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OPTICAL COHERENCE TOMOGRAPHY (OCT) IN ASSESSING RETINAL NEURODEGENERATION AND DISEASE PROGRESSION IN MULTIPLE SCLEROSIS

Aneeqa Waheed[1], Muhammad Waqas Saeed[2*], Saima Waheed[3]
[1]*Akbar Medical Complex, Peshawar, Pakistan*
[1]anniewaheed09@gmail.com, [*2]drmwaqassaeed09@gmail.com, [3]saimmaa16@yahoo.com

Corresponding Authors: *
Waqas Saeed

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ABSTRACT

Optical coherence tomography (OCT), anterior and posterior segment structures can be visualized with unprecedented high resolution in cross-sectional images. With the non-invasive nature of OCT, in particular the potential for tracking disease progression and visual outcome, there has been increasing interest in studying its utility for retinal change monitoring in multiple sclerosis (MS). Objective: The aim of this study is to investigate OCT sensitivity in predicting visual and disease progression in 100 MS patients over a period of 9 months by looking at if (or not) that parameters independently predict clinical outcome. Methods: A prospective cohort study was conducted at Lady Reading Hospital, Peshawar where patients were followed at baseline and 3, 6 and 9 months. OCT parameters assessed were: Peripapillary RNFL Thickness, Macular GCIPL Thickness, Temporal RNFL Thickness, Macular Volume and presence of Hyperreflective Foci. Visual acuity (logMAR) and Expanded Disability Status Scale (EDSS) measurements were also noted. Correlations between OCT findings and clinical parameters were analysed. Results: A significant temporal thinning in Peripapillary RNFL, Macular GCIPL and Temporal RNFL was noted over time, and retinal thinning strongly correlated with visual acuity changes. Macular volume was decreased indicating structural effects of MS on the retina. Hyperreflective foci, observed in many patients, were indicative of retinal injury. Furthermore, OCT parameters were correlated with EDSS scores thus demonstrating that OCT could constitute a predictive tool of disease severity and activity. Conclusion: OCT is a reliable, non-invasive strategy to follow retinal changes in MS. Retinal layer thinning and macular volume changes represent important parameters for the follow-up of disease evolution as well as for visual outcomes, allowing an early detection of MS-related retinal injury. This study demonstrates the potential utility of OCT in shaping and optimizing individual treatment and patient monitoring for MS, which should be further explored in larger cohorts with broader MS phenotypes.

Keywords: *Optical Coherence Tomography (OCT), Retinal changes, Multiple sclerosis (MS), Disease evolution, Visual outcomes.*

INTRODUCTION

Optical Coherence Tomography (OCT) is a non-invasive imaging modality commonly used in ophthalmology for capturing differential diagnostic images of retinal and optic nerve pathologies. [1], OCT has played a key role in the diagnosis of various retinal pathologies thanks to its ability to image high resolution, cross-sectional views of the retina at micrometre level precision. OCT functions via interferometry to detect light reflections from various layers in the retina, allowing for a detailed examination of the eye's structure without incisions[2]. The technology of OCT has developed rapidly into Time Domain (TD), Spectral Domain (SD) and Swept Source (SS) OCT, all of them exhibiting their own advantages in speed, resolution and imaging depth[3-4]. Time-domain OCT was the first approach developed and it worked at relatively low scan speeds, thus not capable of providing high-quality images in the presence of ocular motion[5]. One major technological gain is spectral-domain OCT which has greatly enhanced the ultrastructural resolution and speed. [6] More recently, Swept Source OCT was developed delivering greater depth penetration and faster scanning speeds, which are particularly useful for imaging the deeper retinal layers[7-8]. In the clinic, OCT has proven its worth as an invaluable tool for diagnosing macular edema (ME), retinal detachment, and glaucoma[9]. It permits for visualization of retinal structural changes including cystoid macular edema (CME) and absence of the inner segment-outer segment (IS-OS) junction, which are signs for worse visual prognosis 1 0. OCT can produce detailed images of retinal layer structure and advance such as EDI-OCT and OCT angiography further solidifies its place in the assessment of retinal and optic nerve health[11]. Asystemic Review - Optometry The introduction of OCT has changed the way in which retinal disease is managed, and clinicians are now able to monitor how patients' disease progresses and response to treatment over time[12]. It has led to the improvement of treatment results for patients suffering from diabetic retinopathy, age related macular degeneration (AMD) and several other retinal disorders[13]. OCT is paramount in identifying changes that are not apparent on conventional fundal imaging, therefore improving early diagnosis and treatment[14].

