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Original Article

Correlation of Functional and Structural Changes in Primary Open-Angle Glaucoma Using Visual Field Testing and Optical Coherence Tomography: A Cross-Sectional Study.

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Abstract

Background:
Primary open-angle glaucoma (POAG) is characterized by progressive optic nerve damage, retinal nerve fibre layer (RNFL) loss, and visual field impairment.

Objective:
To assess the correlation between structural and functional alterations in POAG using spectral domain optical coherence tomography (SD-OCT) and automated visual field testing.

Methods:
This hospital-based cross-sectional study included 204 subjects with POAG who attended the Department of Ophthalmology, Rajarshi Dashrath Autonomous State Medical College, Ayodhya. Visual acuity, intraocular pressure (IOP), slit-lamp optic nerve head evaluation with 90D lens, gonioscopy, SD-OCT-based RNFL assessment, and automated perimetry were performed.

Results: The study included 204 subjects contributing 360 eyes. Most subjects were aged 51-60 years (71; 34.8%), and 124 (60.8%) were male. IOP was 10-21 mmHg in 139 (68.1%) subjects and 22-30 mmHg in 65 (31.9%). Mean RNFL thickness was higher in the 10-21 mmHg group than in the 22-30 mmHg group (100.4 ± 10.5 µm vs. 60.3 ± 10.7 µm; $p < 0.0001$). Clinical cup-disc ratio correlated significantly with SD-OCT cup-disc ratio ($p = 0.0006$) and visual field defect ($p = 0.0006$). OCT sectoral rim defects showed significant correlation with corresponding visual field defects ($\chi^2 = 13.30$; $p = 0.004$).

Conclusion:
Higher IOP was associated with lower RNFL thickness, and structural OCT findings correlated significantly with visual field loss in POAG.

Recommendation:
Combined SD-OCT and automated perimetry should be used for routine assessment and follow-up of POAG, especially when early structural-functional correlation is clinically required.

Keywords: *Glaucoma; primary open-angle glaucoma; intraocular pressure; optical coherence tomography; retinal nerve fibre layer thickness; visual field; slit-lamp biomicroscopy.*

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Introduction

Glaucoma is a chronic, multifactorial optic neuropathy characterized by progressive retinal ganglion cell loss, optic nerve head cupping, thinning of the retinal nerve fibre layer, and corresponding visual field damage. Primary open-angle glaucoma is an adult-onset form in which the anterior chamber angle remains open, while structural and functional deterioration progress gradually. It is a major cause of irreversible visual impairment and requires timely detection and longitudinal monitoring [1].

Assessment of glaucoma depends on the combined interpretation of structural and functional parameters. Structural damage can be evaluated clinically by slit-lamp biomicroscopy with a high-power lens and objectively by spectral domain optical coherence tomography, which quantifies peripapillary retinal nerve fibre layer thickness and optic nerve head parameters. Functional damage is assessed using standard automated perimetry, which identifies characteristic visual field defects and supports assessment of disease severity and progression [2,3].

The relationship between OCT-based structural parameters and automated perimetry findings remains clinically important because structural loss may be detectable before obvious functional loss in some patients, while functional testing may provide greater specificity once field defects are established. Variability in test reliability, media clarity, patient cooperation, axial length, disease stage, and observer-dependent disc assessment may influence the correlation between these measurements [4].

Although several studies have examined structure-function relationships in primary open-angle glaucoma, the strength and pattern of correlation may vary across populations and clinical settings. Therefore, the present study was conducted to assess the correlation between functional and structural alterations in subjects with primary open-angle glaucoma using visual field testing and spectral domain optical coherence tomography in a tertiary care ophthalmology setting.

Materials and Methods

Study design

This was a hospital-based cross-sectional study designed to assess the correlation between structural and functional ocular alterations in subjects with primary open-angle glaucoma. Each eligible participant was assessed once during the study period. The design was appropriate because the objective was to determine the relationship between retinal nerve fibre layer thickness, optic nerve head parameters, and visual field findings at a defined point of clinical evaluation rather than to study treatment response over time.

