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Assessment of macular volume, retinal nerve fiber layer thickness, and choroidal thickness using spectral domain optical coherence tomography in individuals with multiple sclerosis

Muge Toprak¹, Fatih Yenihayat², Ozgul Altintas³, Hande Bickin⁴, Husnu Efendi⁵,
 Levent Karabas⁶, Berna Ozkan⁷, Nursen Yuksel⁶, Enes Kesim⁶

¹Department of Ophthalmology, Kocaeli City Hospital, Kocaeli, Turkiye

²Department of Ophthalmology, Kocaeli Health and Technology University, Dunya Goz Hospital, Kocaeli, Turkiye

³Department of Ophthalmology, Acibadem Maslak Hospital, Istanbul, Turkiye

⁴Department of Neurology, Pasaalani Private Sevgi Hospital, Balikesir, Turkiye

⁵Department of Neurology, Kocaeli University Faculty of Medicine, Kocaeli, Turkiye

⁶Department of Ophthalmology, Kocaeli University Faculty of Medicine, Kocaeli, Turkiye

⁷Department of Ophthalmology, Acibadem University Faculty of Medicine, Istanbul, Turkiye

Abstract

Purpose: This investigation aimed to assess structural alterations in the retina and choroid among individuals with multiple sclerosis (MS), both with and without prior optic neuritis (ON), using spectral domain-optical coherence tomography (SD-OCT) and enhanced depth imaging-optical coherence tomography (EDI-OCT).

Methods: In this cross-sectional analysis, participants included patients with relapsing-remitting MS and matched healthy individuals. MS subjects were stratified into ON and non-ON categories. Measurements of retinal nerve fiber layer (RNFL) thickness, macular volume (MV), and choroidal thickness (CT) were conducted and examined in relation to Expanded Disability Status Scale (EDSS) scores and the duration of disease.

Results: Data from 80 individuals (40 MS, 40 controls) were analyzed. RNFL thickness was significantly reduced in the MS group, particularly in the temporal and superior regions ($p < 0.001$ and $p = 0.004$, respectively), with ON patients showing more marked thinning temporally ($p = 0.01$). No notable differences were observed in MV or CT at any location (subfoveal, nasal, and temporal) ($p > 0.05$). A significant inverse association existed between EDSS and RNFL thickness in superior ($r = -0.768$), temporal ($r = -0.501$), and nasal ($r = -0.276$) quadrants. Duration of illness showed a negative correlation with inferior RNFL ($r = -0.631$) and nasal/temporal CT ($r = -0.351$; $r = -0.271$).

Conclusion: Thinning of the RNFL – especially in the temporal and superior regions – was a consistent finding and was linked to both disease severity and chronicity. Conversely, MV and CT parameters did not show substantial variation, implying RNFL thickness could serve as a more sensitive biomarker for MS-related neurodegeneration.

Keywords: Multiple sclerosis; optic neuritis; optical coherence tomography; retinal nerve fiber layer.

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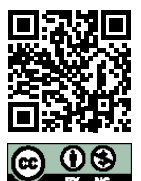


Correspondence: Muge Toprak, M.D. Department of Ophthalmology, Kocaeli City Hospital, Kocaeli, Türkiye

E-mail: mgtoprak@hotmail.com

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Multiple sclerosis (MS) is an autoimmune disorder that targets the central nervous system and involves multifactorial pathological processes. Contemporary studies highlight three core mechanisms in MS pathophysiology: neuroinflammation, demyelination, and axonal degeneration. Previous findings have demonstrated that axonal loss within the optic nerve is strongly associated with functional disability in MS patients.^[1] Several mechanisms have been proposed to explain how MS-related axonal injury contributes to cellular degeneration, including changes to the structural integrity of retinal ganglion cells, astrocytes, and vascular endothelial layers.^[2]

