Original Article

Comparison of Image Quality between Swept Source and Spectral Domain OCT in Media Opacification

Hina Khan, Aamir Asrar, Bisma Ikram, Maha Asrar

Pak J Ophthalmol 2016, Vol. 32, No. 3

See end of article for authors affiliations

Correspondence to:
Hina Khan,
Consultant Ophthalmologist,
Head of Ophthalmic Diagnostics Department, Amanat Eye Hospital, Islamabad
Email:
drhinakhan79@gmail.com

Purpose: The study aimed to compare the image quality of SD OCT and SS OCT in the setting of media opacification i.e. cataract.

Study Design: Prospective cross sectional study.

Place and Duration: Amanat eye hospital from 1st October 2015 till 31st December 2015.

Material and Methods: Prospective cross sectional study was carried out on 366 eyes of 241 subjects. All subjects were scanned with both SS – OCT and SD – OCT with dilated pupils and scans were evaluated by two ophthalmologists. Chi square/ fisher exact test was applied to assess the results.

Results: In the sample of 366 eyes, there were 174 eyes with grade 1; 96 with grade 2; 72 with grade 3; and 24 with grade 4 cataract media opacification. The images obtained from media opacification grade 1 and 4 were almost constant and statistically non significant. The results of images obtained with grade 2 media opacification was significant with $p = 0.001$. Similarly, the results obtained from grade 3 media opacification were highly significant with $p < 0.001$.

Conclusion: The image quality of SS OCT and SD OCT performs better in moderate media opacification. Both machines performed equally and efficiently in mild media opacification whereas failed to provide clinically useful scans for dense media opacification.

Keywords: Swept Source Optical Cohorence tomography, Spectral Domain OCT, Image quality, Media opacity, Cataract.

OCT has established itself as indispensible for monitoring of vitreo retinal choroidal Disorders[1,2]. Since its advent over 20 years ago, it has seen tremendous transformation from time domain models with an axial resolution of 50µm to SD OCT with resolution of less than 5µm. However, two major limitations were consistently observed with previous models.

Firstly visualization of the choroid has been sub optimal. Secondly visualization through media opacification such as cataract leads to a deterioration of image quality[3,4]. The wavelength employed for illumination in SD models is 800 – 870 µm. This is optimal for imaging the retina but does not offer large penetration depths since in SD technology the signal strength seems to decay rapidly with an increase in the spatial distance from zero delay line which is the axial distance for maximum sensitivity for signal detection (conventionally placed near the vitreo retinal interface), a phenomenon known as sensitivity role off[5]. In an attempt to overcome this limitation, the enhance depth imaging (EDI) mode was introduced in SD technology. Parallel to this, swept source OCT technology has been invented which uses a longer wavelength of light (1050mm) with a tunable laser and narrower band width. This technology offers much less sensitivity role off without affecting signal strength in other regions and has claimed to perform better in eyes with media opacification.

Many comparisons between these modalities have already been published. The choroidal thickness estimates[6,7], the automated choroidal segmentation[8], the penetration depth[9,10], the contrast at deep choroidal vessel level, image quality in pathological myopia[11,] have been studied. All of these studies have excluded cases with media opacification, citing it as a limitation.

The purpose of this study was to compare the image quality between SD OCT and SS OCT in the setting of media opacification i.e. cataract.

MATERIAL AND METHODS

A comparative cross – sectional study conducted in the settings of Amanat Eye Hospital, equipped with both SD-OCT (Heidelberg Spectralis) and the SS–OCT (Topcon Triton). Consecutive sampling technique was used to collect the sample of 366 eyes of 241 patients in the time frame of three months (from 1st October 2015 till 31st December 2015). Patients presenting to Amanat Eye Hospital and found to have cataract on ophthalmic examination were included in the study. An informed consent was obtained from all the patients enrolled in the study. An approval was taken from the hospital ethical committee. Two consultant ophthalmologists separately graded the media opacification on the basis of fundus view on slit lamp bio microscopy with the 90D lens (Fig. 1) as in table 1. Where there was a discrepancy in the grades awarded to any opacity by the two consultants, that patient was excluded from the study. Head to head comparison of Swept Source OCT and Spectral domain OCT (SD – OCT) was done in all subjects. For Spectral OCT a 6 mm line scan using EDI setting with 100 images average per scan was used. For Triton 12 mm line scan centered on the fovea with 90 images averaged for each B – scan. All images were taken in mesopic lighting conditions and with a dilated pupil. All scans were performed by single trained ophthalmic technologist. The image thereby acquired was then assessed on the machine and graded on the basis of clarity in table 2. Here again, any image in which there was a disagreement between the two consultants was excluded from the study. The Observers were masked to the patients and the grade of cataract but were not masked to the machine.

