Structure-function correlations and their temporal dynamics in patients with progressive versus stable primary open-angle glaucoma

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Кореляція структурних і функціональних показників та її динаміка у хворих на прогресуючу та стабілізовану первинну відкритокутову глаукому

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Abstract

***Purpose**: To examine structure-function correlations and their temporal dynamics in patients with progressive primary open-angle glaucoma (POAG) versus stable POAG based on optical coherence tomography (OCT) and static automated perimetry.*

***Material and Methods:** We examined and followed up 193 patients (338 eyes). Of 338 eyes with glaucoma, 64 had preperimetric glaucoma and 274 had perimetric glaucoma. Patients were followed up for an average of 70.6 months. Dynamics of structure-function correlations was analyzed in 248 eyes. Each study eye was assessed as to whether the disease course was progressive or stable based on mean deviation (MD) dynamics over the follow-up.*

***Results:** At baseline, in a total sample of patients with POAG, there was a moderate positive correlation between MD and most examined structural parameters (average thicknesses in the retinal nerve fiber layer [RNFL], inferior RNFL, 7/5 clock hour sector, and macular nerve fiber layer [mNFL]). MD was positively weakly correlated with ganglion cell complex (GCC) thickness ($r = 0.2834$, $p < 0.05$). MD was positively moderately correlated with GCC thickness ($r = 0.3976$, $p < 0.05$) in eyes with stable POAG, and positively weakly correlated with it ($r = 0.2506$, $p < 0.05$) in eyes with progressive POAG. Additionally, mNFL thickness was positively strongly correlated with GCC thickness ($r = 0.7069$, $p < 0.05$) in eyes with stable POAG, and positively moderately correlated with it ($r = 0.6235$, $p < 0.05$) in eyes with progressive POAG. In progressive POAG, a positive correlation between MD and GCC thickness changed from weak ($r = 0.277$, $p < 0.05$) to moderate ($r = 0.4136$, $p < 0.05$), whereas a positive correlation between mNFL thickness and GCC thickness changed from moderate ($r = 0.6242$, $p < 0.05$) to strong ($r = 0.7056$, $p < 0.05$) over the follow-up period. In stable POAG, MD was positively moderately correlated with GCC thickness at baseline ($r = 0.3655$, $p < 0.05$), and was not correlated over the follow-up ($p > 0.05$).*

***Conclusion:** At baseline, in a total sample of eyes with POAG, there was a positive correlation between MD and structural OCT-based parameters, with the strongest correlation (moderate correlation between MD and GCC thickness [$r = 0.4989$, $p < 0.05$] and between MD and mNFL thickness [$r = 0.3905$, $p < 0.05$]) found in eyes with stage 2 POAG. Stronger positive structure-function correlations were found in eyes with stable glaucoma (e.g., a moderate correlation between MD and GCC thickness [$r = 0.3976$, $p < 0.05$] and a strong correlation between mNFL thickness and GCC [$r = 0.7069$, $p < 0.05$]) compared to eyes with progressive glaucoma (a weak correlation between MD and GCC thickness [$r = 0.2506$, $p < 0.05$]) and a moderate correlation between mNFL and GCC thickness [$r = 0.6325$, $p < 0.05$]). The strength of structure-function correlation increased over the follow-up period in eyes with progressive glaucoma, and de-*

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creased over the follow-up period in eyes with stable glaucoma. In progressive POAG, a positive correlation between MD and GCC thickness changed from weak (r = 0.277, p < 0.05) to moderate (r = 0.4136, p < 0.05), whereas in stable POAG, MD was positively moderately correlated with GCC thickness at baseline (r = 0.3655, p < 0.05), and did not correlate with it at the final follow-up (p > 0.05).