Optic neuritis (ON) is among the most common initial manifestations of MS, appearing in approximately 25–50% of cases. The optic nerve is affected in the majority of MS patients during the disease course, often leading to measurable thinning of the retinal nerve fiber layer RNFL.^[3–5] ON may trigger axonal degradation either through reduced neurofilament phosphorylation or via axonal transection that results in retrograde neurodegeneration.^[6] This cascade typically culminates in a measurable decline in RNFL thickness.^[7] Clinical evaluation frequently reveals optic atrophy and attenuated RNFL in MS patients with a history of ON.^[8,9]

Optical coherence tomography (OCT) allows for detailed visualization of retinal layers by detecting interference patterns generated by light reflected from various retinal surfaces. This high-resolution imaging modality provides valuable insights into the structural integrity of retinal tissues. The enhanced depth imaging version of OCT (EDI-OCT) extends this capability to deeper structures, enabling accurate evaluation of the choroid, including its thickness and morphology.

In this context, the current study aimed to quantify choroidal thickness (CT) in patients with MS and to determine whether these measurements differ from those observed in healthy individuals. By examining RNFL, macular volume (MV), and CT parameters in MS patients – with and without prior ON – and comparing them to controls, the study sought to identify imaging biomarkers that may reflect disease-related structural changes in the retina and choroid.

Materials and Methods

This investigation utilized a retrospective, cross-sectional design and included individuals diagnosed with MS who were followed at Kocaeli City Hospital. Ethical clearance was granted by the local institutional review board (Approval No: 2024–65, dated January 09, 2025), and all procedures

were conducted in accordance with the principles outlined in the Declaration of Helsinki.

Participants fulfilled the 2017 revision of the McDonald criteria for MS, which integrates clinical assessments with imaging evidence for diagnosis.^[10] Key clinical metrics collected from MS participants included disease duration and neurological disability, the latter quantified using the Expanded Disability Status Scale (EDSS), which scores disability on a scale from 0 (fully functional) to 10 (death from MS-related complications). Disease duration was determined based on patient history and medical records, starting from the onset of initial symptoms. Only those diagnosed with relapsing-remitting MS were considered for this study. Subjects were subdivided into two categories depending on whether they had previously experienced an episode of ON.

Exclusion criteria included active symptomatic ON within 2 months before OCT evaluation, as well as systemic comorbidities such as hypertension, diabetes mellitus, and cardiovascular conditions. Subjects with significant refractive errors – defined as a spherical equivalent beyond ± 5 diopters – were also excluded. Additional exclusion parameters included prior ocular surgeries, retinal or neuro-ophthalmic disorders, pronounced media opacities, and unreliable OCT imaging due to poor fixation or lens opacities.

Each participant was subjected to a detailed neurological examination, and physical disability was assessed using the Kurtzke version of the EDSS. The disease duration was determined based on the interval from the first reported symptom of MS. Only patients with either unilateral ON or no ON history were included in the MS group. These patients were then categorized accordingly into ON and non-ON subgroups. Importantly, none of the enrolled subjects had other significant systemic illnesses. The control group consisted of individuals attending routine ophthalmologic evaluations, with no known history of ocular disorders, intraocular interventions, glaucomatous changes, or MS.

All subjects – both in the patient and control groups – underwent a comprehensive ophthalmologic evaluation. This included objective refraction using an autorefractometer, measurement of best-corrected visual acuity with Snellen charts, slit-lamp examination, intraocular pressure (IOP) readings, and dilated fundus examination.

Spectral-domain optical coherence tomography and EDI-OCT imaging were performed by a single ophthalmologist proficient in retinal imaging. RNFL measurements were obtained using the Optopol Revo 60 SD OCT, operating in high-resolution mode. This system provides an axial

resolution of 3.8 μm and captures 19,000 scans/s. Sixteen circular B-scans, each 3.4 mm in diameter and composed of 1536 A-scans, were averaged to reduce speckle noise. An eye-tracking mechanism ensured accuracy by compensating for involuntary movements. The highest-quality scan for each eye was selected for analysis. The system's internal software calculated RNFL thickness across temporal, nasal, superior, and inferior quadrants, as well as an overall mean. MV was assessed using the Early Treatment Diabetic Retinopathy Study map, delineating central, inner, and outer zones (1.00 mm, 2.22 mm, and 3.45 mm in diameter, respectively). Regional segmentation allowed quadrant-specific evaluation.