Table 1: Media Opacification Gradation.

Media Opacification	Disc	Macula
Grade 1	Clear	Clear
Grade 2	Clear	Mild Blur
Grade 3	Blur	Moderate Blur
Grade 4	No Visibility	No Visibility

The Statistical Package for Social Sciences software (SPSS, version 22) was applied to organize and tabulate the data collected. Descriptive statistics of all variables were calculated and Pearson Chi square/ fisher exact test (95% Confidence Interval) was applied to determine the association between Swept Source OCT and Spectral domain OCT (SD – OCT).

Media opacification was graded on the basis of fundus view on slit lamp biomicroscopy with the 90D lens as in Table 1 (Fig. 1). The image from both OCTs was graded on the basis of clarity of the retinal layers as in Table 2, which was called posterior segment gradation.

RESULTS

There were 366 eyes of 241 patients (151 Females and 90 Males), the mean age was 61 years (±6.22 SD). There were 174 samples of grade 1, 96 of grade 2, 72 of grade 3 and 24 of grade 4 media opacification observed (Table 3). For Grade 1 media opacifiation, there were 174 eyes. No statistics were computed because the image quality with Swept Source OCT and Spectral domain OCT were constant. For Grade 2 Media Opacification, 96 eyes were observed. Fisher Exact test was applied to find out the association between Swept Source OCT and Spectral domain OCT (SD – OCT). It was found to be significant with p value = 0.001 (df 1, n = 96), at significance level (α) 0.05 and 95% confidence interval (CI) (Table 3). For Grade 3 media opacifiation, 72 eyes were observed. Fisher Exact test was applied to find out the association between Swept Source OCT and Spectral domain OCT (SD – OCT). It was found to be significant with p value < 0.001 (df 1, n = 72), at significance level (α) 0.05 and 95% CI (Table 3). For Grade 4 media opacifiation, there were 24 eyes. No statistics were computed because the image quality with Swept Source OCT and Spectral domain OCT were constant.

Table 2: OCT image quality graduation

Image Quality	Retinal Layers	Vitreous
Grade 1	Distinct	Clear
Grade 2	Less distinct but identifiable	Mild haze
Grade 3	Significant blur but gross pathology still visible. Software Misjudging retinal layers.	Moderate haze
Grade 4	Image quality is too low for reliable interpretation.	Severe haze

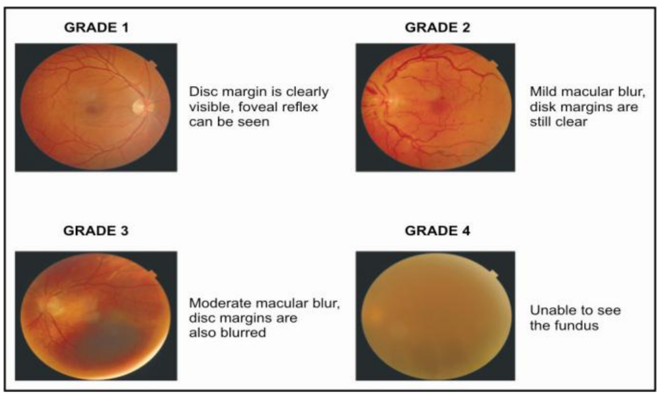

Fig. 1: Grading of media opacification on the basis of fundus view.

DISCUSSION

The effect of cataract on OCT image has been studied before. In a study of 800 nm OCT[12], only moderate cataracts were included the signal strength or reduction thereof was observed but it did not attempt comparison with SS OCT. In another study with moderate cataract, SS OCT provided details of the retinal choroidal structure irrespective of the density of the cataracts[13]. The results of the current study do not reflect the same where it was observed that image quality deteriorated with density of cataract.

A study conducted in UK observed the effect of mild to severe cataract on posterior segment visualization by 3D 1060 nm OCT and compared it with SD OCT. It involved scanning patients with undilated pupils whereas in the present study, patients were scanned with dilated pupil to optimize the images obtained. Studies[14] conclude that pupil size does not affect the quality of scans in modern OCT machines but these studies have excluded eyes with media opacification. It was speculated that due to the presence of cataract, pupil size will have an effect in this setting and will influence the image quality.

