J Biochem Technol (2026) 17(2): 176-184
https://doi.org/10.51847/DjNb9ioG6W
ISSN: 0974-2328

Fourier-Domain OCT Comparison of Macular Ganglion Cell and Retinal Nerve Fiber Layer Diagnostics

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Received: 01 February 2026 / Received in revised form: 26 April 2026, Accepted: 01 May 2026, Published online: 25 May 2026

Abstract

Analysis of the diagnostic ability of the macular ganglion cell complex (GCC) and retinal nerve fiber layer (RNFL) in glaucoma. To correlate functional and structural parameters obtained through Fourier- Domain Optical Coherence Tomography (FD-OCT) and compare the predictive value of each structural parameter between individuals with primary open-angle glaucoma (POAG) and a normal population in Riyadh, Saudi Arabia. Cross-sectional study involving 200 eyes. Participants were divided into two groups: POAG and normal (50 individual in every group, totaling 100 participants). Following a comprehensive ophthalmological tests, all subjects conduct standard automated perimetry and FD-OCT scans using optic nerve head and ganglion cell modes. The association between structural parameters was evaluated by correlating GCC measurements with RNFL values. Data were analyzed using SPSS. Independent t-tests, Mann-Whitney tests, and Spearman's rank correlation were employed. All structural parameters in the POAG group demonstrated significant thinning compared to the control group ($P < 0.001$). A strong correlation was observed between average GCC and average RNFL values ($P < 0.001$). In this study, GCC and RNFL measurements obtained through FD-OCT served as complementary biomarkers in clinical decision-making. Both showed equal predictive capability in distinguishing POAG from normal individuals.

Keywords: Fourier-domain optical coherence tomography, Ganglion cell complex, Retinal nerve fiber layer, Primary open-angle glaucoma

Introduction

Glaucoma Overview and Diagnostic Importance

Glaucoma is one of the leading causes of irreversible blindness worldwide, affecting an estimated 80 million people globally. Early detection and accurate diagnosis are critical to preventing further vision loss, as the disease often progresses silently until significant optic nerve damage has occurred. Glaucoma refers to a group of conditions that damage the optic nerve, typically associated with elevated intraocular pressure (IOP), although it can also develop in individuals with normal IOP—a condition known as normal-tension glaucoma.

There Are Several Types of Glaucoma

Primary Open-Angle Glaucoma (POAG)

This is the most common form of glaucoma. It is characterized by a gradual increase in IOP and progressive optic nerve damage. POAG typically develops without noticeable symptoms until later stages. Although the anterior chamber angle remains open, aqueous humor outflow is impaired due to dysfunction of the trabecular meshwork, resulting in inefficient fluid drainage. Identified risk factors include advanced age, elevated IOP, reduced central corneal thickness (CCT), African ethnicity, high myopia, and a family history of glaucoma.

Among these, elevated IOP is the only modifiable risk factor, making it a central focus of both treatment and monitoring.

Angle-Closure Glaucoma

This occurs when the anterior chamber angle becomes blocked, leading to a sudden and severe rise in IOP. Symptoms can include acute eye pain, nausea, and sudden vision loss. Angle-closure glaucoma is a medical emergency requiring immediate treatment.

Normal-Tension Glaucoma (NTG)

In this form of glaucoma, optic nerve damage occurs despite IOP remaining within the normal range. The exact cause is not fully understood, but reduced blood flow to the optic nerve is believed to be a contributing factor (Talaat *et al*., 2021).

Secondary Glaucoma

This type develops due to another underlying condition, such as eye injury, previous eye surgery, inflammation, or systemic diseases like diabetes. It may also result from the use of certain medications, particularly corticosteroids (Talaat *et al*., 2021).

Congenital Glaucoma

A rare form of glaucoma that affects infants or young children due to abnormal development of the eye's drainage system, leading to increased IOP and optic nerve damage (Sudhalkar *et al*., 2021).

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Each type of glaucoma has distinct causes, patterns of progression, and treatment approaches. However, all share the risk of optic nerve damage, which can result in permanent vision loss if not promptly treated (Sudhalkar *et al*., 2021).

Ocular Hypertension (OH) refers to elevated IOP without detectable optic nerve damage or visual field loss. It may result from increased aqueous humor production or decreased drainage through the trabecular meshwork. Contributing factors include genetic predisposition, aging, ethnicity, and reduced central corneal thickness.

