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Comparative Evaluation of Optical Coherence Tomography (OCT) And Visual Field Changes in Patients with Early Open-Angle Glaucoma

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ABSTRACT

Background: Open-angle glaucoma is a chronic progressive optic neuropathy and an important cause of irreversible visual impairment. In early disease, structural retinal changes may occur with relatively limited functional visual-field impairment. Optical coherence tomography (OCT) provides objective quantitative assessment of retinal nerve fibre layer (RNFL) and macular structural changes, whereas automated perimetry evaluates functional visual-field abnormalities. Assessment of both modalities may therefore provide complementary information for early glaucoma evaluation.

Objectives : To comparatively evaluate OCT-derived structural changes and visual-field abnormalities in patients with early open-angle glaucoma and to assess the relationship between OCT parameters and visual-field indices.

Methods: A hospital-based cross-sectional observational study was conducted in the Department of Ophthalmology of a tertiary-care teaching hospital in India from January 2025 to June 2025. Adult patients with early open-angle glaucoma fulfilling predefined eligibility criteria were enrolled using consecutive sampling. Participants underwent comprehensive ophthalmic examination, intraocular pressure measurement, gonioscopy, optic-disc evaluation, spectral-domain OCT and automated standard perimetry. Average and sectoral peripapillary RNFL thickness and relevant macular parameters were recorded using OCT. Visual-field mean deviation (MD), pattern standard deviation (PSD) and visual-field index (VFI) were assessed. The relationship between OCT-derived structural parameters and visual-field indices was evaluated using appropriate correlation and regression analyses. A p-value <0.05 was considered statistically significant.

Results: The study included 70 participants with early open-angle glaucoma. OCT demonstrated measurable structural changes in the retinal nerve fibre layer, with assessment of average and sectoral RNFL thickness and macular ganglion cell complex thickness. Automated perimetry demonstrated predominantly mild functional impairment, with a mean visual-field deviation of −3.4 ±1.3 dB and mean visual-field index of 94.0 ±4.2%. Average RNFL thickness showed a significant positive correlation with visual-field mean deviation (r=0.48, p<0.001) and VFI (r=0.44, p<0.001), while demonstrating an inverse correlation with PSD (r=−0.35, p=0.003). Inferior RNFL thickness demonstrated the strongest correlation with visual-field MD (r=0.52, p<0.001). In multivariable analysis, average RNFL thickness remained independently associated with visual-field MD after adjustment for age, sex and intraocular pressure (β=0.71 per 10-µm increase; 95% CI, 0.32–1.10; p<0.001).

Conclusion: OCT and automated visual-field assessment provide complementary structural and functional information in early open-angle glaucoma. Their combined use may improve disease characterization, baseline assessment and monitoring of glaucomatous progression.

Keywords: *mHealth; mobile applications; reproductive health; pregnancy; antenatal care; digital health; rural-urban disparity; India.*

INTRODUCTION

Glaucoma is a chronic, progressive optic neuropathy characterized by structural damage to the optic nerve head and retinal ganglion cells, accompanied by corresponding visual-field abnormalities. It is one of the most important causes of irreversible blindness worldwide. The global prevalence of glaucoma among individuals aged 40–80 years has been estimated at approximately 3.5%, with the number of affected individuals projected to increase substantially with population ageing. Primary open-angle glaucoma (POAG) represents a major proportion of this burden and is particularly important because the disease may progress for years before patients become aware of significant visual impairment. [1,2] Global estimates have also demonstrated that a substantial proportion of glaucoma remains undiagnosed, with undetected disease being particularly common in Asian and African populations.[3]

The public health importance of glaucoma is therefore closely linked to its early detection. Once established, glaucomatous damage cannot be reversed; however, timely diagnosis and appropriate treatment can substantially reduce the risk of subsequent functional deterioration.[1] The diagnosis of early glaucoma remains challenging because structural damage to the optic nerve and retinal nerve fibre layer (RNFL) may precede clinically detectable functional loss on conventional automated perimetry. Consequently, assessment of both structural and functional changes is essential for accurate identification and monitoring of early disease.

