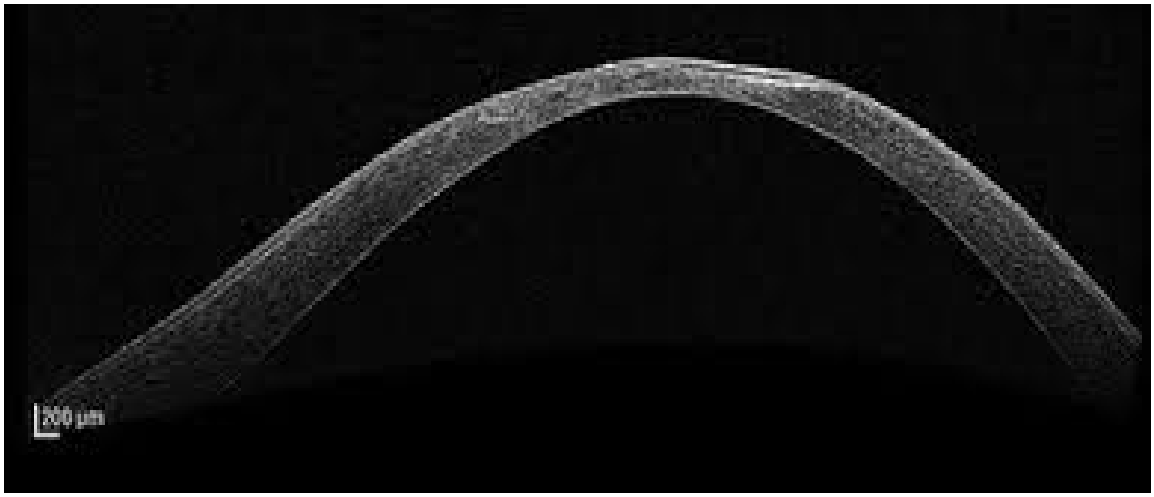

Figure 1. Corneal cone-like appearance in keratoconus as shown on AS-OCT examination.[8]

Corneal Dystrophia

This is a group of genetic disorders in which proteins in the cornea are not arranged normally, causing the formation of abnormal deposits or structural changes (**Figure 2**). Corneal dystrophy can affect one or more layers of the cornea, causing cloudiness, visual disturbances, or even pain.[9]

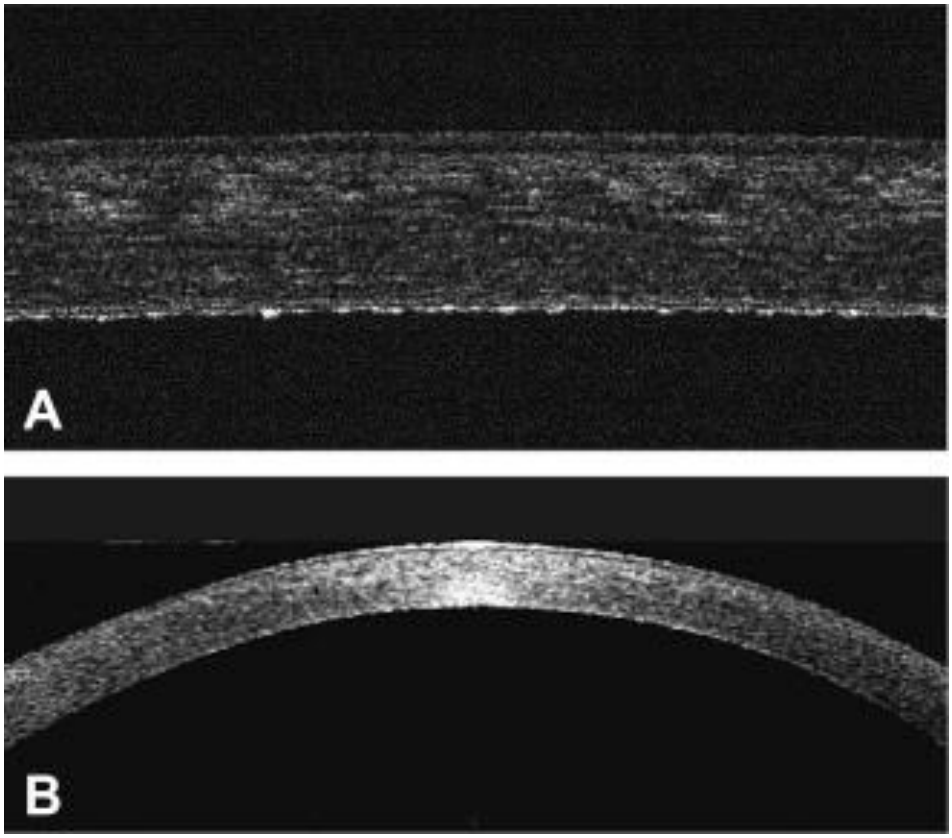

Figure 2. AS-OCT histopathological findings on corneal dystrophy. A. Closer tomogram. B. Curvature tomogram.[9]

