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Importance of Integrating OCT (Anterior/Posterior) in Teleophthalmology Practice

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ABSTRACT:
Recent healthcare challenges & necessity to provide healthcare to growing population has necessitated the need to improvise telemedicine. Teleophthalmology has been a challenging area of Telemedicine. Newer imaging techniques are being employed in Teleophthalmology to enhance quality of care. Spectral Domain optical coherence tomography (SD-OCT), the gold standard for ocular imaging in conventional eye-clinics is being studied in conjunction with Teleophthalmology. Aim: Assess the advantages & disadvantages of integrating SD-OCT in Teleophthalmology. Method: Review of published papers on teleophthalmology that used SD-OCT regardless of their main aims. 9 such articles have been included. Conclusion: Teleophthalmology has the potential to fill the gap in healthcare access when integrated with SD-OCT. It promises to be a promising tool. However, further research is needed to ascertain its efficacy.

INTRODUCTION

The leading causes of blindness are cataract, diabetic retinopathy (DR), glaucoma, and age-related macular degeneration (AMD).[1] Several demographic variables such as race, ethnicity, socioeconomic status, and level of education may influence the prevalence of these common eye diseases, and the rate of eye examinations.[2] However, these remain as the leading causes of loss of vision all over the world. The traditional practice of diagnosing these vision-threatening ocular conditions entails a combination of attending patients in the clinic, using various in-office modalities (slit lamp biomicroscopy, applanation tonometry etc). as well as investigative modalities particularly ocular imaging.

The importance of ocular imaging in identifying ocular diseases has grown significantly in the last couple of decades. Amongst a number of methods, such as confocal scanning laser ophthalmoscopy and scanning laser polarimetry etc., optical coherence tomography (OCT) has emerged as the gold standard for ocular imaging. It is predominantly due to its high resolution, capacity to gather complex 3-dimensional (3D) data, and ability to provide a wide range of information about the structure of concern. Many continuing technical developments are improving the axial and transverse resolution of the images and cutting down on the amount of time needed for the image acquisition.[3]

Optical coherence tomography basically uses low-coherence interferometry to determine the magnitude and echo time delay of backscattered light after it reflects off an object of interest. This method can be used to scan across the layers of a structured tissue sample, such as retina, with incredibly high axial resolution (3 to 15 µm).[4] giving images of the three-dimensional structure. Because OCT has a unique optically clean path through the eye, it has been most commonly used to image disorders affecting the retina.[5]

Now, dearth of healthcare professionals & meagre doctor to patient ratio in different areas of the globe, especially the rural parts, have necessitated healthcare provider to innovate & come up with intuitive solutions to render health to different & even remotest parts of the world. Technology is being employed in a wide scale to upscale reach & quality of Ophthalmic care. One such modality is Telemedicine.

Telemedicine has been there from old times, however the recent healthcare challenges & the necessity to provide healthcare to ever growing population has necessitated the need to improvise & update telemedicine.

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Telemedicine is the application of telecommunications technology to help in delivery of healthcare services at a distance.[6] However, Teleophthalmology has been one of the major challenges of telemedicine.[7]

Telemedicine is now being routinely used to improve screening, diagnosis and monitor eye diseases in populations around the world. Moreover, teleophthalmology units have proven to be beneficial for screening in rural and urban populations even in developed countries. Despite the availability of newer & more efficient technology necessary for transmitting digital ocular images and remote interpretation, it can be safely concluded as of today that teleophthalmology is still in its infancy.[8] There have been several logistic challenges in the course of development of teleophthalmology. Hence, there has been effort to integrate various technological & imaging modalities to make teleophthalmology a tangible reality.

Newer futuristic & evolving technologies like Artificial intelligence, Augmented reality & Virtual reality might be able to completely change the canvas of today's Telemedicine / Teleophthalmology, in the days to come. However, in this article we will be restricting the discussion to imaging modality & teleophthalmology techniques which are in vogue today

There have been many studies which aim to integrate the use of the most promising ocular imaging modality of the last couple of decades: Spectral Domain OCT (SD-OCT) in enhancing quality of care rendered by Teleophthalmology in Diabetic Retinopathy, ARMD, Glaucoma, etc. Hence, the need to evaluate the findings of the wide spread studies conducted all over the globe to come to an understanding about efficacy of integration of Spectral domain OCT in improvement of Teleophthalmology care.

AIMS AND OBJECTIVES

This review article seeks to assess the benefit of integrating Spectral Domain OCT in Teleophthalmology as found in different studies in patients diagnosed with various ocular pathologies and come to a conclusion about this system of integration and ascertain future study goals of study in this issue that might be able to comprehensively conclude more on the same.

