Short communication

Anterior-segment optical coherence tomography for the detection and therapeutic monitoring of corneal disorders

Alejandro Rodriguez-Garcia [1], Andres Bustamante-Arias [1] and Julio C. Hernandez-Camarena [1]

[1] *Tecnologico de Monterrey, School of Medicine and Health Sciences, Institute of Ophthalmology and Visual Sciences. Monterrey, Mexico.*

ABSTRACT

Background: Recent reports have analyzed the microstructural changes of various ocular surface and corneal disorders, particularly ocular surface squamous neoplasia (OSSN) and keratoconus using anterior-segment optical coherence tomography (AS-OCT). This short communication aimed to elaborate on clinical applications of AS-OCT for the detection and therapeutic monitoring of corneal disorders.

Methods: We performed an English literature search without a time limit and intending to identify articles related to the AS-OCT applications in the detection and therapeutic monitoring of corneal disorders. The most relevant articles were selected. practical points of selected papers and advantages and disadvantages of AS-OCT were retrieved and summarized.

Results: Many records reported the AS-OCT applications for diagnosing many ocular surface disorders, microstructural changes of different inflammatory, infectious, degenerative, and dystrophic corneal disorders. Its applications in identifying disease activity and therapeutic monitoring of various corneal pathologies, including stromal edema associated with angle-closure glaucoma, Fuchs' endothelial dystrophy, infectious keratitis, and bullous keratopathy, are promising.

Conclusions: There is a clear prospect for expanding the application of corneal OCT imaging technology, a rapid, non-invasive, and now a promising lower-cost device, which is becoming an in-office standard-of-care tool for the assessment of different corneal and ocular surface pathologies.

KEY WORDS

anterior-segment optical coherence tomography, AS-OCT, ocular surface disorders, corneal disorders, ocular surface squamous neoplasia, OSSN, keratoconus, diagnosis, therapeutic, monitoring

INTRODUCTION

In recent years there has been a revolutionary avenue for imaging technologies to diagnose and monitor the treatment of a varied group of ophthalmic pathologies, particularly posterior segment degenerative and inflammatory disorders like age-related macular degeneration, glaucoma, and macular edema [1]. Recent reports have analyzed the microstructural changes in various ocular surface and corneal disorders, par-ticularly ocular surface squamous neoplasia (OSSN) and keratoconus using anterior-segment optical

Correspondence: Alejandro Rodriguez-Garcia, Hospital Zambrano Hellion, Av. Batallon de San Patricio No, 112. Col. Real de San Agustin. San Pedro Garza Garcia, Nuevo Leon, 66278, Mexico. E-mail: immuneye@gmail.com ORCID iD: https://orcid.org/0000-0002-1419-2109

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coherence tomogra-phy (AS-OCT) [2, 3]. Contrary to the traditional point of view proclaimed by certain corneal specialists that corneal pa-thology can be entirely assessed by direct slit-lamp visualization, arguing that imaging technology, such as AS-OCT, is unnecessary and costly in most cases [4], recent investigators are demonstrating that AS-OCT can be used to examine many ocular surface disorders [5]. In the last couple of years, AS-OCT imaging technology has been the subject of analysis of microstructural changes in different inflammatory, infectious, degenerative, and dystrophic corneal disorders [5-8].

METHODS

We performed an English literature search without a time limit, and identified articles related to the AS-OCT applications in the detection and therapeutic monitoring of corneal disorders. The practical points of selected papers and advantages and disadvantages of AS-OCT were summarized.

RESULTS

Many recent publications have demonstrated the tendency to develop machine learning algorithms that are efficient enough to help the clinician diagnose and detect disease activity and therapeutic monitoring of various corneal pathologies, including stromal edema associated with angle-closure glaucoma, Fuchs endothelial dystrophy, infectious keratitis, and bullous keratopathy [9, 10]. The percentage of diagnostic sensitivity, specificity, and accuracy of artificial intelligence methodologies applied to AS-OCT imaging analysis today has reached 94–100%, depending on the study [9-13]. However, corneal AS-OCT in its current stage is not exempt from limited capabilities. Table 1 shows the advantages and disadvantages of AS-OCT technology for clinical applications. To overcome the conventional spectral-domain AS-OCT, the recent development of the ultra-high resolution-optical coherence tomography (UHR-OCT), capable of taking over 50,000 A-scans per second at an axial resolution of 2–4 μm with scan widths of 5–12 mm, will soon revolutionize the corneal imaging technology to an unimaginable level of clinical applications. This device can provide fine imaging of the tear film and individual corneal layers, distinguish the endothelium from the descemet's membrane, and visualize corneal nerves and epithelial stem cells within the limbal epithelial crypts [14].