Keywords: *glaucoma, primary open-angle glaucoma, macular pathophysiology, optic nerve pathophysiology, primary open-angle glaucoma pathophysiology, primary open-angle glaucoma diagnosis.*

Резюме

Мета. *Вивчення кореляції структурних і функціональних показників та її динаміки у хворих на прогресуючу та стабілізовану первинну відкритокутову глаукому за даними ОКТ та статичної комп'ютерної периметрії.*

Матеріал та методи. *Проведено обстеження і моніторинг 193 пацієнтів (338 очей). В 64 очах діагностована преперіметрична глаукома, в 274 — периметрична первинна відкритокутова глаукома (ПВКГ). Термін спостереження — 70,6 місяця. Динаміка кореляції структурних і функціональних показників досліджена в 248 очах. Перебіг ПВКГ (прогресуючий та стабілізований) визначався протягом терміну спостереження за динамікою середнього відхилення світлочутливості MD.*

Результати. *При першому обстеженні у хворих на ПВКГ встановлено середньої сили прямий кореляційний зв'язок між MD і більшістю структурних показників (RNFL, Inf, 7/5, NFL). Між MD та GCC прямий кореляційний зв'язок був слабкий (r=0,2834, p<0,05). При стабілізованій глаукомі між MD та GCC відмічався прямий кореляційний зв'язок середньої сили (r=0,3976, p<0,05), а при прогресуючій ПВКГ — слабкий (r=0,2506, p<0,05). Між NFL та GCC при стабілізованому перебігу ПВКГ визначався сильний прямий кореляційний зв'язок (r=0,7069, p<0,05), а при прогресуючому перебігу — середньої сили (r=0,6235, p<0,05). За час спостереження прямий кореляційний зв'язок між MD та GCC при прогресуючій ПВКГ зріс зі слабкого (r=0,277, p<0,05) до середньої сили (r=0,4136, p<0,05), між NFL та GCC — зріс з середньої сили (r=0,6242, p<0,05) до сильного (r=0,7056, p<0,05). При стабілізованому перебігу ПВКГ встановлений при першому обстеженні середньої сили прямий кореляційний зв'язок між MD та GCC (r=0,3655, p<0,05) в динаміці став відсутнім (p>0,05).*

Висновки. *У хворих на ПВКГ відмічається прямий кореляційний зв'язок між середнім відхиленням світлочутливості MD і структурними показниками за даними ОКТ, притому найбільш сильний — при другій стадії глаукоми (зокрема, середньої сили між MD та GCC (r=0,4989, p<0,05) та між MD та NFL (r=0,3905, p<0,05). При стабілізованому перебігу ПВКГ був більш сильний прямий кореляційний зв'язок між функціональними та структурними показниками (зокрема між MD та GCC — середньої сили (r=0,3976, p<0,05), між NFL та GCC — сильний (r=0,7069, p<0,05), в порівнянні з прогресуючим перебігом глаукоми (між MD та GCC — слабкий (r=0,2506, p<0,05), між NFL та GCC — середньої сили (r=0,6235, p<0,05). В динаміці при прогресуючій глаукомі сила кореляційного зв'язку між функціональними та структурними показниками за час спостереження збільшилась, а при стабілізованій ПВКГ — зменшилась (зокрема, прямий кореляційний зв'язок між MD та GCC при прогресуючій ПВКГ зріс зі слабкого (r=0,277, p<0,05) до середньої сили (r=0,4136, p<0,05), а при стабілізованій ПВКГ — з середньої сили (r=0,3655, p<0,05) в динаміці став відсутнім).*

Ключові слова: *глаукома, первинна відкритокутова; макула/патофізіологія; зоровий нерв/патофізіологія; глаукома, первинна відкритокутова/патофізіологія; глаукома, первинна відкритокутова/ діагностика.*

Introduction

Glaucoma is a multifactorial and progressive optic neuropathy and the second most common cause of blindness globally [1].

Research on structure-function correlations is important for understanding the nature of glaucomatous damage and for strengthening the basis for diagnostic decisions. However, evidence to date has not provided a clear and unambiguous foundation for understanding how structural and functional damage are related to each other [2].

Understanding the structure-function association of primary open-angle glaucoma (POAG) is important for grading the severity of disease and for understanding the natural history of glaucoma [3, 4]. Clinical measurements of structure and function presented a wide variability between individuals at all stages of glaucoma. Combining the structure and function tests have improved the diagnostic ability to detect glaucoma, but data from large clinical trials have shown structure-function dissociation [3].