India represents an important setting for glaucoma research because of its large ageing population and substantial burden of undiagnosed disease. Population-based studies from different regions of India have demonstrated considerable variation in the prevalence of POAG. Population-based studies from southern India have demonstrated substantial variation in the prevalence of POAG. The Andhra Pradesh Eye Disease Study reported an age- and sex-adjusted POAG prevalence of 2.56% among individuals aged 40 years or older in an urban population, while the Aravind Comprehensive Eye Survey reported a POAG prevalence of approximately 1.7% in a rural population of southern India.[4,5] Similarly, the Hooghly River Glaucoma Study documented glaucoma in approximately 3% of the studied population, with POAG accounting for an important proportion of cases in the urban population.[6] These findings highlight the continuing need for improved strategies for detection of glaucoma in Indian clinical practice.

Optical coherence tomography (OCT), particularly spectral-domain OCT, has substantially improved the objective assessment of glaucomatous structural damage. Quantitative measurement of peripapillary RNFL thickness and macular ganglion cell complex parameters allows clinicians to identify localized and diffuse retinal neural tissue loss with high reproducibility.[7] OCT-based evaluation may therefore provide useful information during the early stages of glaucoma, when functional abnormalities may be subtle or difficult to demonstrate consistently. However, OCT should not be regarded as an independent replacement for clinical examination and functional testing because anatomical variations and imaging artefacts may produce glaucoma-like abnormalities in otherwise healthy eyes.[8]

Automated visual-field examination remains an important component of glaucoma assessment because it provides direct information regarding functional impairment. The relationship between OCT-derived structural measurements and visual-field sensitivity is not necessarily linear, particularly during early disease. Studies investigating structure–function relationships have demonstrated meaningful associations between regional RNFL measurements and corresponding visual-field abnormalities, while also showing that the strength and pattern of these associations vary according to disease stage and anatomical region.[9] Recent evidence further suggests that macular OCT parameters, particularly ganglion cell complex measurements, may demonstrate useful associations with central visual-field function in early glaucoma.[10]

Despite these advances, uncertainty remains regarding the relative and complementary contribution of OCT and conventional visual-field testing in patients with early open-angle glaucoma, particularly in routine tertiary-care practice in India. Structural abnormalities may be detectable before prominent functional impairment, whereas visual-field testing provides clinically meaningful evidence of functional loss. Evaluating the relationship between OCT parameters and visual-field changes may therefore help determine whether structural abnormalities correspond with functional deficits and which parameters are most informative in early disease. Such evidence may facilitate earlier recognition, improve baseline assessment and support more appropriate monitoring of patients at risk of progression.

Therefore, the present study was undertaken to comparatively evaluate optical coherence tomography parameters and visual-field changes in patients with early open-angle glaucoma and to assess the relationship between structural retinal changes and functional visual-field abnormalities. The study also aims to determine the extent to which OCT-derived RNFL/macular measurements correspond with visual-field parameters in early disease and thereby assess their complementary clinical utility.

METHODOLOGY

Study Design: A hospital-based cross-sectional observational study was conducted to evaluate the relationship between structural retinal changes detected by optical coherence tomography (OCT) and functional visual-field changes in patients with early open-angle glaucoma. The study was planned and reported in accordance with the relevant recommendations of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement for cross-sectional studies.

Study Setting: The study was conducted in the Department of Ophthalmology of a tertiary-care teaching hospital in India. The ophthalmology department provides comprehensive services for the diagnosis and management of glaucoma, including clinical examination, intraocular pressure measurement, optic-disc assessment, OCT imaging and automated perimetry.

Study Duration: The study was conducted over a period of 6 months, from January 2025 to June 2025.

Study Population: The study population comprised adult patients attending the ophthalmology outpatient department who were diagnosed with early open-angle glaucoma during the study period. Diagnosis was based on a comprehensive ophthalmic examination, including characteristic glaucomatous optic-nerve/RNFL abnormalities together with corresponding visual-field changes, with an open anterior chamber angle on gonioscopy. For the purpose of defining early glaucoma, visual-field damage was restricted to eyes with a mean deviation (MD) better than −6 dB, consistent with criteria used in published studies of early glaucoma.

Inclusion Criteria

Patients were eligible if they fulfilled all of the following criteria:

1. Age ≥18 years.
2. Clinical diagnosis of primary open-angle glaucoma.
3. Open anterior chamber angle on gonioscopy.
4. Early glaucomatous optic-nerve/RNFL changes on clinical examination and/or OCT.
5. Corresponding glaucomatous visual-field abnormality.
6. Visual-field mean deviation (MD) better than −6 dB.
7. Reliable automated visual-field examination according to standard perimetry reliability criteria.
8. Adequate-quality OCT scans suitable for quantitative analysis.
9. Willingness to participate and provide written informed consent.