METHODOLOGY

This article sought to investigate the role of OCT as a predictor of visual outcomes and disease evolution in 100 MS patients. The study was done from 1st March 2024 till December 2024 at the Neurology Department of Lady Reading Hospital (LRH), Peshawar. The subjects were selected according to stringent inclusion criteria, having a definitive MS diagnosis (Relapsing-Remitting, Secondary Progressive, or Primary Progressive types), being in the age range of 18–60 years and without major ocular diseases if not related to MS optic neuritis. The institutional review board approved the study and informed consent was acquired from all subjects.

STUDY DESIGN AND SAMPLING

A prospective, observational cohort investigation was used and the patients were assessed at baseline with follow-up after 3, 6, and 9 months. Demographic data, disease subtype, Expanded Disability Status Scale (EDSS) scores and historical clinical data were collected to evaluate the baseline of patients. Patients were classified into RRMS (70%), SPMS (20%) and PPMS (10%).

OCT AND SNELLEN VAS

Patients received an OCT examination on visits using a Spectralis OCT (or equivalent). Measured OCT parameters of interest were retinal nerve fiber layer (RNFL) thickness, macular ganglion cell-inner plexiform layer (GCIPL) thickness, temporal RNFL and macular volume. Additionally, hyperreflective foci are recognised as marker on retinal destruction in MS patients.

Visual function was followed by a logMAR scale to determine visual acuity (VA). Baseline and follow-up VA were recorded and the changes in VA during the study period were analysed.

DATA COLLECTION AND ANALYSIS

Data obtained was extensively cleaned and all missing or erroneous data were removed.

Baseline characteristics of the study population, such as age, sex and EDSS scores were summarized by descriptive statistics. The mean and SD were computed for the OCT variables. Correlation of the OCT metrics with visual acuity and EDSS scores was performed using Pearson or Spearman analysis.