Choroidal imaging followed the method described by Spaide et al.^[11] using enhanced depth imaging. To acquire EDI-OCT images, the Optopol Revo 60 SD OCT system was positioned closer to the eye to generate an inverted scan, which was then processed through automated averaging of 100 B-scans. This setup also employed real-time eye tracking to enhance measurement accuracy. Seven scan segments were captured across a rectangular field ($5^\circ \times 30^\circ$), encompassing the macula and optic disc. A horizontal section intersecting the fovea was selected for further evaluation.

CT was measured manually from the external edge of the hyperreflective retinal pigment epithelium band to the internal scleral surface. Measurements were conducted at the fovea (subfoveal CT) and at 1500 μm both temporally and nasally

from the fovea. Two independent and blinded examiners, unaware of participant details, performed all measurements. When the variation between their results exceeded 10%, those data points were excluded from the analysis.

Statistical Analysis

Data analysis was carried out using IBM SPSS Statistics for Windows, Version 27.0 (IBM Corp., Armonk, NY, USA). Continuous variables were reported as means with standard deviations. Group comparisons were performed using the independent samples t-test for normally distributed data, and the Mann–Whitney U test for non-normally distributed variables. Correlation between clinical parameters (EDSS and disease duration) and OCT outcomes was assessed using Pearson or Spearman correlation coefficients, as determined by normality testing. $p < 0.05$ was considered statistically significant.

Results

Table 1 summarizes the demographic and imaging profiles of the study cohort, which was composed of MS patients with and without a history of ON, alongside healthy control subjects. Disease duration was notably longer in the ON group (mean: 49.09 ± 31.27 months) compared to those without ON (42.11 ± 30.1 months). Interestingly, the non-ON subgroup had a marginally higher mean EDSS score (1.47 ± 1.06) than the ON subgroup (1.18 ± 0.34). Age distribution was similar between the MS group (35.39 ± 9.80

Table 1. Clinical and imaging parameters in multiple sclerosis patients with ON, non-ON, and control groups

Parameter (mean \pm SD)	MS (ON and non-ON)	ON subgroup	Non-ON subgroup	Control
Duration of illness (months)	43.27 \pm 30.17	49.09 \pm 31.27	42.11 \pm 30.1	N/A
EDSS	1.42 \pm 0.98	1.18 \pm 0.34	1.47 \pm 1.06	N/A
Age (years)	35.39 \pm 9.80	34.45 \pm 8.82	35.58 \pm 10.05	34 \pm 8.89
MV-Central (μm)	0.21 \pm 0.02	0.21 \pm 0.02	0.21 \pm 0.02	0.21 \pm 0.02
MV-Superior (μm)	2.05 \pm 0.16	2.11 \pm 0.13	2.04 \pm 0.17	2.1 \pm 0.06
MV-Nasal (μm)	2.12 \pm 0.21	2.18 \pm 0.18	2.11 \pm 0.22	2.18 \pm 0.08
MV-Inferior (μm)	2.02 \pm 0.16	2.09 \pm 0.16	2 \pm 0.16	2.07 \pm 0.11
MV-Temporal (μm)	2.01 \pm 0.09	2.04 \pm 0.14	2 \pm 0.08	2.02 \pm 0.07
RNFL-Superior (μm)	108.73 \pm 14.97	102.18 \pm 13.4	110.04 \pm 15.03	118.9 \pm 16.88
RNFL-Nasal (μm)	67.67 \pm 13.82	65.64 \pm 9.21	68.07 \pm 14.6	71 \pm 10.39
RNFL-Inferior (μm)	116.05 \pm 19.05	107.55 \pm 16.07	117.75 \pm 19.27	118.33 \pm 15.26
RNFL-Temporal (μm)	58.21 \pm 13.12	49.45 \pm 11.97	59.96 \pm 12.72	75.5 \pm 22.58
FCT (μm)	272.53 \pm 45.98	262.09 \pm 53.8	274.62 \pm 44.53	278.1 \pm 35.04
FCT-Temporal (μm)	283.85 \pm 46.87	273.82 \pm 52.22	285.85 \pm 45.99	284.67 \pm 36.47
FCT-Nasal (μm)	253.71 \pm 51.36	242.45 \pm 53.57	255.96 \pm 51.12	250.4 \pm 33.94
ODCT-Temporal (μm)	191.77 \pm 36.01	184.55 \pm 41.43	193.22 \pm 35.07	193.87 \pm 34.07
ODCT-Nasal (μm)	175.42 \pm 40.66	165 \pm 47.14	177.51 \pm 37.39	174.03 \pm 31.98