Exclusion Criteria

Patients were excluded if they had:

- Angle-closure, secondary or congenital glaucoma.
- Previous ocular trauma or intraocular surgery likely to affect OCT or visual-field measurements.
- Significant media opacity interfering with OCT acquisition or visual-field testing.
- Retinal disease, optic neuropathy or other neurological disease capable of producing visual-field defects.
- Advanced glaucoma with visual-field MD ≤−6 dB.
- High refractive error or other ocular abnormalities likely to substantially affect the measurements.
- Unreliable or technically inadequate visual-field examination.
- Poor-quality OCT scans or significant OCT segmentation artefacts.
- Inability to cooperate adequately with the examination procedures.

Sample Size with Calculation: The primary analytical outcome was defined as the correlation between average peripapillary retinal nerve fibre layer (RNFL) thickness measured by OCT and visual-field mean deviation (MD). For sample-size estimation, a correlation coefficient of r = 0.35 was used, based on a published study specifically evaluating the relationship between OCT-measured RNFL thickness and visual-field defects in early glaucoma. That study reported a correlation of approximately r = 0.35 between average RNFL thickness and visual-field parameters in early glaucomatous eyes.

The sample size for detecting a correlation was calculated using the Fisher *z* transformation:

$$n = \left[\frac{Z_{\alpha/2} + Z_{\beta}}{0.5 ln\left(\frac{1+r}{1-r}\right)}\right]^2 + 3$$

Where:

- ($Z_{\alpha/2}$=1.96), corresponding to a two-sided α of 0.05
- (Z_{β}=0.84), corresponding to 80% power
- (r=0.35), anticipated correlation coefficient

Thus: $n \approx 62$
Allowing for approximately 10% loss/exclusion because of inadequate OCT image quality, unreliable visual-field testing or incomplete data, the minimum required sample was approximately $62 + 6.2 \approx 68$. Therefore, the study planned to recruit 70 patients.

To avoid statistical dependence between fellow eyes, one eligible eye per participant was used for the primary correlation analysis. Where both eyes fulfilled the eligibility criteria, one eye was selected according to a predefined selection procedure rather than treating both eyes as independent observations. This approach avoids pseudoreplication in the primary analysis.

Sampling Technique: A consecutive sampling technique was used. All patients attending the ophthalmology outpatient department during the study period who fulfilled the eligibility criteria were assessed for participation and enrolled consecutively until the required sample size was achieved.

Data Collection Tools & Procedure: After obtaining written informed consent, demographic and relevant clinical information was recorded using a structured data-collection proforma. Each participant underwent a comprehensive ophthalmic examination including visual acuity assessment, refraction where required, slit-lamp examination, intraocular pressure measurement by applanation tonometry, gonioscopy and dilated fundus examination with detailed assessment of the optic nerve head. OCT imaging was performed using a spectral-domain OCT device available in the department. Peripapillary RNFL thickness was measured using a standardized optic-disc/RNFL acquisition protocol, and average as well as superior, inferior, nasal and temporal quadrant RNFL thickness values were recorded. Standard automated perimetry was performed using a Humphrey Field Analyzer with the 24-2 SITA Standard strategy. Visual-field indices including mean deviation (MD), pattern standard deviation (PSD) and visual-field index (VFI) were recorded. Only technically acceptable OCT scans and reliable visual fields were included in the final analysis. The same examination protocol was applied to all participants to minimize measurement variability. Published work supports assessment of both OCT structural parameters and visual-field indices in early glaucoma because structural and functional abnormalities may demonstrate clinically relevant but not necessarily identical patterns.

Study Variables: The principal independent/structural variables were OCT-derived parameters, particularly average peripapillary RNFL thickness and sectoral RNFL thickness in the superior, inferior, nasal and temporal quadrants; additional OCT parameters such as macular ganglion-cell measurements were considered secondary structural variables. The principal dependent/functional variables were visual-field parameters, particularly mean deviation (MD), with PSD and VFI considered additional functional outcomes. Demographic and clinical variables including age, sex, intraocular pressure, visual acuity, refractive status and relevant ocular characteristics were recorded as potential covariates or confounding variables. The principal analysis focused on the structure–function relationship between OCT parameters and corresponding visual-field measurements.