Therefore, the established concept that corneal AS-OCT adds no benefit experienced clinician in assessing most corneal disorders seems to be changing. There are particular instances where the aid of in-depth and en-face detailed tomographic images of the cornea are most helpful for diagnosing subtle recurrent epithelial and stromal edema in patients with active herpetic stromal keratitis with significant scarring that hinder its direct slit-lamp visualization. Moreover, AS-OCT is very useful for analyzing scar extension and leukoma depth for surgical planning of partial or total corneal transplantation [6, 17, 18].

CONCLUSIONS

The arrival of a commercially available UHR-OCT will permit a detailed visualization of the invasiveness of OSSN lesions, corneal nerves in neurotrophic keratopathy, acanthamoeba keratitis cysts, intracorneal foreign bodies, and corneal scarring extent after chemical burn or herpetic keratitis [14-16, 19]. Additionally, it will help us measure the corneal epithelium and Bowman´s layer vertical thickness accurately for timely detection of subclinical keratoconus [18], preoperative screening in laser refractive surgery [20], and measuring the thickness of the corneal endothelium-Descemet's membrane complex to evaluate the severity of endothelial cell loss after cataract surgery [21]. Finally, UHR-OCT replaces the clinician's direct slit-lamp visualization of the keratoprosthesis-cornea interface in the assessment of potential sight-threatening complications [22]. The corneal OCT imaging technology, a rapid, non-invasive, and now a promising lower-cost device [23], is becoming an in-office standard-of-care tool for the assessment of different corneal and ocular surface pathologies.

Table 1. Advantages and disadvantages of AS-OCT imaging technology for clinical applications

Advantages	Disadvantages
***In-vivo* analysis** [1-4]	Limited availability [14]
Non-invasive procedure [1, 4, 15]	Reduced brand diversity [4, 5]
Rapid image acquisition [4, 5]	Limited image resolution [2, 16]
Reproducible results [5, 6]	Image distortion related to tissue refractive index [6]
Comparable results [6]	Need for high-trained personal [5]
Safe procedure [1, 5]	High sensitivity to movement [17]

ETHICAL DECLARATIONS

Ethical approval: Refer to the type of this study no ethical approval was required.
Conflict of interest: None.