SD: Standard deviation; MS: Multiple sclerosis; EDSS: Expanded disability status scale; MV: Macular volume; RNFL: Retinal nerve fiber layer; FCT: Foveal choroidal thickness; ODCT: Optic disc choroidal thickness.

years) and the control group (34±8.89 years).

No statistically significant differences were identified in central MV across the study groups ($p=0.75-0.97$). However, the superior macular quadrant displayed a significant discrepancy between the non-ON and control cohorts ($p=0.04$), whereas other quadrants, such as nasal, inferior, and temporal, revealed no meaningful variation ($p>0.05$; [Table 2]).

Superior RNFL thickness showed a significant reduction in both the general MS group compared to controls ($p=0.004$) and in the ON subgroup versus controls ($p=0.005$). The ON and non-ON MS groups did not differ significantly in this quadrant ($p=0.11$). Temporal RNFL thickness was considerably decreased in all MS patients relative to controls ($p<0.001$), and further differentiation was evident between ON and non-ON individuals ($p=0.01$). No notable differences emerged in the nasal and inferior RNFL regions among any of the groups ($p>0.05$).

No statistically significant variations were observed in CT at the fovea (FCT), nor in the nasal or temporal choroidal measurements between the studied groups ($p>0.05$). Likewise, optic disc CT (OD-CT) remained consistent across all comparison groups ($p>0.05$).

Correlation analysis revealed strong inverse relationships between EDSS scores and RNFL thickness in the superior ($r=-0.768$, $p<0.01$), inferior ($r=-0.651$, $p<0.05$), and temporal ($r=-0.624$, $p<0.05$) quadrants. Furthermore, a significant negative association was found between disease duration and RNFL thickness in the inferior quadrant ($r=-0.631$, $p<0.05$).

However, other RNFL measurements did not show significant correlation with either EDSS or illness duration ($p>0.05$).

A moderate negative trend was noted between EDSS and FCT in the temporal region ($r=-0.551$), although this did not reach statistical significance. No meaningful correlation was observed between OD-CT and clinical metrics (Table 3). A weak but significant positive correlation was identified between EDSS and MV ($r=-0.289$, $p<0.05$).

Further analyses showed that disease duration was negatively correlated with nasal ($r=-0.375$, $p<0.01$) and temporal ($r=-0.273$, $p<0.05$) FCT values. EDSS also showed a significant inverse correlation with both temporal ($r=-0.501$, $p<0.01$) and nasal ($r=-0.351$, $p<0.01$) RNFL thickness. OD-CT parameters, in contrast, did not display any significant correlations with either EDSS scores or disease duration (Table 4). No relevant associations were found between MV in any quadrant and clinical variables ($p > 0.05$). Additional analysis confirmed the inverse relationship between EDSS and nasal ($r=-0.276$, $p<0.05$) and temporal ($r=-0.432$, $p<0.01$) RNFL, as well as between disease duration and both nasal ($r=-0.351$, $p<0.01$) and temporal ($r=-0.271$, $p<0.05$) FCT values (Table 5).