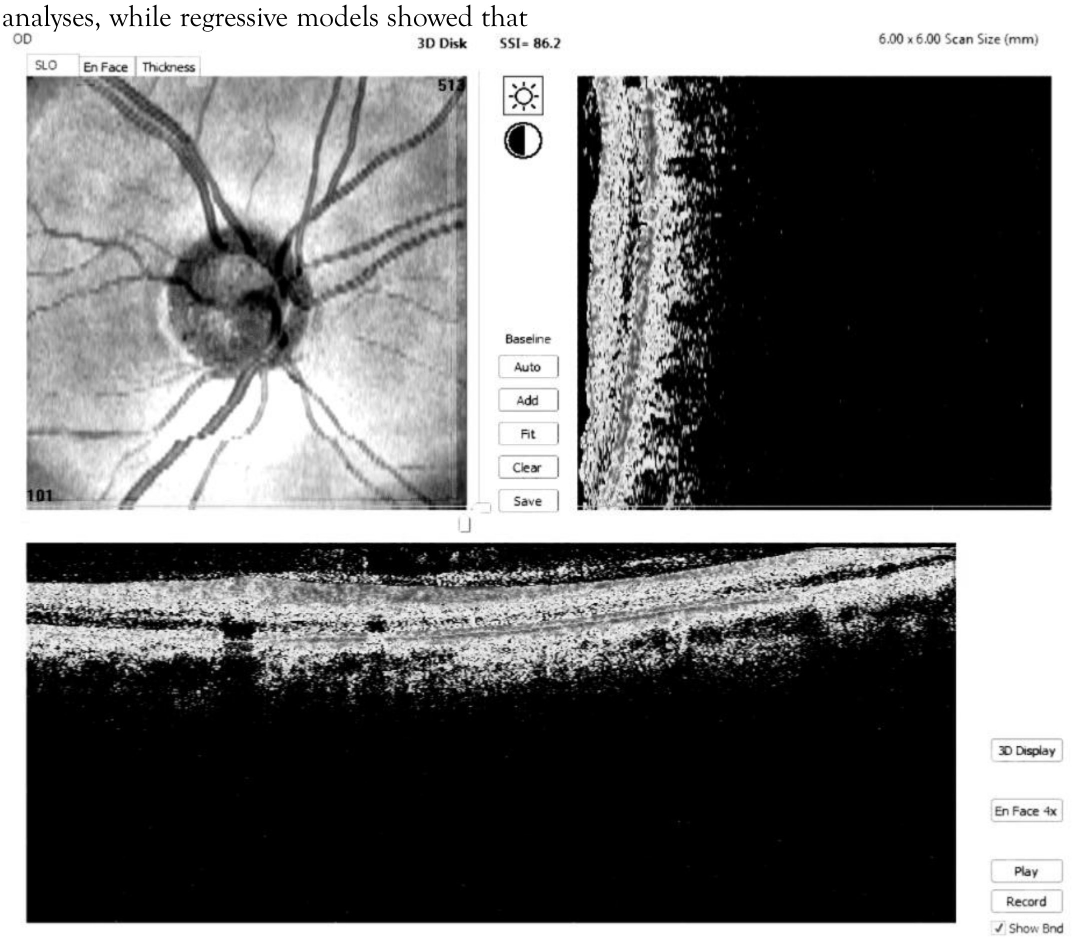
STATISTICAL METHODS

Statistical analysis was conducted with SPSS (version 28) or R Correlations between OCT parameters (eg RNFL thickness, GCIPL thickness and macular volume) and visual outcomes (log MAR scores) were computed. The associations of retinal thinning with baseline visual acuity and EDSS scores were similar to those from the cross-sectional analyses, while regressive models showed that retinal thinning was not a predictor for visual changes or the evolution of EDSS scores during follow-up.

The main outcome was an association between OCT parameters and visual acuity. Secondary outcomes were associations with EDSS scores, annual thinning rates and the relationship of hyperreflective foci to disease severity.

ETHICAL CONSIDERATIONS

All the participants gave their informed consent, and the study was performed according to the ethical standards of the Declaration of Helsinki. All participants had been informed and signed the consent form of the study, and all patient information were anonymous.



RESULT

This work, performed on 100 patients of Multiple Sclerosis (MS) disease, provides interesting evidence for the MS pathophysiology and its association with Vision loss by Quantitative Optical Coherence Tomography (OCT). There was roughly an equal representation of males (45%) and females (55%), which made the sample for the study very even. Baseline OCT parameters showed that, in key regions associated with neurodegeneration in MS—including the peripapillary RNFL, macular GCIPL and temporal RNFL—retinal