Correlations have been found between mean deviation (MD; using Humphrey 10-2 visual field (VF) test [5–9], 24-2 VF test [9, 10, 11], 30-2 full-threshold test [8, 12, 13, 14]) and retinal macular thickness [7, 9], macular volume [14], retinal nerve fiber layer (RNFL) thickness [9–13, 15] and macular ganglion cell layer (mGCL) thickness [5, 6, 8, 9, 10, 12, 15] in patients with POAG and normal-tension glaucoma [16].

Akar and colleagues (2023) [17] and Lee and colleagues [18] found a moderate correlation between macular functional parameters (on the basis of macular integrity assessment microperimetry [17] and Humphrey 10-2 visual field test [17, 18]) and structural characteristics, RFNL thickness [17] and ganglion cell inner plexiform layer thickness [17, 18].

Angular measurement of RNFL defect by OCT en face imaging was correlated with VF loss (MD) [3] and glaucoma severity [19].

However, conclusions of these studies are related only to patients with isolated RNFL defects and early glaucoma [3].

Other studies provided controversial reports on this subject. Hondur et al (2023) [20] found no significant correlation of RNFL thickness with visual field scores in eyes with exfoliation syndrome but a moderate correlation of ganglion cell layer thickness with visual field scores in eyes with exfoliation glaucoma.

In a study by Çelik and colleagues (2025) [21], structural characteristics (the RNFL thickness GCC thickness) showed no statistically significant correlations with functional characteristics (the mean MD) in the 24-2C test in patients with pre-perimetric glaucoma.

Isolated studies reported a correlation of contrast sensitivity function with RNFL thickness and mGCC thickness in patients with POAG [22] and a correlation of pattern electroretinography characteristics with ganglion cell layer thickness in glaucoma suspects [23] and RNFL thickness in patients with early glaucoma [24].

Dynamics of structure-function correlations were reported in isolated studies. Mohammadzadeh and colleagues (2020) [25] found that correlations between central structural and functional rates of change were weak to fair in glaucoma patients enrolled in the Advanced Glaucoma Progression Study. Bollinger and colleagues (2023) [15], however, found no significant changes in correlation of VF mean defect (MD) with RNFL thickness and mGCL thickness in eyes with POAG during a 1-year period.

Another point that should be taken into account is that foveal shape, fovea-disc angle, orientation of the temporal nerve fiber rafe, etc. may exert effects on structure-function correlations in glaucoma [26, 27]. To the best of our knowledge, there have been no reports on the dynamics of structure-function correlations in progressive POAG versus stable POAG.

The purpose of this study was to examine structure-function correlations and temporal dynamics of these correlations in patients with progressive POAG versus stable POAG based on OCT and static automated perimetry (SAP).

Material and Methods

We examined and followed up 193 patients (338 eyes; 78 males and 115 females). Patient age ranged from 40 to 88 years. Of 338 eyes with glaucoma, 64 had preperimetric glaucoma and 274 had perimetric glaucoma. Patient age ranged from 40 to 88 years (mean age, 62.8 years). Of 338 eyes with glaucoma, 64 had preperimetric glaucoma and 274 had perimetric glaucoma. Glaucoma stage 1 was diagnosed in 145 eyes, glaucoma stage 2, in 74 eyes, and glaucoma stage 3, in 55 eyes.

Patients were followed up for an average of 70.6 months (range, 12 to 185 months. Dynamics of structure-function correlations was analyzed in 248 eyes.

Each study eye was assessed as to whether the disease course was progressive or stable based on MD dynamics over the follow-up. Progressive glaucoma was found in 227 eyes and stable glaucoma, in 111 eyes with POAG.

Inclusion criteria were adults with POAG.

Exclusion criteria were media opacity precluding OCT or SAP from being performed, age-related macular degeneration, chorioretinal scars, amblyopia, high myopia, uncompensated arterial hypertendion, uncompensated diabetes, connective tissue disorder, history of abnormal retinal circulation, glaucoma stage 4, a systemic disease precluding OCT or SAP from being performed, or history of eye surgery excepting a longer than 6 month history of uncomplicated cataract or glaucoma surgery [5].