Other investigators have employed the Lens Opacities Classification System III (LOCS III)[15] to

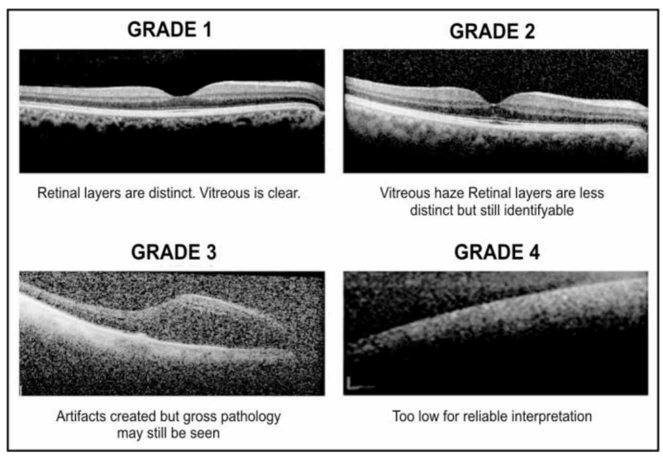

Fig. 2: Grading of image quality of OCT scans.

Table 3: Comparison of image quality between SS-OCT and SD – OCT with increasing density of media opacification.

Media Opacification	SS – OCT Image Quality				SD – OCT Image Quality				P value
	Gr. I	Gr. II	Gr. III	Gr. IV	Gr. I	Gr. II	Gr. III	Gr. IV	
Grade 1 (n = 74)	174	0	0	0	174	0	0	0	
Grade 2 (n = 96)	91	5	0	0	71	25	0	0	P = 0.001
Grade 3 (n = 72)	0	64	8	0	0	57	15	0	P < 0.001
Grade 4 (n = 24)	0	0	2	22	0	0	0	24	

grade the density of cataract. Since LOCIII does not specify the exact location of the cortical and posterior cataract, it has been observed by those investigators[16] that using this classification, there was no consistency in image quality and signal strength with the same LOC III grades. The current study attempts to overcome this limitation by use of two separate arbitrary grading systems (based on clinical significance) devised for assessment of media opacification and the quality of the image consequently obtained. We preferred to use this instead of the LOCS III so that the end point i.e. the degree of haziness of fundus caused by any cataract was directly addressed irrespective of location and type of cataract. As a result, more consistent results were seen using this method.

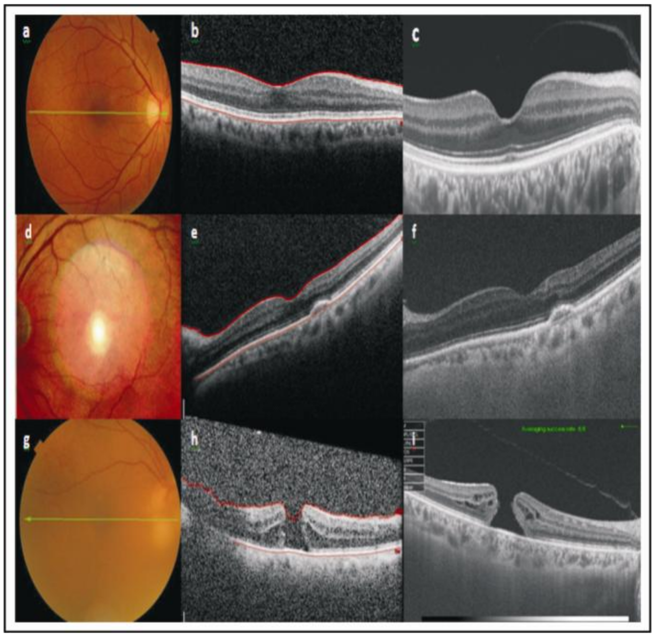

Fig. 3: **(a)** Media Opacification Grade 1; **(b)** Image Quality on SD – OCT (Grade 1); **(c)** Image Quality on SS – OCT (Grade 1); **(d)** Media Opacification Grade 2; **(e)** Image Quality on SD – OCT (Grade 2); **(f)** Image Quality on SS – OCT (Grade 1); **(g)** Media Opacification Grade 3; **(h)** Image Quality on SD-OCT (Grade 3); **(i)** Image Quality on SS-OCT (Grade 2).

For grade I opacification, (Figure. 3 a-c) the image quality from both machines fell in the same category. Although it was clearly seen that SS OCT had better contrast between the retinal layers imaged however, the SD OCT also efficiently detected all retinal layers at this grade of opacification for clinical interpretation and correlation. Important to note is that we did not include choroidal depth and visualization of the choroidoscleral junction as criteria. There are a number of studies[17,18,19] that establish the SS OCT does indeed view to a greater depth due to the use of a tunable laser and a longer wavelength. Therefore, these parameters if included in the present study would have added an obvious bias in favor of SS OCT.