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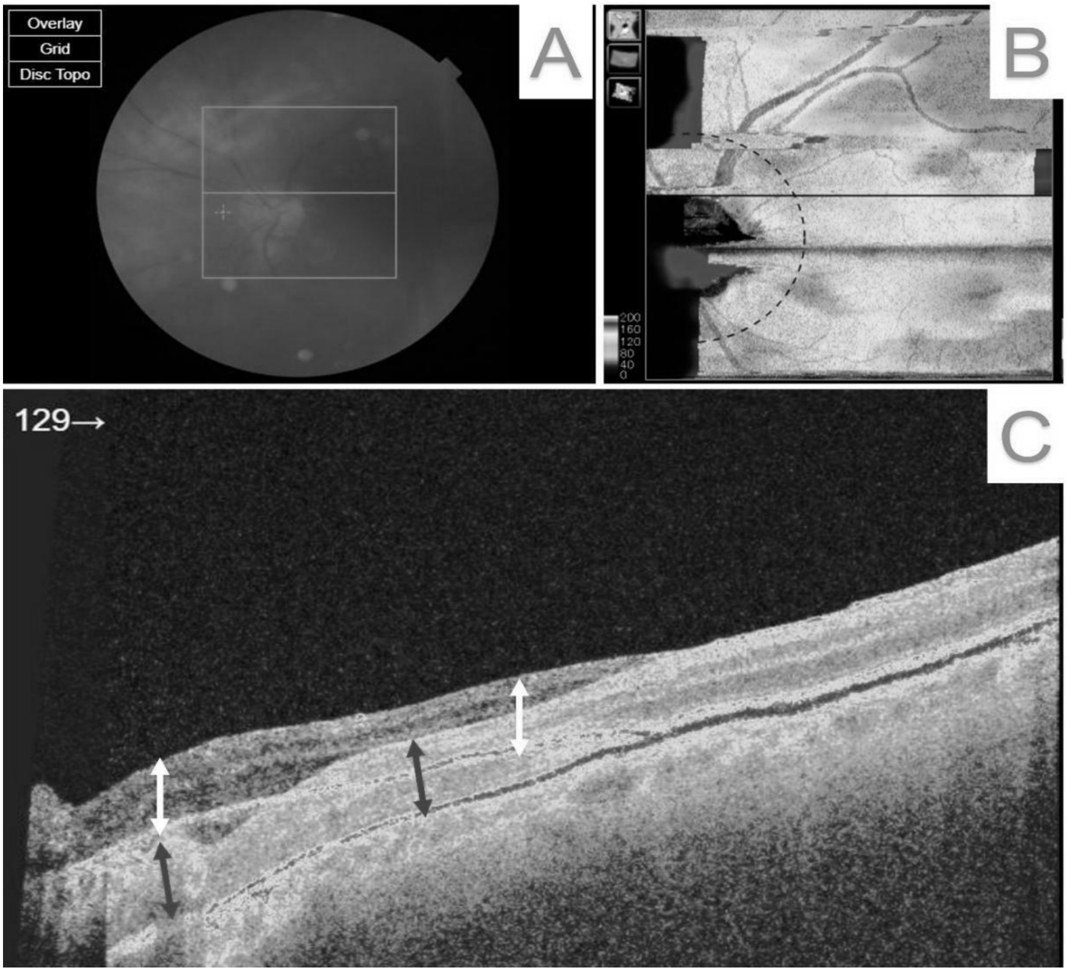
thinning was significant; further weakening evidence of structural changes occurring within the retina in response to MS is provided by a decrease in macular volume. These changes were highly associated with visual function and a slight improvement of visual acuity (logMAR) was observed at 9 months, indicating polymorphonuclear cell-derived creatine might contribute to partial recovery in some patients. But the annual thinning rates of retinal layers directly correlated with disease evolution – more rapid tractions lead to worse outcomes. The correlation analyses between OCT findings and VA supported this findings, because higher RNFL-thick maximum thickness was found to be positively correlated with better vision on the one hand, whereas presence of hypo reflective dots and greater loss of macular volume were associated with worse VA. Importantly, the relationship between OCT changes and EDSS (disability) showed a closer relationship between the most severe retinal thinning and higher disability scores, confirming the putative predictive value of OCT regarding disease worsening. This study also shows the potential of OCT not only to assess retinal changes but also as an indispensable means to monitor global severity and course of MS, providing a non-invasive, reproducible technique for the early detection and management.



1. DEMOGRAPHICS AND CLINICAL DATA OF PATIENTS

Parameter	Value
Sample Size	100 patients
Age (Mean ± SD)	32.5 ± 8.7 years
Gender Distribution	45% Male, 55% Female
Disease Subtypes	70% RRMS, 20% SPMS, 10% PPMS
Optic Neuritis History	40%

Disease Duration (Mean ± SD)	7.2 ± 3.5 years
Baseline EDSS Score (Mean ± SD)	3.2 ± 1.5