Corneal Edema

Corneal edema or swelling is usually caused by excessive fluid buildup in the cornea (**Figure 3**). This condition can occur due to trauma, infection, or health problems such as glaucoma. Corneal edema causes blurred vision as the cornea loses its natural transparency.[10,11]

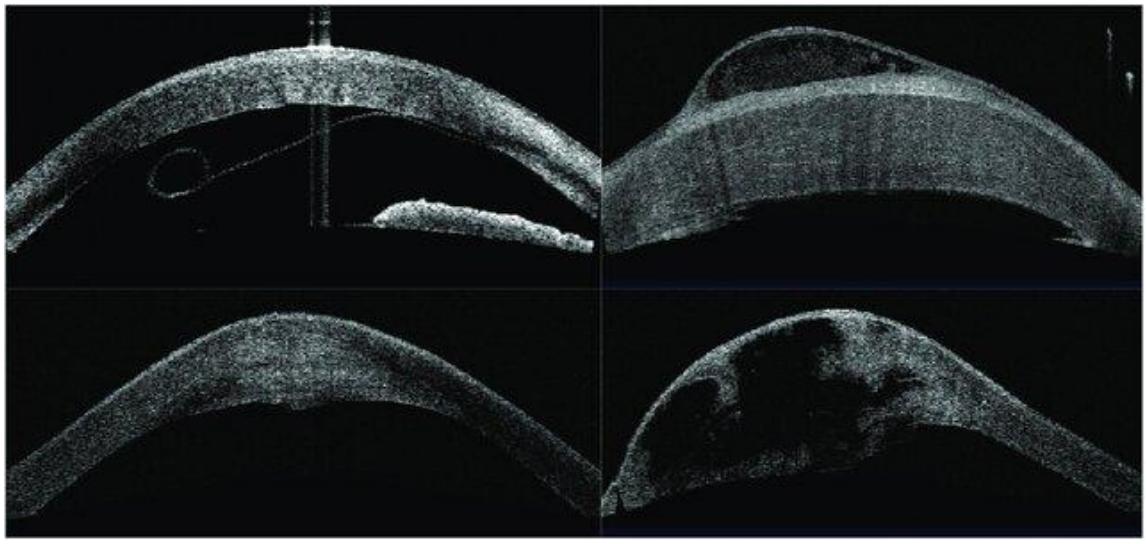

Figure 3. Corneal edema was assessed by AS-OCT. Corneal edema with Descemet membrane detachment (top left). Intra-epithelial collection of fluid in bullous keratopathy (severe corneal edema) with secondary bacterial infection (top right). Intra-stromal lesion in infective keratitis (bottom left). Hydrops in keratoconus demonstrate a break in the Descemet membrane (bottom right).[10]

In the age of phacoemulsification, AS-OCT provides an even bigger role to assist phaco surgeons in assessing the cornea and anterior segment structures.[11-13] AS-OCT allows the surgeons to ensure a better result of surgery and better visual functions for their patients.[2,6,7,11-14]

Principle of operation of the AS-OCT

AS-OCT works on the principle of low-coherence interferometry. This device emits low-coherence light (usually infrared) that is reflected from the eye tissue; ie: the cornea. This reflected light is processed to produce two or three-dimensional images that provide detailed information about the thickness, shape, and structure of the tissue layers in the cornea and anterior segment of the eye. This process is similar to how ultrasound works, but AS-OCT uses light instead of sound waves, which provides a higher definition of image resolution.[15,16]

Main Components of AS-OCT

Infrared Light Source

The infrared light source in AS-OCT produces low-coherence light rays with infrared wavelengths that are safe for the eyes. This light is used to penetrate eye tissue and provide

high-resolution imaging of anterior segment structures, such as the cornea, anterior chamber, and iridocorneal angle. Infrared wavelengths typically range from 800 to 1310 nm, depending on the type of AS-OCT, allowing penetration deep enough for visualization of tissue details.

Interferometer

The interferometer is the core component that measures the time and intensity of light reflection from various layers of eye tissue. It uses the principle of light interference, where the light reflected from the tissue is compared with a reference light. The results of this interference are used to form a cross-sectional image of the anterior segment. The interferometer ensures that the information collected is accurate and allows for precise data processing.

Light Detector

The light detector receives the interference signal generated by the interferometer and converts it into digital data. These detectors are usually CCD (Charge-Coupled Device) detectors or photodiode-based detectors that are highly sensitive to infrared light, ensuring that the reflected light data is converted with high accuracy.