MATERIALS AND METHODS

Review of published papers on teleophthalmology projects that used SD-OCT as an imaging modality to screen, triage or diagnose ARMD, Glaucoma, Diabetic retinopathy etc. regardless of the main aims of those projects. Various bibliographic databases were comprehensively searched with keywords like: Telemedicine, Teleophthalmology, SD-OCT, OCT, 3D-OCT.

Various papers were analysed at depth & 9 papers that not only integrated Teleophthalmology with SD-OCT as imaging modality but also exhibited a considerable change or, commented on the importance of SD-OCT on the outcome of the study was include for detailed scrutiny & further analysis to draw a comprehensive conclusion for this review article & also figure out the hiatus in research & the way forward.

The details of those 9 publications are provided in Tables 1,2,3

TABLE – 1

Sl. No.	Name of Author	Name of Journal	Years	Number of Patients	Objectives	Author's Method
1	Rahul Kapoor[9]	Asia-Pacific Journal of Ophthalmology	2020	326	Assess the benefit and feasibility of the Teleophthalmology GlobeChek kiosk in a community-based program.	Participants underwent comprehensive evaluation: questionnaire form, brief systemic evaluation, screening visual field (VF), and GlobeChek kiosk screening, which included intraocular pressure, pachymetry, anterior segment optical

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						coherence tomography, posterior segment optical coherence tomography, and nonmydriatic fundus photography & more. The results were evaluated by a store-and-forward mechanism and follow-up questionnaires were obtained through phone calls.
2	April Y Maa[10]	American Academy of Ophthalmology	2019	256	Technology-based Eye Care Services (TECS), an Ophthalmologic telemedicine programs was implemented in the Veteran Affairs (VA) Healthcare System in 2015. This study was undertaken to test the impact of OCT on the accuracy of the TECS protocol.	Prospective comparison between the TECS protocol with OCT versus a Face-To-Face (FTF) exam on 256 patients with no prior significant ocular disease. Participants were with no known ocular disease who desired a routine eye exam. Patient received the TECS protocol work up, OCT nerve, OCT macula, and a FTF exam on the same day. Main Outcome Measures were Percent agreement, kappa values, sensitivity, and specificity were calculated for non-expert Readers post-OCT interpretation of the TECS protocol using the FTF exam as the clinical 'goldstandard'.
3	George E. Sanborn[11]	Journal of Diabetes and Its Complications	2018	105	Pilot study to determine whether an instrument combining a non-mydriatic retinal camera and spectral domain Optical coherence tomography (SD-OCT) is effective for screening patients with diabetic retinopathy (DR).	This was an observational case series. Case series conducted between 2012 & 2013. Diabetic Retinopathy imaged with a retinal camera/SD-OCT instrument viewed remotely and was compared to a dilated examination by a retina specialist.
4	Majda Hadziahmetovic[12]	JAMA Ophthalmology	2019	159	To test the feasibility and accuracy of the remote diagnosis imaging model as a clinical screening tool to facilitate the identification of referable macular degeneration	A nonrandomized study of 159 patients was conducted in sites with a relatively high disease prevalence. All patients underwent remote diagnosis imaging: colour fundus photography (CFP) and optical coherence tomography (OCT) of nondilated pupils, acquired by nonexpert imagers using a retinal imaging device located at the point of service. The criterion standard examination was a traditional dilated eye examination

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						performed by retinal specialists. Deidentified remote diagnosis images were graded for interpretability and presence of referable macular degeneration, defined as any condition requiring a retinal specialist attention.
5	Jing Xian Lee[13]	Clinical Ophthalmology	2018	610	Evaluate the use of a medical retina virtual clinic (MRVC), which has expanded into assessing all new medical retina referrals, where the need for urgent treatment was not clear.	Retrospective analysis of all new patients who were seen in the MRVC between April 2016 and May 2018. Pro forma sheets were used in the MRVC to record the patient history, visual acuity, and type of imaging required. Two consultants reviewed the completed pro-formas and images and provided a final diagnosis and management plan. These results and reasons for face-to-face (F2F) clinic appointment requests were analyzed.
6	Subhashini Chandrasekaran[14]	Journal of Telemedicine and Telecare	2019	108	Test a system for telemedicine for glaucoma that will allow a physician comprehensive access to a patient's data and images & to validate the tele-glaucoma programme by comparing results to a traditional clinical exam in a glaucoma clinic.	A prospective study of 107 subjects evaluated in clinic and then tele-glaucoma stations, which consisted of non-mydriatic fundus photography, puff-tonometry, auto-refraction and Optical Coherence Tomography (OCT). The OCT captured central corneal thickness, angle anatomy, cup-to-disc ratio (CDR), retinal nerve fibre layer distribution and posterior-pole ganglion cell complex data.
7	Simon P Kelly[15]	Clinical Ophthalmology	2011	50	To describe a quality improvement for referral of National Health Service patients with macular disorders from a community optometry setting in an urban area.	Service evaluation of teleophthalmology consultation based on spectral domain optical coherence tomography images acquired by the community optometrist and transmitted to hospital eye services.