Systemic conditions such as diabetes and hypertension can also influence IOP levels (Sudhalkar *et al*., 2021).

Although not all individuals with OH will develop glaucoma, it significantly increases the risk. Prolonged elevated IOP can lead to damage of the retinal ganglion cells and the retinal nerve fiber layer (RNFL), potentially resulting in POAG if left untreated (Sudhalkar *et al*., 2021).

Early Diagnosis of POAG

Early diagnosis is essential to prevent irreversible vision loss in POAG. Several key diagnostic tools are commonly used:

- *Tonometry:* Measures IOP. While elevated IOP is a hallmark of POAG, it is not sufficient alone for diagnosis, as some patients may present with normal IOP.
- *Ophthalmoscopy:* Allows examination of the optic disc. The optic nerve head is assessed for signs of cupping and pallor, indicative of glaucomatous damage.
- *Static Perimetry (e.g., Humphrey Visual Field Test):* Evaluates the visual field, particularly useful for detecting peripheral vision loss—a common symptom as POAG progresses.
- *Fourier-Domain Optical Coherence Tomography (FD-OCT):* An advanced, non-invasive imaging technique that provides high-resolution cross-sectional images of the retina and optic nerve head. FD-OCT enables detailed analysis of structural parameters such as RNFL thickness, macular volume, and optic disc morphology, playing a significant role in the diagnosis and monitoring of glaucoma **(Figure 1)**.

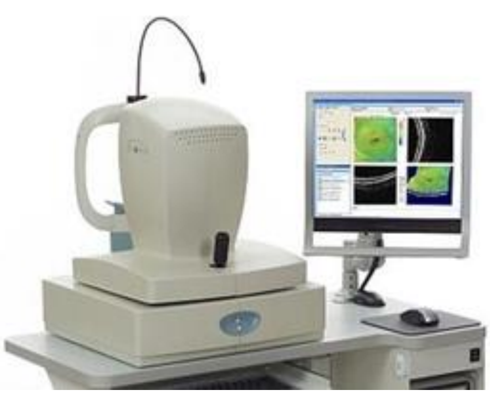

Figure 1. FD-OCT (Bazan, 2021)

Fourier-Domain OCT (FD-OCT)

FD-OCT is a sophisticated form of optical coherence tomography that uses light waves to capture micrometer-resolution images of ocular structures. Compared to traditional time-domain OCT, FD-OCT employs Fourier-domain analysis, which significantly improves both image resolution and acquisition speed. This technology allows for precise visualization of glaucomatous changes in the RNFL, optic nerve head, and macula, making it a critical tool for early detection, accurate diagnosis, and effective management of glaucoma.

Ganglion Cells and RNFL Damage

The optic nerve is composed of axons that originate from retinal ganglion cells (RGCs). When IOP increases, it exerts pressure on the optic nerve head, leading to ischemia and subsequent axonal damage within the ganglion cells. This pressure- induced injury initiates a gradual degeneration of both the ganglion cells and the RNFL.

Ganglion cells, arranged in distinct layers within the retina, are among the first structures affected in POAG. As elevated IOP damages their axons, progressive ganglion cell loss ensues.

The RNFL comprises the unmyelinated axons of these ganglion cells as they converge at the optic disc before exiting the eye. In POAG, sustained IOP elevation imposes mechanical stress on the RNFL **(Figure 2)**, resulting in its gradual thinning and structural degradation. RNFL thinning is one of the earliest and most sensitive indicators of glaucomatous optic nerve damage. As such, it is a critical parameter in the early diagnosis and continuous monitoring of POAG progression.

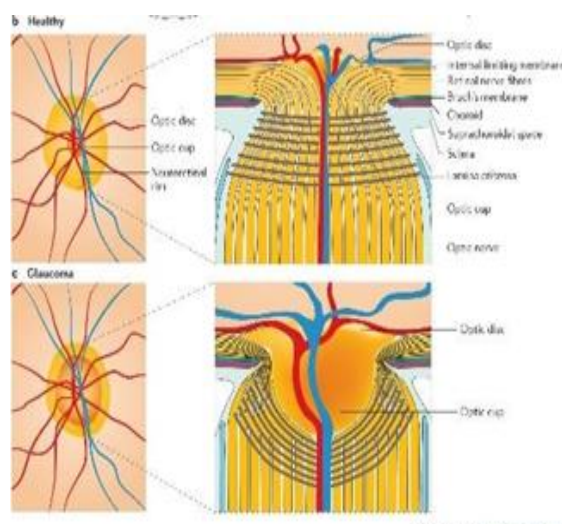

Figure 2. Mechanical stress of optic nerve (Weinreb *et al*., 2016)