Data Processing System

Data processing computer systems are responsible for processing signals from light detectors into images that can be analyzed by doctors. The software processes interference data into two- or three-dimensional images, enabling visualization of the eye's tissue layers in extraordinary detail. The computer can also provide additional features such as pachymetry analysis, corneal thickness mapping, and chamber angle measurement.

Display Screen

The display screen allows the ophthalmologist to see the image results in real time. The resulting image can be adjusted and analyzed, such as zooming in on certain areas for a more detailed examination. This screen also provides an interface for setting scanning parameters and saving imaging results.

Optical Adjustment System

The optical adjustment system ensures that the emitted light rays are focused precisely on the target area of the eye. The system can be adjusted to accommodate variations in the patient's eye anatomy, such as different corneal curvatures, to ensure optimal image quality.

Control Unit

The controller unit manages the overall operation of the AS-OCT device, including controlling the light source, interferometer, and data processing. This allows the operator to adjust settings as needed, such as scanning speed, image resolution, and target area to be scanned.

These components work synergistically to provide accurate and reliable imaging results, which are essential in the diagnosis and treatment of various diseases of the anterior segment of the eye, especially those related to the cornea.[2,6,7,15-16]

Advantages of AS-OCT

AS-OCT plays a significant role in the diagnosis and management of corneal diseases.[17] Following are some of the main advantages of AS-OCT are:

1. High-Resolution Imaging: AS-OCT provides a high-resolution living histological image of the anterior segment of the eye, allowing detailed visualization of corneal structures, including the epithelium, stroma, and endothelium. This facilitates early detection and monitoring of various corneal abnormalities.
2. Non-invasive and ethically safe: As a non-contact device, AS-OCT reduces the risk of infection and increases patient comfort during the examination.
3. Quantitative evaluation: AS-OCT allows quantitative measurement of corneal thickness and other structures, which is important in the diagnosis of conditions objectively such as keratoconus and corneal edema.
4. Postoperative monitoring: AS-OCT is effective in monitoring the healing process after corneal surgery, such as transplantation or refractive procedures, by detecting complications such as edema or graft rejection.
5. Accurate surgical planning: AS-OCT provides detailed information that helps in planning the next surgical procedures, ensuring better results and reducing the potential risk of complications.

6. Detection and management of corneal infections: AS-OCT can be used to assess the depth and extent of infiltration in corneal infections, assisting in determining appropriate treatment and intervention strategies.

Overall, AS-OCT is an invaluable diagnostic tool in eye surgery offering numerous advantages that improve the quality of care for patients with corneal diseases.[15,16]

CONCLUSION

AS-OCT is a very important diagnostic tool for modern ophthalmology. This technology enables high-resolution imaging of the corneal structure, supports early detection of disorders, assists in the planning and evaluation of cataracts and any refractive surgical procedures, and monitors the process of corneal tissue regeneration. With its non-invasive capabilities and superior detail, AS-OCT provides great benefits in cornea-related diagnosis, treatment, and clinical research, supporting more accurate and effective medical decision-making. [2,6,7,15-17]

REFERENCES

Zeppieri M, Marsili S, Enaholo ES, Shuaibu AO, Uwagboe N, Salati C, Spadea L, Musa M. Optical Coherence Tomography (OCT): A Brief Look at the Uses and Technological Evolution of Ophthalmology. Medicina (Kaunas). 2023 Dec 3;59(12):2114. doi: 10.3390/medicina59122114. PMID: 38138217; PMCID: PMC10744394.

Lim SH. Clinical applications of anterior segment optical coherence tomography. J Ophthalmol. 2015;2015:605729. doi: 10.1155/2015/605729. Epub 2015 Mar 3. PMID: 25821589; PMCID: PMC4363581.

Martin R. Cornea and anterior eye assessment with slit lamp biomicroscopy, specular microscopy, confocal microscopy, and ultrasound biomicroscopy. Indian J Ophthalmol. 2018 Feb;66(2):195-201. doi: 10.4103/ijo.IJO_649_17. PMID: 29380757; PMCID: PMC5819094.

Desmond T, Tran V, Maharaj M, Carnt N, White A. Diagnostic accuracy of AS-OCT vs gonioscopy for detecting angle closure: a systematic review and meta-analysis. Graefes Arch Clin Exp Ophthalmol. 2022 Jan;260(1):1-23. doi: 10.1007/s00417-021-05271-4. Epub 2021 Jul 5. Erratum in: Graefes Arch Clin Exp Ophthalmol. 2022

Chiang JCB, Roy M, Kim J, Markoulli M, Krishnan AV. In-vivo corneal confocal microscopy: Imaging analysis, biological insights, and future directions. Commun Biol. 2023 Jun 19;6(1):652. doi: 10.1038/s42003-023-05005-8. PMID: 37336941; PMCID: PMC10279669.