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8	Tina Felfeli[16]	CanadianOphthalmologicalSociety	2018	775	To present results of the TorontoTele-Retinal screening program for patient s with diabetes mellitus and to evaluate the benefit of optical coherence omography (OCT) in combination with monoscopic colour fundus photographs for detection of Diabetic Macular edema.	All electronic medical records for adults with type I and II diabetes mellitus screened through the Toronto Tele-Retinal screening program between September 2013 to August 2017 across 7 screening sites in urban and rural settings were reviewed. Monoscopic colour fundus photographs were graded for presence or absence of Diabetic Retinopathy and Diabetic Macular Edema alone and in combination with OCT scans.
9	Alfonso Anton[17]	Journal of Clinical Medicine	2021	1006	To evaluate interobserver and intertest agreement between optical coherence tomography (OCT) and retinography in the detection of glaucoma through a telemedicine program.	A stratified sample of 4113 individuals was randomly selected, and those who accepted underwent examination including visual acuity, intraocular pressure (IOP), non-mydriatic retinography, and imaging using a portable OCT device. Participants' data and images were uploaded and assessed by 16 ophthalmologists on a deferred basis. Two independent evaluations were performed for all participants. Agreement between methods was assessed using the kappa coefficient and the prevalence-adjusted bias-adjusted kappa (PABAK). Potential factors possibly influencing the level of agreement was analysed.

TABLE – 2

Sl. No.	Name of Author	Result
1	Rahul Kapoor[9]	A total of 326 participants were screened over 4 months. 40.79% participants had 1 condition in either eye, and 14.41% had >1 disease. 21.47% had glaucoma, 11.34% narrow-angles, 1.84% diabetic retinopathy, 1.22% macular degeneration, and 13.10% had other eye disease findings. As for the ocular parameters, all but central corneal thickness, including an intraocular pressure >21 mm Hg, vertical cup to disc ratio >0.7, visual field abnormalities, and retinal nerve fibre layer thinning were found to be significant.

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2	April Y Maa[10]	OCT did not improve the diagnostic accuracy of the TECS protocol when compared to a FTF exam. In most cases, OCT had no impact, and in the case of Reader 2, OCT actually reduced the kappa value from moderate agreement to agreement equal to chance, while lowering the percent agreement by 10%. OCT also did not impact inter or intra-reader variability parameters.
3	George E. Sanborn[11]	The combination instrument was better than the retina specialist in detecting more severe retinopathy, primarily because of the SD-OCT. For severe retinopathy (grade ≥ 3), the image grader had better sensitivity than the retina examiner. Specificities were similar between the instrument grader and retina examiner. When identifying diabetic macular oedema (ME), the retina examiner only identified 47.6% of eyes with ME detected by SD-OCT. The instrument was better than a dilated retinal examination in detecting ME and not as good at detecting mild or proliferative retinopathy.
4	Majda Hadziahmetovic[12]	159 patients included in the study. 22.0% required referral to the retinal specialist by criterion standard examination. Remote diagnosis image interpretability was better when OCT was used compared with Coloured Fundus Photography CFP: 96.4% vs 65.6%. Remote diagnosis had high diagnostic accuracy in identifying referable macular degeneration: OCT and CFP both had 94% sensitivity and OCT had specificity higher than for CFP 93% vs 63%. Substantial agreement was found between the criterion standard and OCT and between the criterion standard and CFP. The non-validated patient satisfaction survey revealed that 76.7% preferred remote imaging over the standard care examination.
5	Jing Xian Lee[13]	610 new referrals were enrolled in the virtual clinic. The most common diagnosis was diabetic eye disease (59.9%). In the virtual clinic 44.1% were followed up, 28.1% were discharged, and 27.8% were booked an F2F clinic appointment (urgent/routine). The main reason for F2F clinic was to offer treatment. Urgent F2F appointments took place on average 11.9 days after virtual clinic attendance. In only two cases was the image quality felt to be inadequate to assess the retina.
6	Subhashini Chandrasekaran[14]	Intraocular pressure (IOP) comparisons between clinical and tele-glaucoma exams had strong positive Pearson correlation coefficients. Strong positive correlations were seen for Cup DISC RATIO CDR as well as diagnosis (glaucoma, no glaucoma or glaucoma suspect). A moderate positive correlation was seen for return to clinic time (RTC). Tele-glaucoma had an average lower RTC. Tele-glaucoma was more likely