It was in the moderate grades of cataract that we found the most significant difference in image quality between the two machines (Figure 3 d-i). SS OCT performed better with less light scattering and artifacts. The retinal layers were adequately detected by the software in more cases than the SD OCT. Subtle retinal pathologies such as early epiretinal membranes intraretinal cystoid spaces which were missed by SD OCT were detected by SS OCT. A comparison of performance between SD OCT and SS OCT in high myopes has been studied[20]. The current study also observed better visualization in pathological myopia with SS OCT. The characters of PED's were seen in more detail. It is clinically important to be able to detect these changes because they are often the cause of unexpected and unfavorable visual results post cataract surgery. This knowledge of pre existing retinal pathology is invaluable in practice since it serves to bring the patients expectations at a reasonable level and makes him more receptive to further treatment.

It is observed that for dense cataracts, the image quality deteriorated for both SS and SD. In cases of dense cataract, where SD OCT failed the SS OCT also was unable to provide adequate and reliable images. A few exceptions noted but not statistically significant (2/24 for this group).

The strength of this study is a large number of subjects that reduced the significance of any confounders. Also the images scanned were by the same experienced technologist and assessed independently by the same consultants.

Limitations are that this study did not include media opacification other than cataracts. The presence of media opacification might affect certain depths of the retinochoroid more than others. Since OCT works on the principle of interferometery the depth at which light is reflected might be affected by the distance of the opacification from the zero delay line. These would certainly be useful areas of study in future.

CONCLUSION

SS OCT performs better than SD OCT in moderate media opacification caused by cataract. Both machines perform equally and efficiently in mild media opacification whereas fail to provide clinically useful scans in the setting of dense cataract.

ACKNOWLEDGMENT

We would like to acknowledge the contribution of Ms Naila Boota, Mr. Mohammad Kashif and Mr. Rizwan Waris for lending us their expertise in scan acquisition.

Competing Interests and Funding

NONE.

Authors Affiliation

Dr. Hina Khan
MBBS, FCPS, Consultant Ophthalmologist, Head of Ophthalmic Diagnostic Department, Amanat Eye Hospital, Islamabad – Pakistan

Dr. Aamir Asrar
MBBS, MRCOphth, FRCS, Fellowship in Vitreo-Retinal Surgery, Fellowship in Corneo- Refractive Surgery, Chief Consultant Ophthalmologist, Amanat Eye Hospital, Islamabad –Pakistan

Ms. Bisma Ikram
Optometrist and Orthoptist, MSPH, Research Consultant, Ophthalmic Diagnostic Department, Amanat Eye Hospital, Islamabad – Pakistan

Ms. Maha Asrar
Medical Student, Shifa College of Medicine, Islamabad

Role of Authors

Dr. Hina Khan
Sharing of data, Write Up, Literature Review, Scan Analysis and Data Collection.

Dr. Aamir Asrar
Sharing of data and Scan Analysis.

Ms. Bisma Ikram
Data Collection and analysis.

Ms. Maha Asrar
Data Collection.