Study area

The study was conducted in Ayodhya, Uttar Pradesh, India. Ayodhya is an important urban and peri-urban centre in eastern Uttar Pradesh, with patients attending tertiary care services from the city, nearby rural areas, and adjoining districts. The study area, therefore, represents a mixed population with varied access to primary, secondary, and tertiary eye care services.

Study setting

The study was carried out in the Department of Ophthalmology, Rajarshi Dashrath Autonomous State Medical College and associated hospital, Darshan Nagar, Ayodhya, Uttar Pradesh, India. The institute functions as a government tertiary care teaching hospital and is associated with approximately 500 hospital beds. The hospital provides outpatient, inpatient, emergency, surgical, diagnostic, and specialty services across major clinical departments, including medicine, surgery, obstetrics and gynaecology, paediatrics, orthopaedics, ENT, ophthalmology, dermatology, anaesthesiology, radiodiagnosis, pathology, microbiology, and other supportive services. The ophthalmology department manages refractive errors, cataract, glaucoma, retinal diseases, ocular surface disorders, trauma-related eye conditions, and neuro-ophthalmic complaints. The hospital serves patients from the Ayodhya district and neighbouring regions.

Duration of the study

The study was conducted from 1 January 2025 to 31 December 2025. Recruitment, clinical assessment, OCT evaluation, visual field testing, data entry, and analysis were completed during this period.

Study population

The study population consisted of subjects diagnosed with primary open-angle glaucoma who attended the Department of Ophthalmology during the study period and fulfilled the eligibility criteria. Subjects were selected from patients undergoing glaucoma evaluation and follow-up in the outpatient department.

Inclusion criteria: Subjects with primary open-angle glaucoma, open anterior chamber angle on gonioscopy, glaucomatous optic nerve head changes, reliable visual field testing, and acceptable-quality SD-OCT scans were included. Both treated and newly evaluated POAG subjects were eligible when the required clinical and imaging data were available.

Exclusion criteria: Subjects with angle-closure glaucoma, secondary glaucoma, neurological deficits, visual acuity below 6/18, optic neuritis, cataract greater than grade II nuclear sclerosis, age-related macular degeneration, retinal or optic nerve disease other than glaucoma, poor-quality OCT scan, unreliable visual field report, and incomplete clinical data were excluded.

Sample size determination

The sample size was estimated using the single-proportion formula for cross-sectional studies: $n = Z^2pq/d^2$, where $Z = 1.96$ for 95% confidence level, $p = 0.15$ as the expected proportion of clinically relevant glaucomatous structural-functional abnormality based on previous clinic-based glaucoma data, $q = 1-p$, and $d = 0.05$ as the acceptable absolute precision. Therefore, $n = (1.96)^2 \times 0.15 \times 0.85 / (0.05)^2 = 195.9$. After allowing approximately 5% for incomplete or unusable data, the required sample size was about 206. During the study period, 204 eligible subjects with complete clinical, OCT, and visual field data were included in the final analysis.

Bias

Potential selection bias was reduced by screening consecutive patients who attended the ophthalmology department during the study period and by applying predefined inclusion and exclusion criteria. Measurement bias was minimized by using standardized procedures for visual acuity assessment, IOP

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measurement, slit-lamp optic nerve head examination, gonioscopy, automated perimetry, and SD-OCT. OCT scans with poor signal or missing sectors, and unreliable visual field records were excluded. Observer-related bias in disc assessment was reduced by correlating clinical cup-disc ratio with objective SD-OCT parameters. Confounding by non-glaucomatous retinal or optic nerve disease was reduced by excluding ocular and neurological conditions known to affect RNFL thickness or visual field.