Discussion

This study focused on identifying structural alterations in the retina and choroid among individuals with MS, stratified by the presence or absence of ON, using SD and EDI imaging OCT technologies. The findings revealed significant reductions in RNFL thickness among MS patients, particularly in the temporal and superior regions, when compared to healthy

Table 2. Statistical comparison of optical coherence tomography measures between groups

	MS* vs. control p	ON vs. control p	Non-ON vs. control p	ON vs. Non-ON p
MV-Central (μm)	0.97 [†]	0.97 [†]	0.96 [†]	0.75 [†]
MV-Superior (μm)	0.07 [†]	0.76 [‡]	0.04[†]	0.42 [†]
MV-Nasal (μm)	0.09 [†]	0.98 [‡]	0.053 [†]	0.56 [†]
MV-Inferior (μm)	0.14 [†]	0.51 [†]	0.051 [†]	0.15 [†]
MV-Temporal (μm)	0.45 [‡]	0.65 [‡]	0.26 [‡]	0.26 [‡]
RNFL-Superior (μm)	0.004[‡]	0.005[‡]	0.02[‡]	0.11 [‡]
RNFL-Nasal (μm)	0.08 [†]	0.14 [‡]	0.11 [†]	0.61 [†]
RNFL-Inferior (μm)	0.56 [‡]	0.06 [‡]	0.89 [‡]	0.11 [‡]
RNFL-Temporal (μm)	<0.001[†]	<0.001[†]	<0.001[†]	0.01[‡]
FCT (μm)	0.56 [‡]	0.27 [‡]	0.71 [‡]	0.41 [‡]
FCT-Temporal (μm)	0.93 [‡]	0.17 [†]	0.9 [‡]	0.24 [†]
FCT-Nasal (μm)	0.75 [‡]	0.58 [‡]	0.59 [‡]	0.43 [‡]
ODCT-Temporal (μm)	0.79 [‡]	0.47 [‡]	0.94 [‡]	0.47 [‡]
ODCT-Nasal (μm)	0.87 [‡]	0.49 [‡]	0.68 [‡]	0.36 [‡]

MS: Multiple sclerosis; ON: Optic neuritis; MV: Macular volume; RNFL: Retinal nerve fiber layer; FCT: Foveal choroidal thickness; ODCT: Optic disc choroidal thickness. *Optic neuritis+Non-optic neuritis; ‡Student-t test; †Mann-Whitney U test.

Table 3. Correlation coefficients between Expanded Disability Status Scale (EDSS) and duration of illness with study parameters in the optic neuritis group

	EDSS	Duration of illness
MV-Central	-0.147 [†]	-0.535 [‡]
MV-Superior	-0.768 ^{†***}	-0.464 [‡]
MV-Nasal	-0.464 [†]	-0.438 [‡]
MV-Inferior	-0.651 ^{†*}	-0.631 ^{‡**}
MV-Temporal	-0.624 ^{†*}	-0.558 [‡]
RNFL-Superior	-0.076 [†]	0.176 [‡]
RNFL-Nasal	0.207 [†]	-0.236 [‡]
RNFL-Inferior	-0.273 [†]	-0.287 [‡]
RNFL-Temporal	-0.308 [†]	-0.296 [‡]
FCT	-0.441 [†]	-0.123 [‡]
FCT-Temporal	-0.551 [†]	-0.386 [†]
FCT-Nasal	-0.366 [†]	-0.096 [‡]
ODCT-Temporal	-0.406 [†]	0.131 [‡]
ODCT-Nasal	-0.273 [†]	0.287 [‡]

EDSS: Expanded Disability Status Scale; MV: Macular volume; RNFL: Retinal nerve fiberlayer; FCT: Foveal choroidal thickness; ODCT: Optic disc choroidal thickness. †Peason; ‡Spearman. *Correlation is significant at the 0.05 level. ** Correlation is significant at the 0.01 level.

controls. By contrast, no meaningful group differences were detected in CT or MVmr, suggesting that retinal structural changes may serve as more sensitive indicators of MS-related neurodegeneration than choroidal alterations.