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7	Simon P Kelly[15]	Fifty patients with suspected macular conditions were managed via telemedicine consultation over 1 year. Responses were provided by hospital eye service-based ophthalmologists to the community optometrist or patient within the next day in 96% and in 68% of patients on the same day. In the consensus opinion 66% patients required further "face-to-face" medical examination and were triaged urgently. 34% were managed in the community and are a potential cost improvement.
8	Tina Felfeli[16]	A total of 775 patient screens, consisting of 566 first-time screens and 209 re-screens were completed over the 48-month study period. Approximately 37% of all patients with a mean disease duration of 7 years had never had an eye examination. Across the sample, 27% of patients had DR, with majority graded to have mild DR, whereas DME was detected in 5% of patients in at least 1 eye. Of all DME detected in the Toronto Tele-Retinal screening program, 38% required the use of adjunct OCT. Other pathologies, including age-related macular degeneration 19% and glaucomatous or optic nerve findings 8%, were also identified.
9	Alfonso Anton[17]	The final sample comprised 1006 participants. Of all suspected glaucoma cases (n = 201), 20.4% were identified in retinographs only, 11.9% in OCT images only, 46.3% in both, and 21.4% were diagnosed based on other data. Overall interobserver agreement outcomes were moderate to good. Higher values were obtained by experienced evaluators. Kappa and PABAK values between OCT and photographs were 0.52 and 0.82 for the first evaluation.

TABLE – 3

Sl. No.	Name of Author	Conclusion
1	Rahul Kapoor[9]	GlobeChek kiosk is both workable and effective in increasing access to care and identifying the most common causes of blindness and their risk factors.
2	April Y Maa[10]	OCT did not appear to improve accuracy of glaucoma or retinal disease detection when added to the standard TECS protocol. In one case, OCT worsened the agreement of the non-expert reader compared to the FTF examiner.
3	George E. Sanborn[11]	The instrument was more effective in identifying Diabetic Retinopathy DR than was dilated and comprehensive eye examination. SD-OCT is needed to accurately identify DR in a screening.
4	Majda Hadziahmetovic[12]	Remote diagnosis imaging and a standard examination by a retinal specialist appeared equivalent in identifying referable macular degeneration in patients with high disease prevalence.
5	Jing Xian Lee[13]	MRVC is an effective way of triaging medical retina referrals to allow those patients needing treatment to be seen promptly in the medical retinal service. The use of multimodal ultra-widefield and optical coherence tomography imaging allows

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		assessment of a wide range of retinal pathologies and is a promising solution to alleviate the burden on Hospitals
6	Subhashini Chandrasekaran[14]	Tele-glaucoma allows for detecting glaucoma remotely. The study indicates that tele-glaucoma protocol is comparable to a clinical exam in its ability to detect glaucoma.
7	Simon P Kelly[15]	Innovation and quality improvement were demonstrated in both optometry to ophthalmology referrals and in primary optometric care by use of telemedicine with spectral domain optical coherence tomography images. E-referral of spectral domain optical coherence tomography images assists triage of macular patients and swifter care of urgent cases..
8	Tina Felfeli[16]	Tele-retinal screening programs may circumvent low rates of DR screening for patients with diabetes mellitus and increase the rate of detection of DME with monoscopic colour fundus photographs and adjunct OCT.
9	Alfonso Anton[17]	In a telemedicine screening setting, interobserver agreement on diagnosis was moderate but improved with greater evaluator expertise.

DISCUSSION

As predicted by the United Nations, the population of the world will surpass 9 billion by 2050.[18] Moreover, changes in the demographic pyramid imply that the proportion of elderly will increase significantly sooner than the rest of the population. Therefore, ophthalmologists will have a more substantial burden as they will need to detect and manage ophthalmological conditions in a larger proportion of the population. Teleophthalmology will likely play a significant role in the near future not only in rural but also in highly populated metropolitan areas. With an increasing population and demographic shifts toward an older population, there is an increasing need for alternative, affordable, and convenient ophthalmic evaluation methods. Ophthalmologic telemedicine programs are being employed globally & they have helped to address the growing demand for eye care in not only elderly but all age groups. It has improved access to healthcare far & wide. It has also reduced wait times for patients, and lessened healthcare disparities for patients. It is being instrumental in decreasing healthcare loads on the hospitals. Therefore, in several countries, we have observed investments that make telemedicine available and accessible to the population (eg, Specavers in UK, Australia, and New Zealand).