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REFERENCES

1. Sakata LM, Deleon-Ortega J, Sakata V, Girkin CA. Optical coherence tomography of the retina and optic nerve - a review. Clin Exp Ophthalmol. 2009;37(1):90-9. doi: 10.1111/j.1442-9071.2009.02015.x pmid: 19338607
2. Atallah M, Joag M, Galor A, Amescua G, Nanji A, Wang J, et al. Role of high resolution optical coherence tomography in diagnosing ocular surface squamous neoplasia with coexisting ocular surface diseases. Ocul Surf. 2017;15(4):688-95. doi: 10.1016/j.jtos.2017.03.003 pmid: 28347855
3. Ouanezar S, Sandali O, Atia R, Temstet C, Georgeon C, Laroche L, et al. Contribution of Fourier-domain optical coherence tomography to the diagnosis of keratoconus progression. J Cataract Refract Surg. 2019;45(2):159-66. doi: 10.1016/j.jcrs.2018.09.024 pmid: 30367937
4. Shih KC, Tse RH, Lau YT, Chan TC. Advances in Corneal Imaging: Current Applications and Beyond. Asia Pac J Ophthalmol (Phila). 2019 Apr 1. doi: 10.22608/APO.2018537 pmid: 30931551
5. Venkateswaran N, Galor A, Wang J, Karp CL. Optical coherence tomography for ocular surface and corneal diseases: a review. Eye Vis (Lond). 2018 Jun 12;5:13. doi: 10.1186/s40662-018-0107-0 pmid: 29942817
6. Rodriguez-Garcia A, Alfaro-Rangel R, Bustamante-Arias A, Hernandez-Camarena JC. In Vivo Corneal Microstructural Changes in Herpetic Stromal Keratitis: A Spectral Domain Optical Coherence Tomography Analysis. J Ophthalmic Vis Res. 2020;15(3):279-88. doi: 10.18502/jovr.v15i3.7446 pmid: 32864058
7. Diez-Feijoo E, Duran JA. Optical coherence tomography findings in recurrent corneal erosion syndrome. Cornea. 2015;34(3):290-5. doi: 10.1097/ICO.0000000000000334 pmid: 25532997
8. Vajzovic LM, Karp CL, Haft P, Shousha MA, Dubovy SR, Hurmeric V, et al. Ultra high-resolution anterior segment optical coherence tomography in the evaluation of anterior corneal dystrophies and degenerations. Ophthalmology. 2011;118(7):1291-6. doi: 10.1016/j.ophtha.2010.12.015 pmid: 21420175
9. Zeboulon P, Ghazal W, Gatinel D. Corneal Edema Visualization With Optical Coherence Tomography Using Deep Learning: Proof of Concept. Cornea. 2020;Publish Ahead of Print. doi: 10.1097/ICO.0000000000002640 pmid: 33410639
10. Eleiwa T, Elsawy A, Ozcan E, Abou Shousha M. Automated diagnosis and staging of Fuchs' endothelial cell corneal dystrophy using deep learning. Eye Vis (Lond). 2020;7:44. doi: 10.1186/s40662-020-00209-z pmid: 32884962
11. Dos Santos VA, Schmetterer L, Stegmann H, Pfister M, Messner A, Schmidinger G, et al. CorneaNet: fast segmentation of cornea OCT scans of healthy and keratoconic eyes using deep learning. Biomed Opt Express. 2019;10(2):622-41. doi: 10.1364/BOE.10.000622 pmid: 30800504
12. Kamiya K, Ayatsuka Y, Kato Y, Fujimura F, Takahashi M, Shoji N, et al. Keratoconus detection using deep learning of colour-coded maps with anterior segment optical coherence tomography: a diagnostic accuracy study. BMJ Open. 2019;9(9):e031313. doi: 10.1136/bmjopen-2019-031313 pmid: 31562158
13. Treder M, Lauermann JL, Alnawaiseh M, Eter N. Using Deep Learning in Automated Detection of Graft Detachment in Descemet Membrane Endothelial Keratoplasty: A Pilot Study. Cornea. 2019;38(2):157-61. doi: 10.1097/ICO.0000000000001776 pmid: 30325845
14. Werkmeister RM, Sapeta S, Schmidl D, Garhofer G, Schmidinger G, Aranha Dos Santos V, et al. Ultrahigh-resolution OCT imaging of the human cornea. Biomed Opt Express. 2017;8(2):1221-39. doi: 10.1364/BOE.8.001221 pmid: 28271013
15. Al-Ghadeer HA, Al-Assiri A. Identification and localization of multiple intrastromal foreign bodies with anterior segment optical coherence tomography and ocular Pentacam. Int Ophthalmol. 2014;34(2):355-8. doi: 10.1007/s10792-013-9800-0 pmid: 23740143
16. Thomas BJ, Galor A, Nanji AA, El Sayyad F, Wang J, Dubovy SR, et al. Ultra high-resolution anterior segment optical coherence tomography in the diagnosis and management of ocular surface squamous neoplasia. Ocul Surf. 2014;12(1):46-58. doi: 10.1016/j.jtos.2013.11.001 pmid: 24439046
17. Ang M, Baskaran M, Werkmeister RM, Chua J, Schmidl D, Aranha Dos Santos V, et al. Anterior segment optical coherence tomography. Prog Retin Eye Res. 2018;66:132-56. doi: 10.1016/j.preteyeres.2018.04.002 pmid: 29635068
18. Xu Z, Jiang J, Yang C, Huang S, Peng M, Li W, et al. Value of corneal epithelial and Bowman's layer vertical thickness profiles generated by UHR-OCT for sub-clinical keratoconus diagnosis. Sci Rep. 2016;6:31550. doi: 10.1038/srep31550 pmid: 27511620
19. Chen-Espinoza V, Nakamura T, Li Y, Trousdale M, Irvine JA, Huang D. High-resolution optical coherence tomography of Acanthamoeba keratitis. Invest Ophthalmol Vis Sci. 2008;49(13):2818. Link
20. Chan TCY, Wang YM, Yu M, Jhanji V. Comparison of Corneal Tomography and a New Combined Tomographic Biomechanical Index in Subclinical Keratoconus. J Refract Surg. 2018;34(9):616-21. doi: 10.3928/1081597X-20180705-02 pmid: 30199566
21. Tao A, Chen Z, Shao Y, Wang J, Zhao Y, Lu P, et al. Phacoemulsification induced transient swelling of corneal Descemet's Endothelium Complex imaged with ultra-high resolution optical coherence tomography. PLoS One. 2013;8(11):e80986. doi: 10.1371/journal.pone.0080986 pmid: 24312254
22. Zarei-Ghanavati S, Betancurt C, Mas AM, Wang J, Perez VL. Ultra high resolution optical coherence tomography in Boston type I keratoprosthesis. J Ophthalmic Vis Res. 2015;10(1):26-32. doi: 10.4103/2008-322X.156092 pmid: 26005549
23. Song G, Chu KK, Kim S, Crose M, Cox B, Jelly ET, et al. First Clinical Application of Low-Cost OCT. Transl Vis Sci Technol. 2019;8(3):61. doi: 10.1167/tvst.8.3.61 pmid: 31293815