As ganglion cells degenerate, there is a corresponding thinning of the RNFL, which can be quantitatively assessed using imaging modalities such as OCT. This progressive loss of ganglion cells and RNFL thinning underlies the characteristic gradual peripheral vision loss seen in POAG, with central vision typically remaining intact until the later stages of the disease.

Early diagnosis of glaucoma remains a significant clinical challenge, as structural damage to the optic nerve and retinal layers often precedes the onset of noticeable symptoms. However, advancements in imaging technology—particularly FD-OCT—have markedly improved the ability to detect these early pathological changes. FD-OCT offers high-resolution imaging of both the macular GCC and the RNFL, providing critical insights into the extent of optic nerve damage. This enables earlier, more accurate diagnosis and facilitates more effective monitoring of glaucoma progression.

Literature Review

Glaucoma refers to a group of progressive optic neuropathies characterized by specific changes to the optic nerve head, the loss of RGCs, and corresponding visual field defects. Among the various types, POAG is the most common.

The primary pathological hallmark of glaucoma is the degeneration of RGCs, which leads to the atrophy of all associated inner retinal layers, including the RNFL, composed of the axons of ganglion cells; the ganglion cell layer (GCL), which contains the cell bodies; and the inner plexiform layer (IPL), where the dendrites reside. The macula, containing nearly 50% of all RGCs, plays a vital role in early disease detection. Since the advent of OCT, objective and quantitative analysis of RNFL thickness has become a standard method for the early detection and monitoring of glaucoma.

Because structural changes may precede detectable visual field loss, advanced imaging tools capable of measuring RNFL and GCC thickness objectively are essential for early diagnosis. Timely detection is critical to prevent irreversible vision loss.

The evaluation of both the macular GCC and the RNFL is essential for assessing retinal structural integrity, particularly in glaucoma (Constantin *et al*., 2022; Mojsak *et al*., 2022; Essah *et al*., 2024; Frost *et al*., 2024; Kajanova & Badrov, 2024; Lee & Ferreira, 2024; Rosellini *et al*., 2024; Umarova *et al*., 2024). The GCC encompasses the RNFL, GCL, and IPL—layers crucial to visual processing. Among these, the RNFL is especially vulnerable to glaucomatous damage. Measurements of these layers using FD-OCT provide significant insights into disease progression and assist in tailoring management strategies (Geevarghese *et al*., 2021).

Diagnostic Capabilities of Macular GCC and RNFL

Macular GCC and Its Role in Diagnosing Glaucoma

The macular GCC has emerged as a sensitive marker of early glaucomatous damage. Studies have demonstrated that GCC thinning may precede noticeable RNFL loss, highlighting its utility in the early diagnosis of POAG. In glaucoma patients, especially those with POAG, GCC thinning is often more pronounced than in individuals with OH or healthy controls.

FD-OCT allows for high-resolution imaging of the macular GCC, facilitating the detection of subtle structural changes and enabling clinicians to diagnose and monitor glaucoma with greater precision.

Functional Correlation

Numerous studies have identified a strong relationship between macular GCC thinning and visual field defects, as assessed by perimetry. For instance, recent literature reported a significant correlation between decreased macular GCC thickness and progressive visual field loss, reinforcing its importance as a structural marker of functional impairment in glaucoma.

RNFL and Its Role in Diagnosing Glaucoma

The RNFL is widely recognized as one of the most reliable structural markers for early glaucoma detection. RNFL thinning is often the earliest detectable sign of optic nerve damage in glaucoma. FD-OCT enables precise, reproducible measurements of RNFL thickness, and numerous studies have shown that RNFL is significantly thinner in POAG patients compared to healthy individuals.

Additionally, RNFL thickness helps differentiate POAG from OH. Patients with OH typically present with normal RNFL measurements despite elevated IOP, whereas those with POAG show marked thinning.