Eye examination included conventional examination techniques, SAP (Oculus Twinfield 2 (Oculus Optikgeräte GmbH, Wetzlar, Germany, Program 30-2 full-threshold test) and OCT (MOCEAN 4000 OCT, MOPTIM, Shenzhen Slton Technology Co. Ltd, Shenzhen, China; Topcon 3D OCT-1000™, Topcon Healthcare Inc, Tokyo, Japan). POAG stage was determined by a reduction in retinal light sensitivity with mean deviation (MD), and eyes were classified [28] as those with glaucoma stage I (early glaucoma; MD ≥ -6 dB), glaucoma stage II (moderate glaucoma; MD, -6.01 to -12 dB), and glaucoma stage III (advanced or severe glaucoma; MD, -12.01 to -20.0 dB), based on the number of points affected, i.e., with reduced retinal light sensitivity.

Each study eye was assessed as to whether the disease course was progressive or stable based on MD dynamics over the follow-up [29]. Glaucoma eyes with a VF MD change of at least 0.05 dB/year were considered progressive; a MD change of less than 0.04 dB/year was considered stable.

Preperimetric glaucoma was defined as the earliest stage of POAG with the presence of glaucomatous changes in the optic nerve and without glaucomatous changes in the visual field [30, 31].

The control group comprised 29 healthy individuals (58 eyes).

This study was approved by the Ethics and Bioethics Committee of Kharkiv National Medical University and adhered to the tenets of the Declaration of Helsinki. Written informed consent was obtained from all subjects.

Statistical analysis was conducted using IBM SPSS Statistics 27 software (IBM Corp., Armonk, NY). Pearson coefficient of correlation was calculated to determine the degree of correlation between structural parameters (RNFL thickness, inferior RNFL thickness (Inf), RNFL thickness in the 7/5 clock hour sector (7/5 sector thickness), macular nerve fiber layer (mNFL) thickness, and ganglion cell complex (GCC) thickness) and functional parameters (MD). The strength of correlation was classified as strong ($r \geq 0.66$), moderate (0.33 - 0.66) or weak ($r < 0.33$). Correlation was considered absent if $p \geq 0.05$.

Results

At baseline, in a total sample of patients with POAG, there was a moderate positive correlation between MD

and most examined structural parameters (average RNFL thickness, inferior RNFL thickness, 7/5 sector thickness, and mNFL thickness). Thus, MD was positively moderately correlated with RNFL thickness ($r = 0.5444$, $p < 0.05$) and mNFL thickness ($r = 0.5186$, $p < 0.05$) (Figs. 1 and 2), and positively weakly correlated with GCC thickness ($r = 0.2834$, $p < 0.05$).

Additionally, there was a positive strong correlation between average RNFL thickness, inferior RNFL thickness, and RNFL thickness in the 7/5 sector ($r = 0.9286$, $r = 0.7954$, and $r = 0.8477$ respectively, $p < 0.05$). Moreover, there was a positive moderate correlation between mNFL thickness and GCC thickness ($r = 0.6327$, $p < 0.05$) and between them and above mentioned structural parameters (average RNFL, thickness, inferior RNFL thickness, and RNFL thickness in the 7/5 sector).

In patients with pre-perimetric glaucoma, of note was a positive moderate correlation between MD and average RNFL thickness ($r = 0.3615$, $p < 0.05$) and a weak positive moderate correlation between MD and inferior RNFL thickness ($r = 0.2683$, $p < 0.05$), with no correlation between MD and other structural parameters (mNFL thickness, GCC thickness, or RNFL thickness in the 7/5 sector).

Additionally, there was a positive moderate correlation between average RNFL thickness, GCC thickness and RNFL thickness in the 7/5 sector ($r = 0.583$, $r = 0.3311$ and $r = 0.4855$, respectively, $p < 0.05$); and between mRNFL thickness, average RNFL thickness, and RNFL thickness in the 7/5 sector ($r = 0.5503$, $r = 0.3777$ and $r = 0.4129$, respectively, $p < 0.05$). Moreover, there was a positive strong correlation between average RNFL thickness and RNFL thickness in the 7/5 sector ($r = 0.7499$, $p < 0.05$).