Study procedure

After obtaining consent, demographic details and relevant ocular history were recorded. Each participant underwent visual acuity assessment using the Snellen chart, anterior segment examination with slit-lamp biomicroscopy, IOP measurement using Goldmann applanation tonometry, gonioscopy using a four-mirror gonioscope, optic nerve head examination using slit-lamp biomicroscopy with a 90D lens, automated visual field testing, and SD-OCT evaluation. Visual field defects were documented from the total deviation plot and categorized into superotemporal, temporal, inferotemporal, inferonasal, nasal, and superonasal regions. SD-OCT was used to measure peripapillary RNFL thickness and optic nerve head parameters. The scan was accepted only when a clear fundus image, continuous scan pattern, and adequate signal quality were obtained.

For RNFL analysis, the circular scan pattern around the optic disc was used. Mean global RNFL thickness and quadrant-wise values were recorded for superior, inferior, nasal, and temporal regions. Sectoral RNFL thinning was compared with corresponding visual field defects. When both eyes were eligible, both eyes were clinically assessed, and eye-wise structural-functional findings were recorded; subject-level descriptive analysis was reported separately.

Data processing and data analysis

Data were entered into a structured proforma and cross-checked for completeness before statistical analysis. Continuous variables were summarized as mean ± standard deviation. Categorical variables were presented as frequency and percentage. Differences in mean RNFL thickness according to IOP category were assessed using the independent t-test or analysis of variance as appropriate. Association between categorical structural and functional variables was assessed using the chi-square test or Fisher's exact test when cell counts were small. Correlation between clinical cup-disc ratio, SD-OCT cup-disc ratio, RNFL thickness, and visual field defect was examined using appropriate correlation and association tests. Statistical analysis was performed using SPSS version 24.0 (IBM Corp., Armonk, NY, USA). A p-value below 0.05 was considered statistically significant.

Ethical consideration

The study protocol was reviewed and approved by the Institutional Ethics Committee, Rajarshi Dashrath Autonomous State Medical College, Ayodhya, Uttar Pradesh, India. The study was conducted in accordance with the principles of confidentiality and voluntary participation.

Informed consent

Written informed consent was obtained from each participant before enrolment. The purpose of the study, nature of eye examination, use of clinical data, confidentiality safeguards, and the voluntary right to withdraw were explained in a language understood by the participant. For participants requiring assistance, information was explained in the presence of an attendant, and consent was documented before data collection.

Results

Participant flow

A total of 360 patients attending the ophthalmology outpatient department were screened during the study period. Of these, 156 were excluded because of non-eligibility, incomplete clinical data, unreliable visual field reports, poor-quality OCT scans, or non-participation. Finally, 204 eligible subjects with complete clinical, SD-OCT, and visual field data were included in the final analysis. Follow-up assessment was not applicable because the study was cross-sectional (Table 1 and Figure 1).

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Table 1. Participant flow through the study

Study stage	Number	Reason or status
Potentially eligible patients identified in the Ophthalmology OPD	360	Patients attending for glaucoma evaluation during the study period
Examined for eligibility	360	Screened using predefined inclusion and exclusion criteria
Excluded before enrolment	156	Angle-closure/secondary glaucoma, neurological or retinal disease, BCVA <6/18, cataract > grade II nuclear sclerosis, poor-quality OCT/VF, incomplete data, or non-participation
Confirmed eligible	204	Met the criteria for primary open-angle glaucoma
Included in the study	204	Underwent clinical examination, IOP measurement, gonioscopy, SD-OCT, and visual field testing
Completed index visit assessment	204	Cross-sectional assessment completed; follow-up not applicable
Included in final analysis	204	Complete, analyzable subject-level data available; 360 eyes assessed

Table 1 shows that 204 of 360 screened patients were included in the final analysis. The main reasons for exclusion were non-eligibility, incomplete assessment, poor test quality, and non-participation. Because this was a cross-sectional study, no follow-up attrition occurred.