Functional Correlation

RNFL thinning correlates strongly with functional visual field loss in POAG patients. As RNFL thickness decreases, the severity of visual field damage tends to increase, as confirmed by standard automated perimetry.[8] However, in OH patients— where structural damage may be minimal—the correlation between RNFL thickness and functional deficits is weaker (Almutairi *et al*., 2023; Genc *et al*., 2023; Ku *et al*., 2023; Simonyan *et al*., 2023; Tsiganock *et al*., 2023; Delcea *et al*., 2024; Ribeiro *et al*., 2024; Sanlier & Yasan, 2024; Snodin & McCrossen, 2024; Uneno *et al*., 2024). This highlights the need for a multimodal diagnostic approach that combines structural imaging and functional testing for accurate diagnosis and monitoring.

Functional Correlation and Clinical Implications

POAG

In POAG, both macular GCC and RNFL thinning show strong correlations with visual field loss, reinforcing their diagnostic significance:

- Macular GCC thinning is effective in identifying early glaucomatous changes, particularly because the macula houses a high concentration of RGCs.
- RNFL thinning is more strongly associated with disease progression and is particularly useful in monitoring moderate to advanced stages of glaucoma.

These correlations support the integration of both GCC and RNFL assessments in clinical practice. Early GCC analysis facilitates timely intervention, while RNFL monitoring aids in tracking disease progression and optimizing treatment strategies (Chan, 2020).

OH

Patients with OH often exhibit normal RNFL and macular GCC thickness despite elevated IOP. This poses a challenge for diagnosis based solely on structural imaging.

FD-OCT may not fully capture the risk of POAG progression in OH patients.

Functional testing, such as visual field assessment, remains essential to evaluate functional deficits and determine true risk.

Studies suggest that while macular GCC measurements can detect subclinical changes in OH, visual field testing is critical for monitoring functional decline (Al Abadie *et al*., 2023; Guzek *et al*., 2023; Lee *et al*., 2023; Ncube *et al*., 2023; Oran & Azer, 2023; Szklener *et al*., 2023; Tam *et al*., 2023; Tsvetkova *et al*., 2023; Snodin & McCrossen, 2024). A combined structural-functional diagnostic approach enhances accuracy and supports early management (Chan, 2020).

Normal Population

In healthy individuals, both macular GCC and RNFL thickness fall within established normative ranges. However, variability can occur due to factors such as age, ethnicity, and refractive status. Several studies have provided normative data for GCC and RNFL measurements, serving as important reference standards in clinical practice.

FD-OCT has transformed glaucoma diagnosis by enabling high-resolution, non-invasive assessment of macular GCC and RNFL thickness. These structural parameters are essential for detecting glaucomatous damage, with GCC proving particularly sensitive in early-stage detection and RNFL serving as a reliable marker for later disease stages.

The combined analysis of GCC and RNFL significantly enhances diagnostic accuracy, especially in distinguishing POAG and OH from the normal population. Moreover, the strong correlation between structural parameters and functional visual field loss highlights the importance of integrating FD-OCT with perimetry in routine clinical evaluation. This dual approach facilitates timely intervention, personalized treatment, and improved outcomes for glaucoma patients.

Materials and Methods

Objectives

To correlate functional and structural parameters obtained through FD-OCT and compare the predictive value of each structural parameter between individuals with POAG and a normal population in Riyadh, Saudi Arabia.

Research Significance

Glaucoma is the leading cause of irreversible blindness and visual impairment worldwide. Early detection is critical to preventing permanent damage, including optic nerve head deterioration and visual field loss. This study addresses the urgent need to evaluate the diagnostic and early detection capabilities of FD-OCT for POAG in Riyadh, Saudi Arabia—a region where such research is currently limited.

Hypothesis

This study aims to evaluate the predictive value of GCC thickness and its correlation with retinal sensitivity using FD-OCT. Additionally, it seeks to compare macular thickness parameters and RNFL measurements between patients with POAG and a healthy control population.

Study Procedures

This cross-sectional, non-invasive study was approved by the Institutional Review Board (IRB) and the Ethical Committee. All assessments were conducted during a single clinic visit at the glaucoma clinics of Prince Sultan Military Medical City (PSMMC) and MAGRABI Hospital. A trained ophthalmologist performed all examinations.