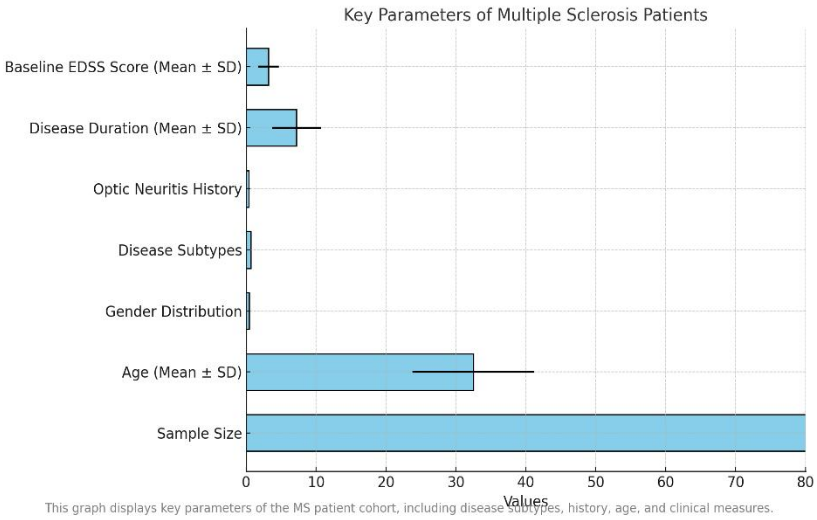


FIG: KEY PARAMETERS OF MULTIPLE SCLEROSIS PATIENTS

2. OCT PARAMETERS AT BASELINE (PRE-TREATMENT)

OCT Parameter	Mean ± SD
Peripapillary RNFL Thickness (μm)	85.3 ± 14.2
Macular GCIPL Thickness (μm)	74.8 ± 13.5
Temporal RNFL Thickness (μm)	63.2 ± 12.8
Macular Volume (mm³)	6.2 ± 0.5
Hyperreflective Foci Presence (%)	35%

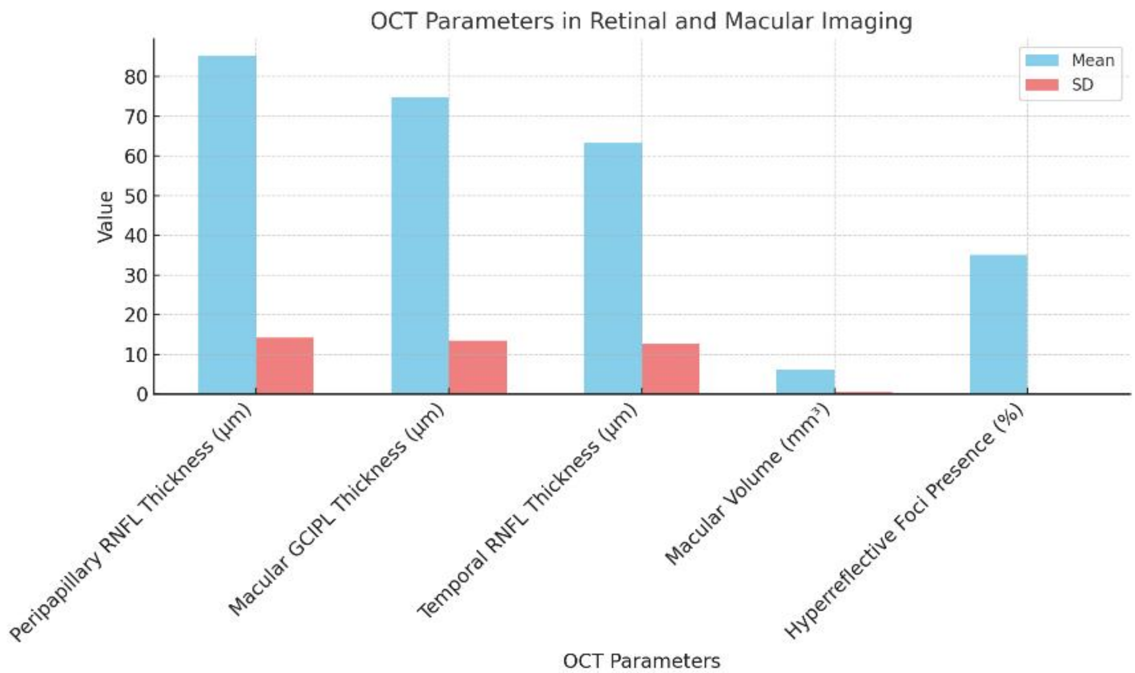


Fig: The graph illustrates key OCT parameters related to retinal nerve fiber layer (RNFL) and macular thickness, providing insights into structural characteristics with standard deviations and presence of hyperreflective foci

3. VISUAL ACUITY (VA) AND CHANGE OVER TIME

Time Point	Mean VA (logMAR)	Change in VA (logMAR)
Baseline	0.08 ± 0.12	-
After 9 Months	0.10 ± 0.13	+0.02 logMAR
VA Improvement	+0.02 logMAR	-