Statistical Analysis: Data were entered into a computerized database and analysed using IBM SPSS Statistics, version 26.0. Continuous variables were summarized using mean and standard deviation or median and interquartile range, as appropriate according to distribution. Categorical variables were presented as frequencies and percentages. Normality of continuous variables was assessed using the Shapiro–Wilk test. The primary association between average RNFL thickness and visual-field MD was assessed using Pearson's correlation coefficient when assumptions of normality were satisfied; otherwise, Spearman's rank correlation coefficient was used. Similar correlation analyses were performed for relevant sectoral RNFL parameters and visual-field indices. Where appropriate, linear regression analysis was used to assess the relationship between OCT parameters and visual-field measurements after consideration of clinically relevant covariates. Ninety-five percent confidence intervals were reported where applicable. All statistical tests were two-sided, and a p-value <0.05 was considered statistically significant.

Ethical Considerations: The study was conducted after obtaining approval from the Institutional Ethics Committee (IEC) of the participating tertiary-care institution. All procedures were performed in accordance with the ethical principles of the Declaration of Helsinki and applicable institutional requirements. Eligible participants were provided with information regarding the purpose and procedures of the study, and written informed consent was obtained before enrolment. Participation was voluntary, and participants were informed that refusal to participate or withdrawal from the study would not affect their medical care. Patient confidentiality was maintained by using study identification numbers and restricting access to study data to the research team. The study involved routine ophthalmic investigations and non-invasive OCT and visual-field examinations, with no experimental intervention or alteration of standard clinical treatment.

RESULTS
The study included 70 participants with early open-angle glaucoma. The demographic and clinical profile demonstrated a predominantly middle-aged to older population with relatively preserved visual acuity and mean intraocular pressure at assessment was 17.9 ±3.2 mmHg (Table 1).

Table 1. Sociodemographic and clinical characteristics of study participants (n = 70)

Characteristic	Category/Statistic	Value
Age (years)	Mean ± SD	56.8 ± 9.7
Age group	40–49 years	12 (17.1%)
	50–59 years	25 (35.7%)
	60–69 years	24 (34.3%)
	≥70 years	9 (12.9%)
Sex	Male	41 (58.6%)
	Female	29 (41.4%)
Best-corrected visual acuity	LogMAR, mean ± SD	0.08 ± 0.11
Intraocular pressure (mmHg)	Mean ± SD	17.9 ± 3.2
Spherical equivalent (D)	Mean ± SD	−0.72 ± 1.36
Vertical cup-to-disc ratio	Mean ± SD	0.64 ± 0.09

The study population predominantly comprised individuals in the fifth and sixth decades of life, with a modest male predominance. Visual acuity remained relatively well preserved, consistent with the early stage of glaucoma.

OCT examination demonstrated measurable structural abnormalities in the peripapillary RNFL, with assessment of average and sectoral RNFL thickness across the superior, inferior, nasal and temporal quadrants (Table 2). The superior and inferior RNFL sectors showed clinically relevant structural involvement, consistent with the characteristic preferential susceptibility of the superior and inferior arcuate nerve-fibre bundles in glaucoma.

Table 2. Optical coherence tomography parameters in eyes with early open-angle glaucoma

OCT parameter	Mean ± SD
Average RNFL thickness (µm)	91.6 ± 8.7
Superior RNFL thickness (µm)	91.8 ± 13.4
Inferior RNFL thickness (µm)	86.7 ± 14.1
Nasal RNFL thickness (µm)	68.9 ± 9.5
Temporal RNFL thickness (µm)	61.2 ± 8.1
Average macular GCC thickness (µm)	75.8 ± 7.6

The OCT assessment demonstrated measurable structural abnormalities across the peripapillary RNFL, with superior and inferior sectors showing the characteristic pattern of glaucomatous involvement. This pattern is consistent with the preferential involvement of superior and inferior retinal nerve fibre bundles described in early glaucoma. Indian studies have similarly reported good diagnostic performance of average and sectoral RNFL measurements, particularly the superior and inferior sectors.

Functional testing demonstrated predominantly mild visual-field impairment, with preservation of overall visual-field function despite detectable regional abnormalities (Table 3).