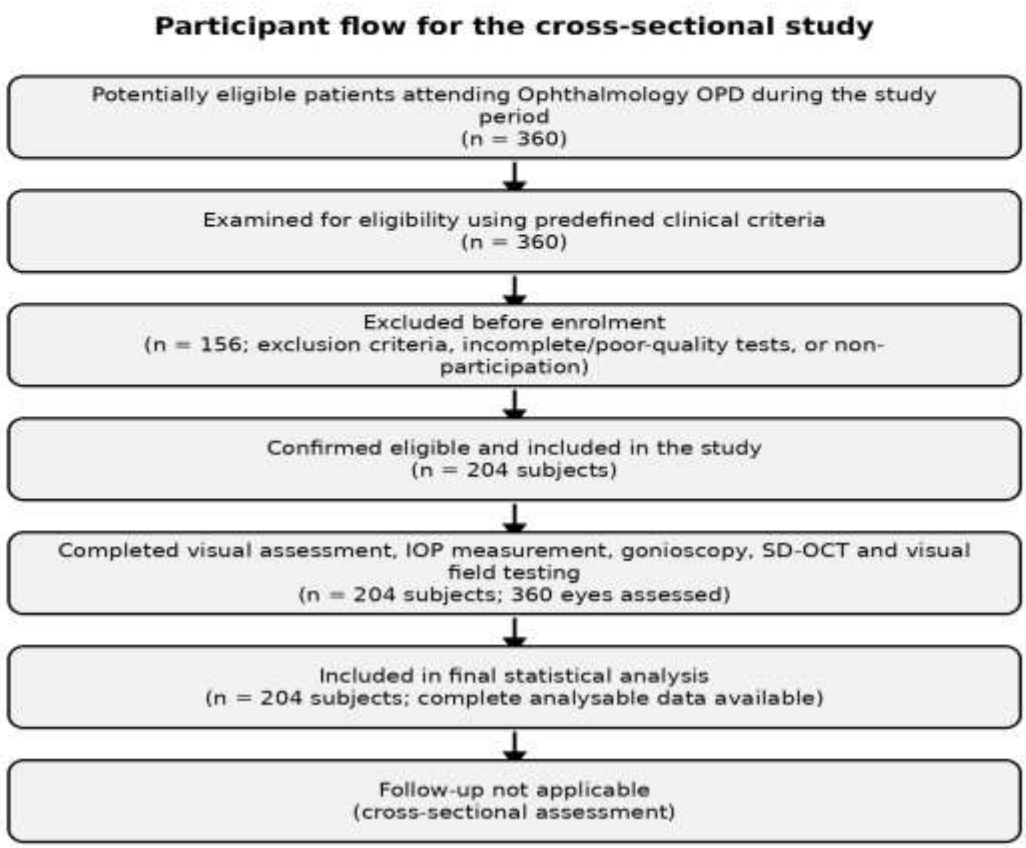

Figure 1. Participant flow diagram for the cross-sectional study.

Descriptive data

The study included 204 subjects with primary open-angle glaucoma. Most subjects were in the age group of 51-60 years, accounting for 71 (34.8%) participants. Male participants constituted 124 (60.8%) of the sample. Bilateral eye assessment was possible in 156 subjects, while 48 subjects contributed one eligible eye each, resulting in 360 eyes assessed for structural and functional parameters (Table 2).

Table 2. Socio-demographic and clinical characteristics of the study participants

Variable	Number of subjects	Percentage
Age group, years		
≤40	28	13.7
41-50	54	26.5
51-60	71	34.8
61-70	38	18.6
>70	13	6.4
Sex		
Male	124	60.8
Female	80	39.2
Eye assessment pattern		
Bilateral eye assessment	156	76.5
Unilateral eligible eye assessment	48	23.5

Table 2 indicates that the study population was predominantly middle-aged to elderly, with the highest proportion in the 51-60-year age group. A male predominance was observed, and most participants had both eyes assessed for POAG-related changes.

Intraocular pressure and retinal nerve fibre layer thickness

Table 3. Intraocular pressure category and mean retinal nerve fibre layer thickness

IOP category	Number of subjects	Percentage	Mean RNFL thickness, µm	p-value
10-21 mmHg	139	68.1	100.4 ± 10.5	<0.0001
22-30 mmHg	65	31.9	60.3 ± 10.7	<0.0001

Table 3 shows that subjects with higher IOP had substantially lower mean RNFL thickness. The difference between the 10-21 mmHg and 22-30 mmHg groups was statistically significant ($p < 0.0001$), indicating that increasing IOP was associated with greater structural retinal nerve fibre layer loss.