Our analysis of structure-function correlations in different stages of glaucoma demonstrated that, in glaucoma stage 1, there was a positive weak correlation between MD and RNFL thickness in the 7/5 sector ($r = 0.221$, $p < 0.05$), with no correlation between MD and other structural parameters (average RNFL thickness, mNFL thickness, GCC thickness, or RNFL thickness in the 7/5 sector).

As in the total sample of patients with POAG, there was a positive strong correlation between average RNFL thickness and inferior RNFL thickness ($r = 0.8973$, $p < 0.05$), and between inferior RNFL thickness and RNFL thickness in the 7/5 sector ($r = 0.7271$, $p < 0.05$). Additionally, there was a positive moderate correlation between average RNFL thickness, RNFL thickness in the 7/5 sector and mNFL thickness ($r = 0.5985$, $r = 0.377$ and $r = 0.4525$, respectively, $p < 0.05$), and between inferior RNFL thickness and mNFL thickness ($r = 0.3759$, $p < 0.05$) and GCC thickness ($r = 0.4107$, $p < 0.05$).

In glaucoma stage 2, MD was positively moderately correlated with mNFL thickness ($r = 0.3905$, $p < 0.05$) and GCC thickness ($r = 0.4989$, $p < 0.05$), and positively weakly correlated with other structural parameters (average RNFL thickness, inferior RNFL thickness, and RNFL thickness in the 7/5 sector). For glaucoma stage 2, correlations strengths were similar to those observed for the total sample of patients with POAG, excepting weaker correlations in particular cases. Thus, there was a positive weak correlation between RNFL thickness in the 7/5 sector and GCC thickness ($r = 0.3207$, $p < 0.05$), between mNFL thickness and average RNFL thickness ($r = 0.296$, $p < 0.05$), but there was no correlation with inferior RNFL thickness.

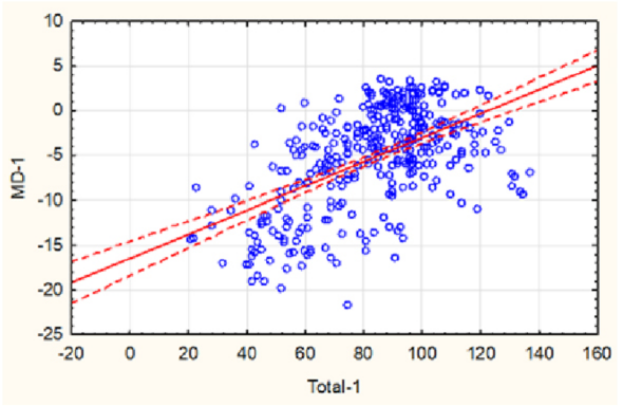

Fig. 1. Scattering plot presenting reflecting a structure-function correlation between average retinal nerve fiber thickness (Total-1) and 30-2 visual function mean deviation (MD-1) for the total sample of patients with primary-angle glaucoma ($r = 0.5444$, $p = 0.001$)

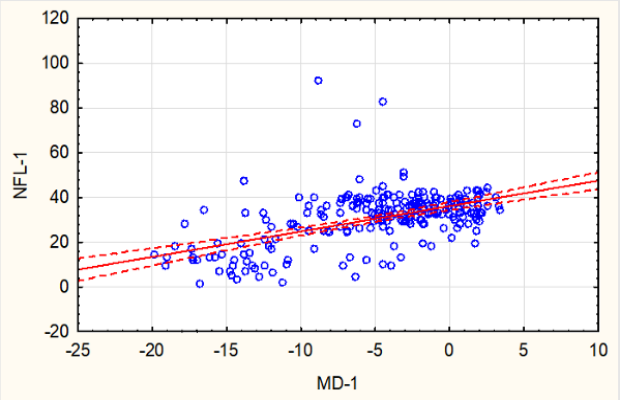

Fig. 2. Scattering plot presenting reflecting a structure-function correlation between 30-2 visual function mean deviation (MD-1) and mean macular nerve fiber layer thickness (NFL-1) for the total sample of patients with primary-angle glaucoma ($r = 0.5186$, $p = 0.0001$)

In glaucoma stage 3, there was no correlation between MD and any structural parameter. Additionally, no significant correlation was found between average RNFL thickness and GCC thickness.