Each participant underwent the following procedures:

- Medical History Review
- Best-Corrected Visual Acuity (BCVA) and documentation of refractive error
- IOP Measurement using:
    - Ocular Response Analyzer
    - ICARE IC200 Tonometer
- Slit-Lamp Biomicroscopy to evaluate the anterior segment, including lenticular changes
- Gonioscopy to assess the anterior chamber angle
- Direct Ophthalmoscopy and Optic Disc Evaluation using a 90D lens
- Central Corneal Thickness (CCT) measurement (via Ocular Response Analyzer)
- Standard Automated Perimetry (SAP) for visual field assessment
- FD-OCT to evaluate:
    - RNFL thickness
    - Macular GCC thickness

All evaluations were performed on the same day to ensure consistency and minimize variability.

Inclusion Criteria POAG Group

Participants diagnosed with POAG must meet all of the following criteria:

- Evidence of glaucomatous optic nerve head (ONH) changes, including:
  - Diffuse or localized rim thinning
  - Disc hemorrhage
  - Notching, bayonetting, or baring of blood vessels
  - Vertical cup-to-disc ratio (CDR) > 0.3 or asymmetry > 0.2 between eyes (in the absence of significant disc size difference)
- Presence of glaucomatous visual field defects consistent with RNFL abnormalities confirmed via SAP
- Gonioscopically confirmed open angles
- Refractive error between +4.00 and -6.00 diopters

Control Group (Healthy Participants)

Participants must meet all of the following criteria:

- Intraocular pressure (IOP) < 21 mmHg
- Normal-appearing optic disc with no signs of glaucomatous changes
- No RNFL defects on red-free photography
- Normal SAP results with no glaucomatous visual field defects

Exclusion Criteria POAG Group

Participants were excluded if they met any of the following:

- Presence of posterior segment pathology (e.g., retinal disease, optic neuritis)
- History of accelerated hypertension
- Coronary artery disease
- Diabetes mellitus or previous cerebrovascular accident (stroke)
- BCVA of 6/60 or worse
- Presence of a significant cataract affecting imaging or visual field reliability

Control Group

Exclusion criteria include:

- BCVA less than 6/6
- Presence of chronic ocular disease (e.g., uveitis, age-related macular degeneration)
- History of systemic diseases affecting the eyes (e.g., diabetes mellitus, autoimmune disorders)
- Current or past use of systemic corticosteroids

Statistical Analysis

Participants were categorized into two groups: cases (POAG patients) and controls (healthy individuals).

- Continuous variables with normal distribution were presented as means ± standard deviations (SD); non-normally distributed variables were expressed as medians with interquartile ranges (IQR).
- Categorical variables were summarized as frequencies and percentages **(Table 1)**.

Comparative Analysis

- An independent samples t-test was used for normally distributed continuous variables.
- The Mann-Whitney U test was used for non-normally distributed variables.

Variables compared between groups included:

- Average GCC thickness
- Superior GCC
- Inferior GCC
- Average RNFL
- Superior RNFL
- Inferior RNFL

Correlation Analysis

- Spearman's rank-order correlation was used to evaluate the association between average GCC and average RNFL due to non-normal data distribution.
- Scatter plots with linear regression lines were generated to visually represent the relationship between these variables for the POAG group and the overall study population.

All statistical analyses were performed using IBM SPSS Statistics, version 23.0.

A p-value ≤ 0.05 was considered statistically significant (IBM, n.d.).

Results and Discussion

The demographic characteristics of participants in both the control group (n = 50) and the POAG group (n = 50) are summarized in **Table 1**. Data are presented as counts and percentages (%) for categorical variables such as gender, age group, laterality, and ethnicity.

Table 1. The demographic characteristics of participants in both the control group (n = 50) and the POAG group (n = 50)

Variable **Sex n (%)**	**Cases (n=50)**	**Controls (n=50)**
Female	15 (30)	27 (54)
Male	35 (70)	23 (46)
Age **Median [IQR]**	**59.5 [18.3]**	**22 [2.3]**

Table 2. Comparison of GCC and RNFL Thickness (Average, Superior, Inferior) between Cases and Controls (n=100).