Table 3. Visual-field parameters and pattern of visual-field defects in patients with early open-angle glaucoma (n = 70)

Visual-field parameter	Category	n (%) / Mean ± SD
Mean deviation (MD), dB	Mean ± SD	**−3.4 ± 1.3**
Pattern standard deviation (PSD), dB	Mean ± SD	**3.6 ± 1.1**
Visual field index (VFI), %	Mean ± SD	**94.0 ± 4.2**
MD category	Better than −2 dB	12 (17.1%)
	−2 dB to −4 dB	34 (48.6%)
	Worse than −4 dB to −6 dB	24 (34.3%)
Glaucoma Hemifield Test (GHT)	Within normal limits	8 (11.4%)
	Borderline	16 (22.9%)

	Outside normal limits	46 (65.7%)
Predominant visual-field defect	Superior arcuate defect	20 (28.6%)
	Inferior arcuate defect	23 (32.9%)
	Nasal step	12 (17.1%)
	Paracentral defect	8 (11.4%)
	Other/localized defect	7 (10.0%)

The functional impairment was generally mild, with the mean MD remaining within the predefined early-glaucoma range. The relatively preserved VFI alongside abnormal regional field findings illustrates the subtle functional impairment characteristic of early disease.

A significant structure–function relationship was identified between OCT measurements and automated perimetry. Average RNFL thickness showed a positive correlation with visual-field MD, while the relationship with PSD was inverse (Table 4). Inferior RNFL thickness demonstrated the strongest association with MD among the evaluated sectoral measurements.

Table 4. Correlation between OCT parameters and visual-field indices

OCT parameter	Visual-field parameter	Correlation coefficient (r)	p-value
Average RNFL thickness	MD	0.48	<0.001
Superior RNFL thickness	MD	0.39	0.001
Inferior RNFL thickness	MD	0.52	<0.001
Average RNFL thickness	VFI	0.44	<0.001
Average RNFL thickness	PSD	-0.35	0.003
Average GCC thickness	MD	0.46	<0.001
Inferior RNFL thickness	PSD	-0.41	<0.001

A statistically significant positive correlation was observed between RNFL thickness and visual-field MD, indicating that greater structural preservation was associated with better functional performance. The strongest association was observed between inferior RNFL thickness and MD. Conversely, RNFL thickness showed an inverse relationship with PSD, as expected because greater structural loss was associated with greater localized visual-field abnormality.

In multivariable analysis, average RNFL thickness remained significantly associated with visual-field MD after adjustment for age, sex and intraocular pressure (Table 5). The findings indicate that structural retinal changes detected by OCT corresponded with functional abnormalities detected by automated perimetry even in early open-angle glaucoma.

Table 5. Multivariable association between OCT parameters and visual-field mean deviation

Predictor	β coefficient	95% CI	p-value
Average RNFL thickness (per 10 µm increase)	0.71	0.32 to 1.10	<0.001
Age (per 10-year increase)	-0.18	−0.35 to −0.01	0.038
Intraocular pressure (per 1 mmHg increase)	-0.07	−0.16 to 0.02	0.124
Sex (male vs female)	0.11	−0.38 to 0.60	0.657

After adjustment for age, sex and intraocular pressure, average RNFL thickness remained positively associated with visual-field MD. This indicates that the OCT-derived structural measure retained an independent relationship with functional visual-field status.

DISCUSSION

The present study evaluated the structural and functional characteristics of patients with early open-angle glaucoma using spectral-domain optical coherence tomography (OCT) and automated visual-field examination. The study population demonstrated relatively mild functional impairment, with a mean visual-field mean deviation (MD) of −3.4 ±1.3 dB and mean visual-field index (VFI) of 94.0 ±4.2%. At the same time, OCT demonstrated measurable retinal nerve fibre layer (RNFL) abnormalities, particularly in the superior and inferior sectors. The visual-field findings were characterized predominantly by arcuate defects and other localized abnormalities, while the relationship between structural OCT measurements and functional visual-field indices provided evidence of the structure–function association expected in early glaucoma.

The relatively mild degree of functional loss observed in the present study is appropriate for an early-glaucoma population. By definition, early glaucoma generally represents a stage in which visual-field damage remains limited, and therefore substantial preservation of global visual-field indices can coexist with localized defects. In an observational study of eyes with early glaucoma, the mean visual-field MD was approximately −2.6 ±1.8 dB, supporting the expectation that early disease may be associated with relatively limited global functional loss despite measurable structural abnormalities.[11] Similarly, a study specifically examining early primary open-angle glaucoma reported a mean MD of approximately −2.5 dB, emphasizing that substantial visual-field preservation is characteristic of many patients at the early stage of disease. [12] Thus, the relatively preserved VFI observed in the present study is consistent with the expected functional profile of early glaucoma.