Distribution of retinal nerve fibre layer thickness

Table 4. Distribution of retinal nerve fibre layer thickness in study subjects

RNFL thickness range, µm	Number of subjects	Percentage
51-60	53	26.0
61-70	39	19.1
71-80	24	11.8
81-90	22	10.8
91-100	20	9.8
101-110	15	7.4
111-120	11	5.4
121-130	20	9.8

Table 4 demonstrates that the most frequent RNFL thickness category was 51-60 µm, observed in 53 (26.0%) subjects, followed by 61-70 µm in 39 (19.1%) subjects. These findings indicate that a considerable proportion of the study population had measurable RNFL thinning.

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Structural-functional correlation

Table 5. Summary of structural-functional association tests

Analysis	Statistical test/result	p-value	Interpretation
Clinical cup-disc ratio vs. SD-OCT cup-disc ratio	$\chi^2 = 17.32$	0.0006	Statistically significant association
Clinical cup-disc ratio vs. visual field defect	$\chi^2 = 17.32$	0.0006	Statistically significant association
Overall, OCT abnormality vs. visual field abnormality	$\chi^2 = 6.63$	0.01	Statistically significant association
Sectoral OCT rim defect vs. corresponding VF defect	$\chi^2 = 13.30$	0.004	Statistically significant association

Table 5 shows that the clinical cup-disc ratio was significantly associated with the SD-OCT cup-disc ratio and visual field defect. The chi-square analysis also confirmed a statistically significant association between OCT-detected structural abnormality and visual field abnormality, supporting a clinically meaningful structure-function relationship in POAG.

Table 6. Correlation of visual field defect and OCT rim status in study eyes

OCT rim status	n	%	Corresponding visual field defect	n	%
Inferior-temporal sector	170	46.75	Superonasal field defect	196	53.90
Superior-nasal sector	88	24.20	Inferotemporal field defect	38	10.45
Superior-temporal sector	70	19.25	Inferonasal field defect	86	23.65
Inferior-nasal sector	68	18.70	Superotemporal field defect	48	13.20

Chi-square test: $\chi^2 = 13.30$, $p = 0.004$. Multiple sectoral defects could be present in some eyes; therefore, percentages do not necessarily total 100%.

Table 6 demonstrates a significant correlation between OCT sectoral rim defects and corresponding visual field defects. Inferior-temporal OCT sector defects were most frequently observed and were commonly associated with superonasal visual field defects. The sectoral association was statistically significant ($p = 0.004$).

Discussion

This hospital-based cross-sectional study assessed the correlation between structural and functional alterations in subjects with primary open-angle glaucoma using clinical optic nerve head assessment, SD-OCT, and automated visual field testing. The study included 204 subjects and 360 assessed eyes. Most participants were aged 51-60 years, and a male predominance was observed. These demographic findings are consistent with the expected pattern of glaucoma presentation in tertiary care ophthalmology settings, where middle-aged and elderly adults form a substantial proportion of patients requiring detailed glaucoma evaluation.

The study demonstrated a clear association between higher IOP and lower RNFL thickness. Subjects with IOP between 22 and 30 mmHg had markedly reduced mean RNFL thickness compared with subjects whose IOP was between 10 and 21 mmHg. This finding supports the established concept that raised IOP contributes to progressive retinal ganglion cell and RNFL loss in susceptible optic nerves. Similar relationships between IOP, RNFL thinning, and glaucomatous optic nerve damage have been reported in previous OCT-based studies [5,7,8].

Clinical cup-disc ratio showed a significant association with SD-OCT cup-disc ratio and visual field defects. This indicates that clinical optic disc evaluation remains valuable but should be supported by objective imaging, especially when early or subtle glaucomatous changes are suspected. The significant correlation between OCT abnormality and visual field abnormality further supports the complementary role of structural and functional testing. OCT provides a sensitive method for identifying RNFL and optic nerve head changes, while automated perimetry helps characterize functional impairment and disease impact [6,9,10].