There was, however, a positive strong correlation (from $r = 0.7948$ to $r = 0.876$, $p < 0.05$) between the examined structural parameters of the optic nerve (average RNFL thickness, inferior RNFL thickness, and RNFL thickness in the 7/5 sector), and a positive moderate cor-

relation (from r = 0.3446 to r = 0.6222, p < 0.05) in other cases.

There was a difference in the strength of positive structure-function correlation between eyes with progressive glaucoma and eyes with stable glaucoma. Thus, MD was positively moderately correlated with GCC thickness (r = 0.3976, p < 0.05) in eyes with stable POAG, and positively weakly correlated with GCC thickness (r = 0.2506, p < 0.05) in eyes with progressive POAG. Additionally, mNFL thickness was positively strongly correlated with GCC thickness (r = 0.7069, p < 0.05) in eyes with stable POAG, and positively moderately correlated with GCC thickness (r = 0.6235, p < 0.05) in eyes with progressive POAG. There was, however, no difference in the strength of correlations for other examined parameters in eyes with progressive and stable glaucoma, and these correlations were similar in strength to those mentioned above for the total sample of patients with POAG.

Over the follow-up period, there was an increase in the strength of structure-function correlations in eyes with progressive POAG. Thus, in progressive POAG, a positive correlation between MD and GCC thickness changed from weak (r = 0.277, p < 0.05) to moderate (r = 0.4136, p < 0.05), whereas a positive correlation between mNFL thickness and GCC thickness changed from moderate (r = 0.6242, p < 0.05) to strong (r = 0.7056, p < 0.05).

In stable POAG, there was a decrease in the strength of structure-function correlations over the follow-up period. Thus, MD was positively moderately correlated with GCC thickness at baseline (r = 0.3655, p < 0.05), and did not correlate with GCC thickness during the follow-up (p > 0.05). In eyes with progressive and stable glaucoma, there was no substantial change in the strength of correlations between other examined parameters over the follow-up period.

Discussion

Our finding of positive correlations of MD with OCT structural parameters for the total sample of examined patients with POAG is in agreement with those of other studies [8, 12, 13]. Additionally, our finding of positive moderate correlation of RNFL thickness and GCC thickness in patients with POAG is in indirect agreement with a report by Shin and colleagues [10] that statistically significant correlations between the macular ganglion cell–inner plexiform layer (GCIPL) thickness and corresponding RNFL thickness were found in all GCIPL sectors (R = 0.534–0.807).

Our finding regarding preperimetric glaucoma confirms the finding by Kim and colleagues [12] and Çelik and colleagues [21] that, in preperimetric glaucoma, the association between macular mean sensitivity and GCIPL thickness were not significant. It, however, does not confirm the finding of Çelik and colleagues [21] that, in preperimetric glaucoma, the RNFL thickness values showed no statistically significant correlations with the MD.

In our opinion, it may indicate that, in preperimetric glaucoma, changes in the ganglion cell layer precede changes in the RNFL and possibly changes in the 7/5 clock hour sector.

In POAG stage 1, our finding of positive correlation between MD and RNFL thickness in the 7/5 sector and no correlation between MD and RNFL thickness (which was also reported by Pang and colleagues (2024) [22]) is in indirect agreement with the reports that, in eyes with POAG, RNFL thinning is most commonly seen in this sector [32]. We believe the finding of no correlation between mean MD and RNFL thickness in POAG stage 1 in the presence of positive moderate correlation between mean MD and RNFL thickness in preperimetric glaucoma may be caused by faster and more marked changes in retinal sensitivity and mean MD compared to changes in RNFL thickness in early POAG.