REFERENCES

1. **Wang J, Gao X, Huang W, Wang W, Chen S, Du S, Li X, Zhang X.** Swept – source optical coherence tomography imaging of macular retinal and choroidal structures in healthy eyes. BMC Ophthalmol. 2015. 17; 15:122.
2. **Costa RA, Skaf M, Melo LAS et al.** "Retinal assessment using optical coherence tomography, "Prog in Retin Eye Res. 2006; 25 (3): 325–353.
3. **Velthoven ME, Linden MH, Smet MD, Faber DJ, Verbraak FD.** Influence of cataract on optical coherence tomography image quality and retinal thickness. Br J Ophthalmol. 2006; 90 (10): 1259–1262.
4. **Velthoven V, Linden VD, Smet D, et al.** Influence of cataract on optical coherence tomography image quality and retinal thickness. Br J Ophthalmol. 2006; 90: 1259–62.
5. **Barteselli G1, Bartsch DU, Weinreb RN, Camacho N, Nezgoda JT, Marvasti AH, Freeman WR.** Real – time full-depth visualization of posterior ocular structures: Comparison between Full – Depth Imaging Spectral Domain Optical Coherence Tomography and Swept – Source Optical Coherence Tomography. Retina, 2015. 11.
6. **Adhi M, Liu JJ, Qavi AH, Grulkowski I, Lu CD, Mohler KJ, Ferrara D, Kraus MF, Baumal CR, Witkin AJ, Waheed NK, Hornegger J, Fujimoto JG, Duker JS.** Choroidal analysis in healthy eyes using swept – source optical coherence tomography compared to spectral domain optical coherence tomography. Am J Ophthalmol. 2014 Jun; 157 (6): 1272-1281.
7. **Tan CS, Ngo WK, Cheong KX.** Comparison of choroidal thicknesses using swept source and spectral domain optical coherence tomography in diseased and normal eyes.Br J Ophthalmol. 2015 Mar; 99 (3): 354-8.
8. **Zhang L, Buitendijk GH, Lee K, Sonka M, Springelkamp H, Hofman A, Vingerling JR, Mullins RF, Klaver CC, Abràmoff MD.** Validity of Automated Choroidal Segmentation in SS – OCT and SD – OCT. Invest Ophthalmol Vis Sci. 2015 May; 56 (5): 3202-11.
9. **Waldstein SM, Faatz H, Szimacsek M, Glodan AM, Podkowinski D, Montuoro A, Simader C, Gerendas BS, Schmidt – Erfurth U.** Comparison of penetration depth in choroidal imaging using swept source vs. spectral domain optical coherence tomography. Eye (Lond.), 2015 Mar; 29 (3): 409-15.
10. **Thomas D, Duguid G.** Optical Coherence Tomography- A Review of the Principles and Contemporary Uses in Retinal Investigation. Eye, 2004; 18 (6): 561-570.
11. **Lim LS, Cheung G, Lee SY.** Comparison of spectral domain and swept – source optical coherence tomography in pathological myopia. Eye (Lond). 2014 Apr; 28 (4): 488-91.
12. **Velthoven ME, Linden MH, Smet MD, Faber DJ, Verbraak FD.** Influence of cataract on optical coherence tomography image quality and retinal thickness. Br J Ophthalmol. 2006 Oct; 90 (10): 1259–1262.

13. **Povazay B, Herman B, Unterhuber.** A three dimentsional Optical Coherence Tomogrpahy at 1050nm versus 800nm in retinal pathologies: enhanced performance and choroidal penetration in cataract patients. J Biomed Opt. 2007; 12 (4): 7.
14. **Tanga L, Roberti G, Oddone F, Quaranta L, Ferrazza M, Berardo F, Manni G, Centofanti M.** Evaluating the effect of pupil dilation on spectral – domain optical coherence tomography measurements and their quality score. BMC Ophthalmol. 2015; 15: 175.
15. **Chylack LT Jr, Wolfe JK, Singer DM, Leske MC, Bullimore MA, Bailey IL, Friend J, McCarthy D, Wu SY.** The Lens Opacities Classification System III. The Longitudinal Study of Cataract Study Group. Arch Ophthalmol. 1993; 111 (6): 831-6.
16. **Esmaeelpour M, Povazay B, Hermann B, Hofer B, Kajic V, Kapoor K, Sheen NJ, North RV, Drexler W.** Three – dimensional 1060-nm OCT: choroidal thickness maps in normal subjects and improved posterior segment visualization in cataract patients. Invest Ophthalmol Vis Sci. 2010; 51 (10): 5260-6.
17. **Adhi M, Ferrara D, Mullins RF, Baumal CR, Mohler KJ, Kraus MF, Liu J, Badaro E, Alasil T, Hornegger J, Fujimoto JG, Duker JS, Waheed NK.** Characterization of Choroidal Layers in Normal Aging Eyes Using Enface Swept-Source Optical Coherence Tomography. PLoS One. 2015 Jul 14; 10 (7):
18. **Barteselli G, Bartsch DU, Weinreb RN, Camacho N, Nezgoda JT, Marvasti AH, Freeman WR.** Real – Time Full – Depth Visualization of Posterior Ocular Structures: Comparison Between Full-Depth Imaging Spectral Domain Optical Coherence Tomography and Swept – Source Optical Coherence Tomography. Retina, 2015 Nov 11.
19. **Copete S, Flores – Moreno I, Montero JA, Duker JS, Ruiz – Moreno JM.** Direct comparison of spectral domain and swept source OCT in the measurement of chroidal thickness in normal eyes.Br J Ophthalmol. 2014; 98 (3): 334-8.
20. **Itakura H, Kishi S, Li D, Nitta K, Akiyama H.** Vitreous changes in high myopia observed by swept-source optical coherence tomography. Invest Ophthalmol Vis Sci. 2014. 10; 55 (3): 1447-52.