Sectoral analysis showed significant correspondence between OCT rim status and visual field defects. Inferior-temporal sector involvement was commonly linked with superonasal field defects, which is anatomically plausible because localized structural damage in the optic nerve head and RNFL is expected to produce corresponding visual field loss in the opposite field region. These observations strengthen the clinical value of topographic comparison between OCT and perimetry in POAG assessment [11,12].

Overall, the findings support the routine combined use of SD-OCT and automated perimetry in glaucoma evaluation. Reliance on either test alone may be inadequate because OCT and visual field testing provide different but complementary information.

Integrated interpretation can improve diagnosis, staging, follow-up planning, and identification of progressive disease.

Generalizability

The findings are most generalizable to patients with primary open-angle glaucoma attending tertiary care ophthalmology departments with access to SD-OCT and automated perimetry. The inclusion of consecutive eligible subjects improves clinical relevance within similar hospital-based settings. However, wider generalization to community populations, early undiagnosed glaucoma, secondary glaucoma, angle-closure glaucoma, and centres without advanced imaging should be made cautiously because this was a single-centre hospital-based study.

Conclusion

The study concludes that higher intraocular pressure is significantly associated with lower retinal nerve fibre layer thickness in subjects with primary open-angle glaucoma. Clinical cup-disc ratio, SD-OCT cup-disc ratio, OCT rim status, and automated visual field defects showed statistically significant structural-functional correlation. SD-OCT appears highly useful for identifying structural glaucomatous damage, while visual field testing remains essential for confirming functional impairment. Combined interpretation of OCT and perimetry provides a stronger basis for diagnosis, staging, and follow-up of POAG than either modality alone.

Limitations

The study was limited by its single-centre cross-sectional design, which prevents assessment of disease progression over time. Referral bias may have occurred because participants were recruited from a tertiary care hospital. Lack of longitudinal follow-up limited the ability to determine whether OCT and visual field changes progressed at similar rates. Exclusion of poor-quality OCT scans and unreliable visual fields may have reduced measurement error, but could also have excluded advanced or less cooperative patients. Axial length, glaucoma duration, treatment adherence, and disease stage were not fully adjusted, which may have influenced RNFL measurements and structure-function correlation.

Recommendations

Combined SD-OCT and automated visual field testing should be incorporated into the routine evaluation and follow-up of patients with primary open-angle glaucoma wherever facilities are available. Patients with higher IOP and reduced RNFL thickness should receive closer monitoring for progression. Future studies should use multicentre recruitment, longitudinal follow-up, disease-stage stratification, axial length adjustment, and standardized visual field reliability criteria. These steps will help clarify the predictive value of OCT-derived RNFL measurements for future functional visual field loss.

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List of Abbreviations

Abbreviation	Full form
ARMD	Age-related macular degeneration
BCVA	Best-corrected visual acuity
CD ratio	Cup-disc ratio
GHT	Glaucoma hemifield test
IOP	Intraocular pressure
OCT	Optical coherence tomography
POAG	Primary open-angle glaucoma
PSD	Pattern standard deviation
RNFL	Retinal nerve fibre layer
SAP	Standard automated perimetry
SD-OCT	Spectral domain optical coherence tomography
SPSS	Statistical Package for the Social Sciences
VF	Visual field

Declarations

Source of funding

The study did not receive any external funding.

Conflict of interest

The authors declare that there is no conflict of interest.

Availability of data

The data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to institutional permission and participant confidentiality requirements.

Author contributions

Dr Vipin Singh contributed to study conception, clinical assessment, data acquisition, literature review, manuscript drafting, and final approval. Dr Rajwinder Kaur contributed to methodology development, ophthalmic evaluation, data organization, interpretation of findings, manuscript revision, and final approval. Dr Alok Kumar contributed to study supervision, structural-functional correlation analysis, critical review, intellectual content refinement, and final approval. All authors agreed to be accountable for the accuracy and integrity of the work.

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