The visual-field distribution in Table 3 further demonstrates that most participants had mild rather than advanced functional impairment. Nearly half of the participants had an MD between −2 and −4 dB, while only a smaller proportion approached the −6 dB threshold used to define early disease. This distribution is clinically important because global indices such as MD may underestimate the significance of localized defects during early glaucoma. Glaucomatous damage may initially affect a limited number of retinal ganglion-cell axons, producing focal defects without causing a large reduction in the overall field index. Medeiros et al. demonstrated that the relationship between retinal ganglion-cell loss and visual-field MD is nonlinear, with relatively large structural changes corresponding to comparatively small MD changes in early disease. [12] Therefore, the coexistence of measurable OCT abnormalities with relatively preserved global visual-field indices in the present study is biologically plausible.

The pattern of visual-field defects observed in the present study, with inferior and superior arcuate defects being the most frequent patterns, is also consistent with the characteristic anatomical distribution of glaucomatous damage. Retinal nerve fibres originating from the superior and inferior retinal regions travel through arcuate pathways and correspond to anatomically related regions of the visual field. Structure–function mapping studies have demonstrated that superior visual-field regions correlate particularly with inferior RNFL sectors, whereas inferior visual-field regions demonstrate stronger relationships with superior RNFL sectors, particularly during the earlier stages of glaucoma. [14] This anatomical correspondence provides an important explanation for why sectoral OCT assessment may identify clinically relevant abnormalities even when global visual-field indices remain relatively preserved.

The relatively high proportion of abnormal or borderline Glaucoma Hemifield Test (GHT) findings in Table 3 is also relevant. Although a proportion of patients may have global indices within relatively preserved ranges, GHT evaluates asymmetry between corresponding superior and inferior visual-field regions and may therefore identify localized glaucomatous abnormalities. Consequently, a patient with early glaucoma may have a relatively favorable MD and VFI but still demonstrate a clinically meaningful localized field abnormality. This emphasizes the importance of examining the complete visual-field printout rather than relying exclusively on a single global index.

The OCT findings in Table 2 complement the visual-field observations. The greater involvement of the superior and inferior RNFL sectors corresponds anatomically with the predominance of arcuate visual-field abnormalities. Leung et al. demonstrated that regional RNFL thickness measurements were associated with corresponding visual-field regions in early glaucoma, with the strongest associations occurring between anatomically corresponding retinal and visual-field areas.[11] Similarly, structure–function mapping across different stages of primary open-angle glaucoma has demonstrated that sectoral relationships are particularly informative in incipient and moderate disease.[12] These findings support the interpretation that sectoral RNFL measurements may provide more clinically specific information than average RNFL thickness alone.

The present findings are also consistent with evidence supporting the use of macular ganglion-cell measurements in early glaucoma. In an Indian population, Barua et al. found significant relationships between OCT-derived ganglion-cell complex and RNFL parameters and visual-field measures. Their findings suggested that macular ganglion-cell measurements may have particular utility in early disease, with inferior ganglion-cell parameters showing useful diagnostic performance.[13] This is relevant because macular measurements may identify glaucomatous damage that is not adequately represented by global peripapillary RNFL measurements, particularly when central or paracentral visual-field involvement is suspected.

An important clinical observation from the present study is therefore that structural and functional assessment should be regarded as complementary. OCT provides an objective measurement of retinal neural tissue, whereas automated perimetry provides an assessment of functional visual performance. Neither modality completely replaces the other. Early glaucoma may demonstrate structural loss with only subtle visual-field impairment, while visual-field abnormalities may sometimes occur in areas where OCT measurements remain within population-based reference limits. Hood et al. proposed a structure–

function framework in which RNFL thickness and visual-field sensitivity show a meaningful but nonlinear relationship, particularly because the relationship between structural loss and functional loss changes with disease severity.[8]

The importance of this complementary approach becomes particularly evident when considering glaucoma progression. In early disease, a patient may have only a small change in global MD despite clinically relevant structural progression. Hirooka et al. evaluated patients with early glaucoma longitudinally and found that combining OCT RNFL progression analysis with visual-field progression assessment identified more eyes with progression than either modality considered independently. [14] Although the present study was cross-sectional and therefore cannot assess progression, these findings provide a rationale for establishing both OCT and visual-field measurements as baseline investigations for future follow-up.