Variable	**Cases (N=50) (Mean ± SD or Median [IQR])**	**Controls (N=50) (Mean ± SD or Median [IQR])**	**p-value**
Average GCC	40 [9]	74[9]	<0.001
Superior GCC	42[10]	75[10]	<0.001
Inferior GCC	39[9]	74 [8.8]	<0.001
Average RNFL	74 ±19.43	113.76±16	<0.001
Superior RNFL	96 [52]	139 [27.5]	<0.001
Inferior RNFL	**83.5 [46.8]**	**144 [31.8]**	**<0.001**

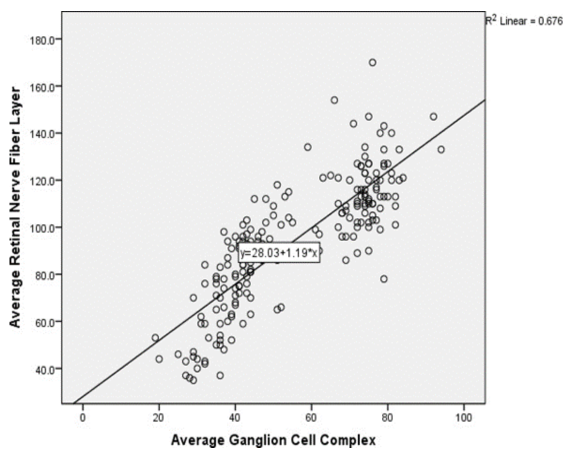

Figure 3. scatter plot with linear regression line using Spearman's Correlation, between average GCC and average RNFL among control and POAG (n=100), with a p-value <0.001 and Correlation Coefficient =0.851.

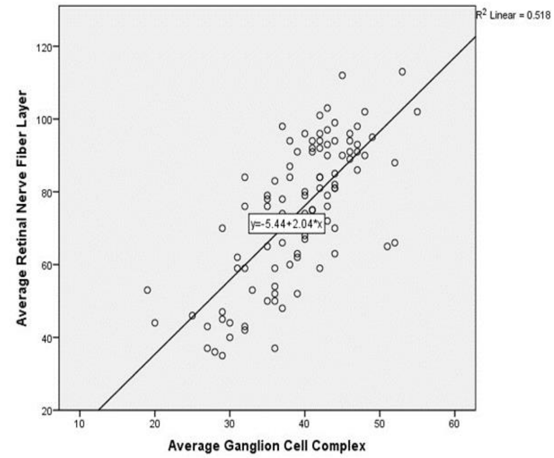

Figure 4. Scatter plot with linear regression line using Spearman's Correlation, between average GCC and average RNFL among POAG (n=50), with a p-value <0.001 and Correlation Coefficient =0.714.

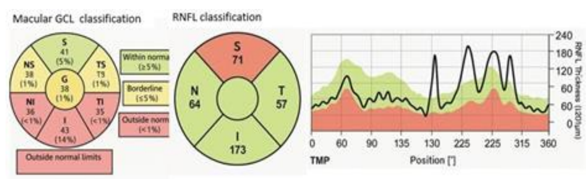

Figure 5. Prototype of an FD-OCT reading of a POAG patient OS (RNFL classification and deviation map).

A total of 200 eyes were included in the study: 100 eyes from patients diagnosed with POAG and 100 eyes from healthy controls. Each group consisted of 100 participants. The mean age of the POAG group was 59.5 ± 18.3 years, significantly higher than the control group, which had a mean age of 22 ± 2.3 years. There were no statistically significant differences in gender distribution or laterality (right vs. left eye) between the two groups **(Table 1)**.

Parameter Analysis

Comparative Analysis of Structural Parameters. All measured parameters showed statistically significant differences between POAG and control eyes ($p < 0.001$ for all comparisons) **(Table 2)**. Specifically:

- Average GCC thickness was significantly reduced in the POAG group (40 ± 9 µm) compared to controls (74 ± 9 µm).
- Superior GCC: POAG (42 ± 10 µm) vs. Control (75 ± 10 µm)
- Inferior GCC: POAG (39 ± 9 µm) vs. Control (74 ± 8.8 µm)

Similarly, RNFL measurements revealed notable thinning in glaucomatous eyes:

- Average RNFL: POAG (74 ± 19.43 µm) vs. Control (113 ± 16 µm)

- Superior RNFL: POAG (96 ± 52 μm) vs. Control (139 ± 27.5 μm)
- Inferior RNFL: POAG (83.5 ± 46.8 μm) vs. Control (144 ± 31.8 μm)

Among these, inferior RNFL thinning was particularly prominent, indicating a consistent pattern of structural damage in glaucomatous eyes.