The prominent thinning observed in the temporal and superior RNFL quadrants is consistent with existing literature, which highlights these areas as especially susceptible to MS-associated axonal injury. For instance, the work of Abalo-Lojo et al. [12] reported a relationship between RNFL thickness and cerebral atrophy indices, such as the bicaudate ratio, across MS subtypes using magnetic resonance imaging. This supports the notion that retinal axonal degeneration in MS may reflect broader central nervous system pathology.

Temporal RNFL thinning was most pronounced in individuals with prior ON, likely reflecting retrograde degeneration following acute optic nerve inflammation. The lack of significant alterations in the nasal and inferior quadrants may indicate selective vulnerability of particular retinal nerve fiber pathways.

The inverse associations identified between EDSS scores and RNFL thickness in multiple quadrants (superior, temporal, and nasal) reinforce the link between retinal structural loss and clinical disability. These findings support the use of RNFL parameters as surrogate markers for disease severity and neurological deterioration, particularly in the context of prior ON.

Table 4. Correlation coefficients between Expanded Disability Status Scale (EDSS) and duration of illness with study parameters in the non-optic neuritis group

	EDSS	Duration of illness
MV-Central	0.289*	-0.090
MV-Superior	-0.070	0.075
MV-Nasal	-0.109	0.198
MV-Inferior	0.031	0.094
MV-Temporal	0.136	0.060
RNFL-Superior	-0.295*	0.152
RNFL-Nasal	-0.351**	-0.211
RNFL-Inferior	-0.238	-0.107
RNFL-Temporal	-0.501**	-0.160
FCT	-0.029	-0.269*
FCT-Temporal	-0.113	-0.273*
FCT-Nasal	-0.023	-0.375**
ODCT-Temporal	-0.199	-0.019
ODCT-Nasal	-0.223	0.169

EDSS: Expanded Disability Status Scale; MV: Macular volume; RNFL: Retinal nerve fiber layer; FCT: Foveal choroidal thickness; ODCT: Optic disc choroidal thickness. *Correlation is significant at the 0.05 level. ** Correlation is significant at the 0.01 level. Spearman's rho test was used for correlation analysis.

The potential of RNFL thickness to function as a biomarker for disease burden and progression in MS, particularly in patients with a history of ON, is further supported by our results.[13,14] Prior work by Martin et al. [15] demonstrated that OCT can detect subtle differences in RNFL thickness, even in the absence of overt clinical symptoms such as reduced visual acuity or visual field defects. This reinforces the diagnostic value of OCT in revealing early or subclinical neurodegenerative alterations.

Interestingly, the literature remains divided regarding CT alterations in MS. Masala and colleagues observed that CT tended to be greater in MS patients than in healthy controls, and somewhat reduced in ON-affected eyes compared to the contralateral eye; however, these findings did not achieve statistical significance.[16] Their study, like ours, found a consistently thinner RNFL in both MS and ON groups compared to controls. In contrast, no statistically significant changes in CT – whether subfoveal, temporal, nasal, or optic disc – were detected in our cohort. This may suggest that while vascular dysregulation could be present in MS, it might not translate into overt structural changes of the choroid measurable by EDI-OCT.

Esen et al.[17] demonstrated a significant reduction in subfoveal and parafoveal CT in both MS eyes with and without a history of ON. These findings support the hypothesis that vascular dysregulation may play a

Table 5. Correlation coefficients between Expanded Disability Status Scale (EDSS) and duration of illness with study parameters in the multiple sclerosis group

	EDSS	Duration of illness
MV-Central	0.224	-0.094
MV-Superior	-0.160	0.041
MV-Nasal -0.168	0.146	
MV-Inferior	-0.109	0.037
MV-Temporal	0.026	-0.003
RNFL-Superior	-0.240	0.166
RNFL-Nasal	-0.276*	-0.187
RNFL-Inferior	-0.214	-0.110
RNFL-Temporal	-0.432**	-0.196
FCT	-0.067	-0.253*
FCT-Temporal	-0.155	-0.271*
FCT-Nasal	-0.064	-0.351**
ODCT-Temporal	-0.231	-0.033
ODCT-Nasal	-0.216	0.144