Hence, I believe that this review will be helpful in figuring out the effect of the most promising ocular imaging of the time: SD-OCT in improving teleophthalmology.

Though the aforementioned studies considered in this review article had their own limitations, majority of these studies, included in this review article, upholds the fact that Teleophthalmology has the potential to fill the gap in health care access when integrated with the evolving ocular imaging technologies specifically: SD-OCT. It serves as a promising tool for screening as well triaging of the leading causes of blindness: Glaucoma, Diabetic retinopathy, ARMD with a relatively fast method. Even though we are not presenting an exhaustive analysis here, this article provides a comprehensive evaluation with refence to usage of SD-OCT in the ever evolving & progressing practice of Teleophthalmology as a reliable mode of eye care for patients suffering from ocular pathology.

While looking at the brighter sides of the conjunction, it is worthwhile to try figuring out the challenges that might be there while trying to employ this on large scale or, regular practice. A broad literature review on teleophthalmology shows that a large number the teleophthalmology studies did not include >2 ocular instrumentations, and many of them have not used OCT

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imaging.[19] Particularly, retinal studies in teleophthalmology limit their instrumentation to just a fundus camera possibly due to the cost effectiveness of the same over SD-OCT. Adequate training of technicians, doctors & optometrist in obtaining a perfect image might pose another threat. OCT interpretation differences between two readers of different skill might be another potential challenge. These days Artificial intelligence & machine learning modules are being deployed globally to overcome the challenges. OCT is also a heavy machine & portability might be an issue when integrated in teleophthalmology unless we have technological advancement in the domain.

The supremacy of the OCT in the identification of eye conditions like glaucoma and retinal diseases can hardly be refuted. Therefore, we believe it will play an essential role in teleophthalmology in the near future & upgrade the quality of teleophthalmological care to patients all over & will be helpful in filling up for the dearth of accessibility to eye care in remote areas as well as cities.

However, despite majority of the studies vocalising about the effectiveness of the SD-OCT- Teleophthalmology integration, there are some examples of teleophthalmologic studies with OCT as imaging modality such as Maa et al.[10.] which negate the integration of OCT in Teleophthalmology. In this study, the researchers partially inserted SD-OCT in the last step of the study TECS clinical trial. They also didnot provided the OCT images or fundus photographs to the doctors who carried out the in-person clinical examinations of the patients being studied & subsequently shared the participants' information and images with two different readers. The study concluded that OCT was inconsistent between the face-to-face examiners and readers results. This decreased the confidential interval of the diagnosis between the two readers. The researchers concluded that this might be due to the lack of specific guidelines for interpretation of OCT. They also thought that it might be due to inconsistent OCT interpretation due to lack of training in the healthcare providers. However, they acknowledged that the small number of patients with AMD and incapability of their OCT device about macular ganglion cell analysis might have affected their results.

As a foot note to this review, we recommend areas that can be addressed in future studies. It will be worthwhile to examine the cost-effectiveness of this method of OCT-Teleopthalmology integration & comparing it with traditional protocols of examining patients with eye pathology, also how far it has been successful in increasing reach of eye care to patients in remote areas. Also, a future study can also be conducted for a comprehensive analysis specifically designed to detect false-negative in diagnosis of ocular pathologies by this conjunction. It is also worth finding out in future studies whether the considerable amount of investment as required in SD-OCT imaging would lead to increased diagnostic accuracy to ensure better patient care when deployed as diagnostic modality complementary with Teleophthalmology.

We believe that our article encompasses an enriched and comprehensive review on the importance of integrating SD-OCT as an imaging modality in conjunction with delivery of eye care via teleophthalmology.

CONCLUSION

In conclusion, the integration of OCT technology in teleophthalmology practice, encompassing both anterior and posterior segments, is of paramount importance in modern eye care delivery. It ensures better screening, enables remote monitoring and management of eye diseases, facilitates efficient triage and referral systems, promotes patient engagement and education, and improves accessibility of eye care services. By leveraging the synergy between teleophthalmology and OCT, healthcare providers can deliver comprehensive, timely, and patient-centred eye care, ultimately improving clinical outcomes and enhancing the overall quality of eye health services.

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