Correlation between GCC and RNFL

A linear regression analysis was conducted to assess the relationship between average GCC and average RNFL thickness in the entire cohort (n = 200), including both POAG and control subjects **(Figure 3)**.

- The analysis demonstrated a strong positive linear correlation between the two parameters, with a correlation coefficient (r) = 0.851, indicating a very strong relationship **(Figure 3)**.
- The regression model was statistically significant and is represented by the equation:

RNFL=28.03+1.19×GCC

- The coefficient of determination (R^2) was 0.676, suggesting that approximately 67.6% of the variability in RNFL thickness can be explained by the variability in GCC thickness.

This finding supports a robust structural relationship between the ganglion cell complex and the retinal nerve fiber layer in both healthy and glaucomatous eyes.

Interpretation

These results confirm the hypothesis that both GCC and RNFL parameters are significantly reduced in POAG compared to normal eyes. The consistent thinning patterns—particularly in the inferior RNFL and both superior and inferior GCC— highlight the structural impact of glaucoma on the inner retina. The strong correlation between average GCC and RNFL also suggests that GCC thickness may serve as a reliable biomarker for early detection and monitoring of POAG progression.

This study aimed to evaluate the diagnostic utility of GCC and RNFL thickness in POAG compared to a healthy population, using FD-OCT. Our findings reinforce the clinical value of both GCC and RNFL measurements in the structural assessment of glaucomatous damage.

The significantly reduced GCC and RNFL thickness in the POAG group compared to healthy controls is consistent with prior studies that identify ganglion cell loss as an early pathological hallmark of glaucoma. Notably, average GCC thickness in the POAG group (40 ± 9 μm) was markedly lower than in controls (74 ± 9 μm), supporting the sensitivity of macular GCC analysis for early glaucoma detection.

Similar trends were observed in both superior and inferior sectors of the GCC and RNFL, with inferior RNFL exhibiting the most pronounced thinning—a pattern commonly reported in glaucomatous optic neuropathy (Ghita *et al*., 2023).

The robust positive correlation observed between GCC and RNFL thickness (r= 0.851, R^2 = 0.676) highlights a strong structural relationship between these two parameters. This suggests that GCC measurements can serve as a surrogate marker for RNFL integrity and vice versa. The linear regression model (RNFL = 28.03 + 1.19 × GCC) offers a predictive framework for estimating RNFL values based on GCC, which may enhance the clinical utility of FD-OCT in monitoring disease progression.

These findings are particularly significant given that structural changes in glaucoma can precede detectable visual field loss. By leveraging FD-OCT's high- resolution imaging capabilities, clinicians can detect subtle retinal changes early in the disease course, allowing for earlier intervention and potentially preventing irreversible vision loss (Mahmoud *et al*., 2023).

It is worth noting that in patients with OH, structural parameters may remain within normal limits despite elevated intraocular pressure. This underscores the need for a multimodal diagnostic approach that combines structural imaging with functional testing to improve diagnostic accuracy, especially in early or pre-perimetric stages of the disease (Mahmoud *et al*., 2023).

Several limitations should be considered. First, the cross-sectional nature of the study limits the ability to conclude disease progression over time. Second, the age disparity between the POAG and control groups may influence GCC and RNFL measurements, as both parameters are known to decline with age.

However, the magnitude of difference observed is unlikely to be fully explained by age alone. Future longitudinal studies with age-matched cohorts could help clarify these relationships further (Tan *et al*., 2008).

Conclusion

This study demonstrates that both macular GCC and RNFL thickness are significantly reduced in eyes with POAG compared to healthy eyes. The strong correlation between GCC and RNFL thickness suggests that these parameters are interrelated and can serve as complementary structural biomarkers in glaucoma assessment.

FD-OCT proves to be a powerful, non-invasive imaging tool capable of detecting early glaucomatous changes. Integrating macular GCC and RNFL analysis into routine glaucoma evaluation enhances diagnostic accuracy, enables earlier intervention, and supports more effective disease monitoring and management.

Acknowledgments: The authors acknowledge the support of the Research Center of the Female Scientific & Medical College. Deanship of Scientific Research at King Saud University.

Conflict of interest: None

Financial support: None

Ethics statement: This study received an ethical approval # E-24-9337 from King Saud University research center.

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