EDSS: Expanded Disability Status Scale; MV: Macular volume; RNFL: Retinal nerve fiber layer; FCT: Foveal choroidal thickness; ODCT: Optic disc choroidal thickness. *Correlation is significant at the 0.05 level. **Correlation is significant at the 0.01 level. Spearman's rho test was used for correlation analysis.

role in the pathophysiology of MS, independent of ON status. In a swept-source OCT study, MS patients showed significantly reduced CT in the outer macular ring, while peripapillary choroidal thinning was mild and not statistically significant.^[18] These discrepancies may arise from heterogeneity in disease stage, treatment status, imaging methodology, or segmentation protocols. Thus, while choroidal measurements may reflect disease-related vascular alterations in select populations, their diagnostic consistency across broader MS cohorts remains uncertain.

Similarly, central MV was comparable between MS patients and healthy individuals, implying that MV may not serve as a reliable indicator for MS-associated retinal damage. The correlations identified between EDSS and both RNFL and choroidal metrics were weak or non-significant, with the exception of a few temporal and nasal parameters. This suggests that RNFL may be a more robust marker of disease impact than macular or choroidal measurements.

Taken together, the limited differences observed in macular and choroidal parameters, as well as the weak associations between these measures and clinical variables, suggest that RNFL thickness may serve as a more consistent and clinically meaningful marker of disease burden in MS. The robust negative correlations between RNFL and EDSS scores support its potential role in monitoring disease trajectory. In addition, the negative relationships between disease duration and

inferior quadrant RNFL and FCT in nasal and temporal regions suggest that cumulative disease effects may contribute to structural degradation in select retinal areas.

Conversely, the lack of meaningful associations between OD-CT and clinical variables such as EDSS or disease duration implies that this parameter may not provide additional insight into MS-related neurodegenerative processes. Similarly, the slight positive correlation noted between EDSS and central MV may be of limited clinical importance and requires further validation.

While the present study stratified MS patients based on a clinically confirmed history of ON, it did not systematically incorporate functional assessments such as visual field analysis (VFA) or objective quantification of relative afferent pupillary defect (RAPD) during the inclusion process. These tools provide valuable insights into anterior visual pathway dysfunction, even in cases where structural damage may not be overtly visible on OCT. Previous studies have highlighted that RAPD can serve as an early indicator of optic nerve asymmetry, whereas VFA may detect localized defects before substantial RNFL thinning becomes apparent.^[19-21] Future research should consider incorporating these parameters into both diagnostic stratification and exclusion criteria to enhance phenotypic classification and better control for residual or subclinical optic nerve involvement.

This study is not without limitations. The cross-sectional nature of the design precludes any determination of temporal or causal relationships between structural changes and clinical progression. The relatively modest sample size, especially when stratified into ON and non-ON subgroups, could reduce statistical power and obscure more nuanced effects. Furthermore, the use of manual measurement for CT introduces the possibility of inter-observer variability, despite standardized measurement protocols and blinding.

Future research should prioritize longitudinal cohort studies to better delineate how retinal and choroidal structures evolve over the disease course. The integration of newer imaging modalities, such as OCT angiography (OCTA), may yield additional insights into vascular and microstructural contributions to MS pathology. Broadening patient recruitment to include individuals with progressive disease forms and evaluating systemic factors could also help contextualize retinal changes within the wider framework of MS pathogenesis.

Conclusion

In summary, our findings underscore the significance of RNFL thinning – particularly in the temporal and superior sectors

– as a potential imaging biomarker for neurodegeneration in MS. While choroidal and macular measurements offered limited diagnostic utility, RNFL metrics demonstrated strong associations with clinical disability and disease chronicity, supporting their integration into routine MS monitoring.

Ethics Committee Approval: This study was approved by The Kocaeli City Hospital Ethics Committee (09.01.2025 date; number 2024-165).

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