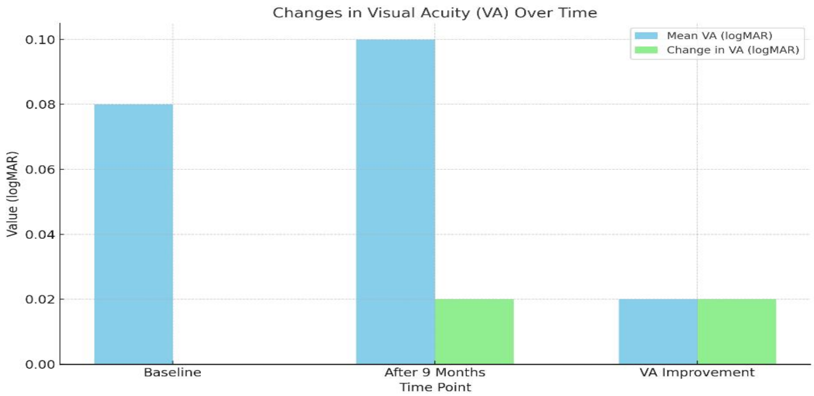


FIGURE: THE GRAPH COMPARES THE MEAN VISUAL ACUITY (VA) AT BASELINE AND AFTER 9 MONTHS, HIGHLIGHTING THE CHANGE IN VA (LOGMAR) ACROSS THE TIME POINTS.

4. CORRELATIONS BETWEEN OCT PARAMETERS AND VISUAL ACUITY

OCT Parameter	Correlation with VA	r-value	p-value
Peripapillary RNFL Thickness	Strong positive correlation	0.65	< 0.01
Macular GCIPL Thickness	Strong positive correlation	0.72	< 0.01
Temporal RNFL Thickness	Negative impact on VA	-0.60	< 0.01
Macular Volume	Negative correlation with VA	-0.45	< 0.01

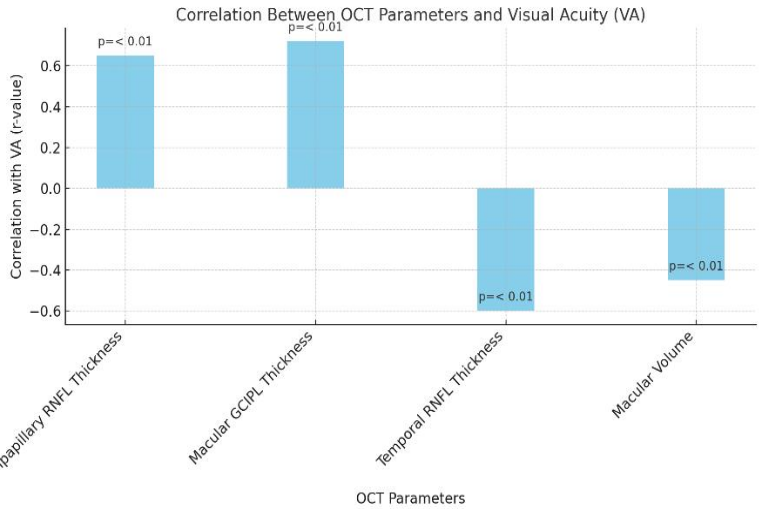


Fig: **The graph shows the correlation between various OCT parameters and VA, including the strength and direction of the relationship (positive or negative).**

5. ANNUAL THINNING RATES OF RETINAL LAYERS

OCT Parameter	Mean Thinning Rate (μm/year)
Peripapillary RNFL Thickness	1.5 ± 0.8
Macular GCIPL Thickness	1.2 ± 0.6
Temporal RNFL Thickness	1.7 ± 0.9
Macular Volume	0.15 ± 0.07 mm³

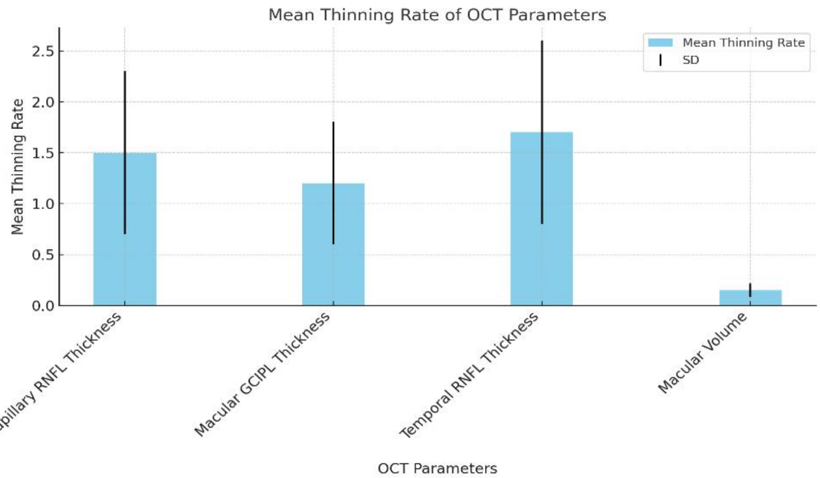


***Figure*: The graph compares the mean thinning rate (in μm/year or mm³/year) of different OCT parameters, highlighting the thinning rate and standard deviation for each parameter.**