Shan J, DeBoer C, Xu BY. Anterior Segment Optical Coherence Tomography: Applications for Clinical Care and Scientific Research. Asia Pac J Ophthalmol (Phila). 2019 MarchApril 01;8(2):146-157. doi: 10.22608/APO.201910. PMID: 31020820; PMCID: PMC7903991.

Gupta N, Varshney A, Ramappa M, Basu S, Romano V, Acharya M, Gaur A, Kapur N, Singh A, Shah G, Chaudhary I, Patel N, Tiwari A, Kate A, Sangwan V, Mathur U. Role of AS-OCT in Managing Corneal Disorders. Diagnostics (Basel). 2022 Apr 7;12(4):918. doi: 10.3390/diagnostics12040918. PMID: 35453966; PMCID: PMC9030521.

Shaaban YM, Badran TA. Compensatory Corneal Epithelial Changes After Femtolaser-Assisted Intracorneal Rings Implantation in Early and Moderate Cases of Keratoconus. Clin Ophthalmol. 2023 Nov 22;17:3591-3599. Doi: 10.2147/OPTH.S432446. PMID: 38026597; PMCID: PMC10676668.

Siebelmann S, Scholz P, Sonnenschein S, Bachmann B, Matthaei M, Cursiefen C, Heindl LM. Anterior segment optical coherence tomography for the diagnosis of corneal dystrophies according to the IC3D classification. Surv Ophthalmol. 2018 May-Jun;63(3):365-380. doi: 10.1016/j.survophthal.2017.08.001. Epub 2017 Aug 9. PMID: 28801092.

Ang M, Baskaran M, Werkmeister RM, Chua J, Schmidl D, Aranha Dos Santos V, Garhöfer G, Mehta JS, Schmetterer L. Anterior segment optical coherence tomography. Prog Retin Eye Res. 2018 Sep;66:132-156. doi: 10.1016/j.preteyeres.2018.04.002. Epub 2018 Apr 7. PMID: 29635068.

Dhami A, Dhami AS, Singh H, Dhami GS. Role of anterior segment optical coherence tomography for safer management of mature white cataracts. J Cataract Refract Surg. 2019 Apr;45(4):480-484. doi: 10.1016/j.jcrs.2018.11.009. Epub 2019 Feb 4. PMID: 30733105.

Gupta N, Varshney A, Ramappa M, Basu S, Romano V, Acharya M, Gaur A, Kapur N, Singh A, Shah G, Chaudhary I, Patel N, Tiwari A, Kate A, Sangwan V, Mathur U. Role of AS-OCT in Managing Corneal Disorders. Diagnostics (Basel). 2022 Apr

7;12(4):918. doi: 10.3390/diagnostics12040918. PMID: 35453966; PMCID: PMC9030521.

Kucumen RB, Yenerel NM, Gorgun E, Kulacoglu DN, Dinc UA, Alimgil ML. Anterior segment optical coherence tomography measurement of anterior chamber depth and angle changes after phacoemulsification and intraocular lens implantation. J Cataract Refract Surg. 2008 Oct;34(10):1694-8. doi: 10.1016/j.jcrs.2008.05.049. PMID: 18812120.

Li H, Jhanji V, Dorairaj S, Liu A, Lam DS, Leung CK. Anterior Segment Optical Coherence Tomography and its Clinical Applications in Glaucoma. J Curr Glaucoma Pract. 2012 May-Aug;6(2):68-74. Doi: 10.5005/jp-journals-10008-1109. Epub 2012 Aug 16. PMID: 28028349; PMCID: PMC5161770.

Han SB, Liu YC, Noriega KM, Mehta JS. Applications of Anterior Segment Optical Coherence Tomography in Cornea and Ocular Surface Diseases. J Ophthalmol. 2016;2016:4971572. doi: 10.1155/2016/4971572. Epub 2016 Sep 19. PMID: 27721988; PMCID: PMC5046038.

Garcia Marin YF, Alonso-Caneiro D, Vincent SJ, Collins MJ. Anterior segment optical coherence tomography (AS-OCT) image analysis methods and applications: A systematic review. Comput Biol Med. 2022 Jul;146:105471. Doi: 10.1016/j.compbiomed.2022.105471. Epub 2022 Apr 6. PMID: 35533455.

Abdelghany AA, D'Oria F, Alio Del Barrio J, Alio JL. The Value of Anterior Segment Optical Coherence Tomography in Different Types of Corneal Infections: An Update. J Clin Med. 2021 Jun 27;10(13):2841. doi: 10.3390/jcm10132841. PMID: 34199039; PMCID: PMC8267702.