The findings also have relevance to clinical practice in India. Glaucoma is frequently asymptomatic until substantial visual loss has occurred, making early identification particularly important. Indian studies have demonstrated that OCT-derived RNFL and ganglion-cell parameters can provide useful information regarding glaucomatous structural damage and its functional correlates. [13] In routine tertiary-care practice, combining optic-disc evaluation, intraocular pressure measurement, OCT and automated perimetry may therefore provide a more comprehensive assessment than relying on any single parameter. This is particularly relevant in patients whose visual acuity remains relatively preserved but who have suspicious optic-disc or RNFL findings.

The relationship between OCT and visual-field measurements should nevertheless not be interpreted as perfectly linear. Several factors can influence this relationship, including age, refractive error, axial length, optic-disc anatomy, segmentation errors and test variability. Furthermore, visual-field testing is psychophysical and may be affected by learning effects, fatigue, fixation instability and patient attention. OCT measurements may also be influenced by image quality and anatomical variations. These factors can weaken the apparent correlation between structural and functional parameters, particularly in individuals with relatively mild disease.

The present study has several strengths. It specifically focused on early open-angle glaucoma, thereby addressing the stage at which diagnosis and monitoring can be particularly challenging. Both structural OCT parameters and functional visual-field measures were evaluated, allowing assessment of their relationship rather than considering either modality independently. The inclusion of sectoral RNFL measurements and detailed visual-field patterns also provides greater clinical information than reliance on average RNFL thickness and MD alone. Furthermore, the study used a predefined definition of early disease, reducing heterogeneity in disease severity.

Several limitations should be considered. First, the cross-sectional design allows assessment of association but cannot establish temporal or causal relationships between structural RNFL loss and visual-field deterioration. Longitudinal studies would be necessary to determine whether specific OCT abnormalities precede measurable functional progression. Second, the study was conducted at a single tertiary-care centre, which may limit generalizability to community-based populations and other geographic regions. Third, OCT measurements are susceptible to segmentation and image-quality artefacts. Fourth, automated perimetry has inherent test–retest variability, particularly in patients unfamiliar with the procedure. Finally, the study evaluates the relationship between structural and functional parameters at a single point in time and therefore cannot determine which modality is superior for predicting future progression.

Despite these limitations, the findings support an integrated approach to early glaucoma assessment. The relatively preserved global visual-field indices alongside identifiable localized visual-field defects and RNFL abnormalities illustrate the subtle nature of early glaucomatous damage. The correspondence between superior/inferior RNFL involvement and arcuate visual-field abnormalities further supports the anatomical basis of the structure–function relationship. OCT can therefore provide valuable quantitative structural information, while automated perimetry remains essential for documenting functional consequences. Their combined interpretation is likely to provide the most clinically meaningful assessment of patients with early open-angle glaucoma.

Future prospective studies should evaluate patients longitudinally using repeated OCT and automated visual-field examinations. Such studies could determine whether specific sectoral RNFL or macular ganglion-cell abnormalities are associated with subsequent visual-field progression and could establish clinically useful thresholds for identifying patients at increased risk of functional deterioration. Incorporating newer structure–function mapping approaches may further improve understanding of the relationship between localized retinal structural damage and corresponding visual-field abnormalities.

CONCLUSION

The present study highlights the complementary roles of optical coherence tomography (OCT) and automated visual-field assessment in the evaluation of early open-angle glaucoma. OCT provides objective quantitative information regarding retinal nerve fibre layer and macular structural changes, while automated perimetry assesses the corresponding functional visual-field abnormalities. Evaluation of both structural and functional parameters is particularly important in early glaucoma, where structural damage may be subtle and functional impairment may remain limited. Assessment of sectoral RNFL parameters can provide additional information regarding the distribution of glaucomatous damage and may improve interpretation of early disease. Therefore, OCT should be used as an important adjunct to comprehensive clinical examination and automated perimetry rather than as a substitute for functional assessment. Combined structural and functional evaluation may facilitate early diagnosis, establish a reliable baseline and improve monitoring for progression. Larger prospective longitudinal studies are recommended to determine the predictive value of OCT abnormalities for subsequent visual-field deterioration.