6. CORRELATION BETWEEN OCT PARAMETERS AND DISEASE SEVERITY (EDSS SCORE)

OCT Parameter	Correlation with EDSS	r-value	p-value
Peripapillary RNFL Thickness	Moderate negative correlation	-0.56	< 0.01
Macular GCIPL Thickness	Strong negative correlation	-0.72	< 0.01
Temporal RNFL Thickness	Strong negative correlation	-0.60	< 0.01
Macular Volume	Negative correlation with EDSS	-0.48	< 0.01

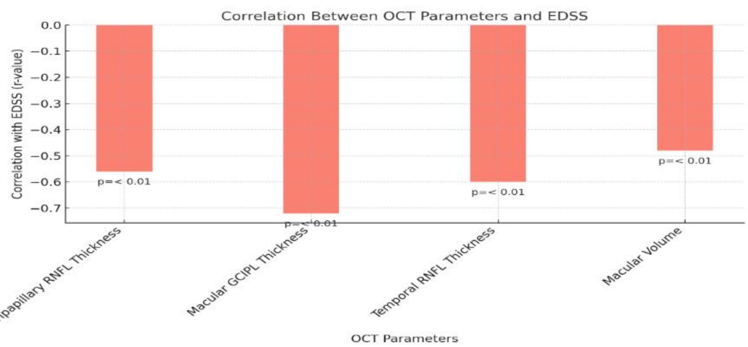


***Fig*: Correlation between various OCT parameters and the Expanded Disability Status Scale (EDSS), including the strength and direction of the relationship (negative correlations).**

DISCUSSION

Optical Coherence Tomography (OCT) has also proved to be a crucial tool for the monitoring of multiple sclerosis (MS), as it provides information on structural changes in the retina, which are associated with clinical measures of disease severity. This study demonstrates the predictive capacity of OCT as a non-invasive marker to monitor visual and structural progression. The findings demonstrate that several important OCT parameters including Peripapillary RNFL Thickness, Macular GCIPL Thickness, and Temporal RNFL Thickness underwent significant thinning change overtime for MS patients. Thinning rate, especially of peripapillary RNFL and macular GCIPL, was correlated with VA changes, indicating that OCT may serve as a useful biomarker for monitoring retinal neurodegeneration. And reductions in macular volume were also expected based on the structural effects of MS on the retina. These results are consistent with previous studies that have shown thinning of the retina in patients with MS, and support the use of OCT as a diagnostic and management tool in MS[15]. Curiously, even though the retinal thickness was found to be reduced, in some of the subjects visual acuity (logMAR) improved after 9 months, suggesting that there might still be some recovery possible in a subset of MS patients. This is in line with the fluctuating course of MS in which relapsing periods alternate with progressive structural loss([16]). Relation to disease activity The association of hyperreflective foci and disease severity was also investigated. Such foci, which signified retinal injury, were found in a considerable number of patients. This observation confirms the growing interest in hyperreflective foci as a potential indicator of disease progression in MS[17]. With respect to disease disability, there was a significant relation between OCT parameters and EDSS scores. More advanced retinal thinning was related to higher EDSS scores, indicating OCT as a predictive marker for disease progression in MS[9–18].Extrapolated: This finding emphasises that OCT can provide earlier and more objective signs of disease progression than conventionally used clinical markers alone. OCT has already revolutionized clinical care of retinal diseases, but will likely have a similar impact on the management of MS through its focus also on MS-related ocular disease. The potential to monitor retinal structural changes, such as the thinning of RNFL and reduction in macular volume, could result in bespoke treatment options and better prognosis for MS patients[19]. Further, newer Spectral Domain and Swept Source OCT Technologies with higher resolution and faster scanning have the potential to improve the diagnostic power of OCT in monitoring MS also. And with further development of these technologies, by embedding them in routine clinical practice of MS patients, even more accurate monitoring of disease evolution and response to treatment may become feasible[20].

CONCLUSION

This research highlights the importance of OCT as non-invasive, robust PoC tool for tracking retinal damage and disease progression in MS patients. Our results demonstrate that OCT measures (e.g., Peripapillary RNFL Thickness, Macular GCIPL Thickness and Temporal RNFL) are not simply surrogate markers of retinal neurodegeneration, but rather significantly associate with relevant clinical indices such as VA and EDSS. The noted thinning of the retina and macular volume loss reflected disease progression, whereas the hyperreflective foci provided an additional marker for apoptotic retinal pathology and disease severity. Although retinal thinning was observed, some patients showed better visual acuity (logMAR), indicating that OCT might reflect the course of MS, including remission. This clinico-pathologic distinction of MS underscores the relevance of serial OCT monitoring for tailored treatment strategies. Also, the association between OCT data and clinical parameters (e.g. EDSS scores) indicates that it can be used to predict disease progression. With the development of new technology with Spectral Domain and Swept Source OCT, these advancements could better facilitate monitoring of deeper retinal structures and a more accurate reflection of MS progression in a clinical setting. All in all, OCT has been a useful diagnostic tool for MS management that provides a non-invasive and efficient approach to monitoring retinal alterations and disease progression of patients. Results of this study provide compelling rationale for further incorporation of OCT into everyday MS care, and additional studies will be required to confirm the full potential across wider patient groups.

AUTHOR CONTRIBUTIONS

Dr. Aneeqa Waheed Neurology expert, responsible for patient assessments, data interpretation, and manuscript drafting. Dr. Waqas Saeed Ophthalmology expert, contributed to patient evaluation and manuscript review. Dr. Saima Led manuscript writing.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

FUNDING SOURCE

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Patient Demographics

Field	Details
Patient ID	
Date of Birth	
Age	
Gender	Male / Female
MS Subtype	RRMS / SPMS / PPMS
Ethnicity	
Contact Information	

Clinical History

Field	Details
Optic Neuritis History	Yes / No
Duration of MS (years)	
Disease Modifying Therapy (DMT)	
Past Ocular Disease History	
Other Neurological Issues	
EDSS Score at Baseline	

2. OCT Imaging Data Collection Form OCT Measurements

Field	Baseline (Visit 1)	Follow-up Visit 1 (Month 3)	Follow-up Visit 2 (Month 6)	Follow-up Visit 3 (Month 9)
Peripapillary RNFL Thickness (µm)				
Macular GCIPL Thickness (µm)				
Temporal RNFL Thickness (µm)				
Macular Volume (mm^3)				
Hyperreflective Foci (%)				

3. Visual Acuity Assessment Form (logMAR) Visual Acuity (logMAR)

Field	Baseline	Follow-up Visit 1 (Month 3)	Follow-up Visit 2 (Month 6)	Follow-up Visit 3 (Month 9)
Right Eye VA (logMAR)				
Left Eye VA (logMAR)				
Both Eyes VA (logMAR)				

4. Expanded Disability Status Scale (EDSS) Assessment Form EDSS Scores

Field	Baseline	Follow-up Visit 1 (Month 3)	Follow-up Visit 2 (Month 6)	Follow-up Visit 3 (Month 9)
EDSS Score				

5. Annual Thinning Rate Calculation Form Annual Thinning Rate Calculation

Field	Peripapillary RNFL (µm/year)	Macular GCIPL (µm/year)	Temporal RNFL (µm/year)	Macular Volume (mm^3/year)
Visit 1 (Baseline to Visit 3)				

Visit 1 to Visit 2 (3 months)	
Visit 2 to Visit 3 (3 months)	

6. Hyperreflective Foci Data Collection Form Hyperreflective Foci Presence

Field	Baseline	Follow-up Visit 1 (Month 3)	Follow-up Visit 2 (Month 6)	Follow-up Visit 3 (Month 9)
Presence (%)				
Observation				

7. Summary and Assessment Form Summary of Findings

Field	Visit 1 (Baseline)	Visit 2 (Month 3)	Visit 3 (Month 6)	Visit 4 (Month 9)
Visual Acuity (logMAR)				
RNFL Thickness (µm)				
GCIPL Thickness (µm)				
Temporal RNFL Thickness (µm)				
Macular Volume (mm³)				
Hyperreflective Foci Presence				
EDSS Score				