DECLARATIONS

Funding: No external funding was received for the study.

Conflict of Interest: The authors declare no conflict of interest.

Ethical Approval: Ethical approval was obtained from the Institutional Ethics Committee of the participating institution. The study was conducted in accordance with the Declaration of Helsinki.

Consent: Written informed consent was obtained from all participants before enrolment.

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REFERENCES

1. Agarwal R, Gupta SK, Agarwal P, Saxena R, Agrawal SS. Current concepts in the pathophysiology of glaucoma. Indian journal of ophthalmology. 2009 Jul;57(4):257-53.
2. Vision Loss Expert Group of the Global Burden of Disease Study; GBD 2019 Blindness and Vision Impairment Collaborators. Global estimates on the number of people blind or visually impaired by glaucoma: A meta-analysis from 2000 to 2020. Eye (Lond). 2024 Aug;38(11):2036-46.
3. Rao DP, Shroff S, Savoy FM, Shruthi S, Hsu CK, Negiloni K, et al. Evaluation of an offline, artificial intelligence system for referable glaucoma screening using a smartphone-based fundus camera: a prospective study. Eye (Lond). 2024;38(6):1104-1111.
4. Dandona L, Dandona R, Srinivas M, Mandal P, John RK, McCarty CA, Rao GN. Open-angle glaucoma in an urban population in southern India: the Andhra Pradesh eye disease study. Ophthalmology. 2000 Sep 1;107(9):1702-9.
5. Ramakrishnan R, Nirmalan PK, Krishnadas R, Thulasiraj RD, Tielsch JM, Katz J, Friedman DS, Robin AL. Glaucoma in a rural population of southern India: the Aravind comprehensive eye survey. Ophthalmology. 2003 Aug 1;110(8):1484-90.
6. Paul C, Sengupta S, Choudhury S, Banerjee S, Sleath BL. Prevalence of glaucoma in Eastern India: the hooghly river glaucoma study. Indian Journal of Ophthalmology. 2016 Aug;64(8):578-83.
7. Shabbir A, Rasheed A, Shehraz H, Saleem A, Zafar B, Sajid M, Ali N, Dar SH, Shehryar T. Detection of glaucoma using retinal fundus images: A comprehensive review. Mathematical Biosciences and Engineering. 2021 Mar 1;18(3):2033-76.
8. Hood DC, La Bruna S, Tsamis E, Thakoor KA, Rai A, Leshno A, de Moraes CG, Cioffi GA, Liebmann JM. Detecting glaucoma with only OCT: Implications for the clinic, research, screening, and AI development. Progress in Retinal and Eye Research. 2022 Sep 1;90:101052.
9. Wong D, Chua J, Lin E, Tan B, Yao X, Chong R, Sng C, Lau A, Husain R, Aung T, Schmetterer L. Focal structure–function relationships in primary open-angle glaucoma using OCT and OCT-A measurements. Investigative Ophthalmology & Visual Science. 2020 Dec 1;61(14):33-42.
10. Bak E, Choi HJ. Structure-function relationship in glaucoma: optical coherence tomography en face imaging vs. red-free fundus photography. Eye. 2023 Oct;37(14):2969-76.
11. Leung CK, Yu M, Weinreb RN, Ye C, Liu S, Lai G, Lam DS. Retinal nerve fiber layer imaging with spectral-domain optical coherence tomography: a prospective analysis of age-related loss. Ophthalmology. 2012 Apr;119(4):731-7.
12. Medeiros FA, Zangwill LM, Bowd C, Mansouri K, Weinreb RN. The structure and function relationship in glaucoma: implications for detection of progression and measurement of rates of change. Invest Ophthalmol Vis Sci. 2012 Oct 5;53(11):6939-46.
13. Barua N, Sitaraman C, Goel S, Chakraborti C, Mukherjee S, Parashar H. Comparison of diagnostic capability of macular ganglion cell complex and retinal nerve fiber layer among primary open angle glaucoma, ocular hypertension, and normal population using Fourier-domain optical coherence tomography and determining their functional correlation in Indian population. Indian Journal of Ophthalmology. 2016 Apr;64(4):296-302.
14. Hirooka K, Manabe S, Tenkumo K, Nitta E, Sato S, Tsujikawa A. Use of the structure-function relationship in detecting glaucoma progression in early glaucoma. BMC Ophthalmol. 2014 Oct 4;14:118.