We found the strongest correlation between functional parameters (mean MD) and structural changes in retinal ganglion cells (GCC) only in glaucoma stage 2, which is in agreement with the finding by Hwang and colleagues (2023) [5] who reported on the presence of correlation between GCC thickness and visual field sensitivity. Additionally, we found significant correlations between mean MD and all structural parameters examined (mNFL thickness, RNFL thickness, inferior RNFL thickness, and RNFL thickness in the 7/5 clock hour sector). Our findings, however, are in disagreement with those by Rezkallah and colleagues (2022) [33] who found no significant correlations between RNFL thickness and retinal sensitivity in patients with advanced glaucoma (mean MD worse than -12 dB).

In our opinion, our finding of no structure-function correlation in glaucoma stage 3 may be caused by the fact that a substantial portion of eyes in this group have reached the RNFL floor. Our findings are in agreement with those by Rezkallah and colleagues (2022) [33] who reported no correlation between retinal sensitivity and RNFL thickness in POAG eyes with MD worse than -20 dB and with those by Blumenthal and colleagues [34] who reported no correlation between structural parameters (RNFL) and functional parameters (MD) in eyes with end-stage glaucoma.

We found a positive moderate correlation between GCC thicknesses and mean MD in stable glaucoma and a weak correlation between them in progressive glaucoma. Additionally, we found a positive strong correlation between GCC thickness and macular RNFL thickness in stable glaucoma, and a positive moderate correlation between them in progressive glaucoma. Our finding of a weaker structure-function correlation in progressive glaucoma compared to stable glaucoma may indicate the presence of various types of POAG progression.

Our finding of the discrepancy in the temporal change in the strength of correlation between the mean MD and GCC thickness between progressive glaucoma and stable

glaucoma reflect substantial differences between these forms of POAG, since it is between these parameters that the highest correlation of change rates was observed [25].

Our finding of an increase in the strength of structure-function correlations during the follow-up in progressive POAG indicate unidirectional changes in the parameters analyzed in eyes with progressive glaucoma. An opposite tendency in stable glaucoma indicated the presence of opposite directional changes, and may indicate worsening of the structural parameters with the preservation of stable MD in a proportion of patients examined, which is in agreement with the finding by Mohammadzadeh and colleagues (2020) [25] that structural changes were detected more frequently than functional changes in POAG eyes with ≥3 years of follow-up.

A possible limitation of this study was the use of SAP 30-2 pattern, which substantially increases the retinal area whose functions are to be examined compared to SAP 10-2 pattern (although, in the opinion of some researchers [2], the averaging perimetric sensitivities over larger areas may result in higher correlation coefficients).

A possible advantage of this study was that we determined whether POAG was stable or progressive throughout the follow-up period.

Conclusion

First, at baseline, in a total sample of eyes with POAG, there was a positive correlation between MD and structural OCT-based parameters The strongest correlation between functional parameters (the mean MD) and structural changes (e.g., those in retinal ganglion cells) was found in eyes with stage 2 POAG.

Second, there was a discrepancy in the strength of positive structure-function correlation between eyes with progressive glaucoma and eyes with stable glaucoma. Stronger positive structure-function correlation was found in eyes with stable glaucoma compared to eyes with progressive glaucoma.

Third, eyes that had different courses of POAG showed opposite directional changes with time in the strength of structure-function correlation. Thus, the strength of structure-function correlation increased with time in eyes with progressive glaucoma, and decreased with time in eyes with stable glaucoma.

This study not only determined changes with time of the strength of structure-function correlation in eyes with progressive vs stable glaucoma, but demonstrated the need for a differential approach to the involvement of structural changes when determining a progressive disease in various stages of POAG.

Author Contributions

Author contributions: VMP: Investigation, Data Collection and Analysis, Methodology, Writing – original draft; review & editing; OMH: Investigation, Data Analysis, Writing – review & editing; HIuP: Conceptualization, Data Collection, Writing – review & editing; IVK: Data Collection and Analysis, Conceptualization, Writing – original draft; review & editing. All authors read and approved the final manuscript.

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Ethical standards

Study subjects: Totally, 193 patients (78 men and 115 women; age, 48 to 69 years) with primary open-angle glaucoma were included in the study and underwent examination and treatment. The control group comprised 29 healthy individuals. This study was approved by the Ethics and Bioethics Committee of Kharkiv National Medical University and adhered to the tenets of the Declaration of Helsinki.

Informed Consent: Written informed consent was obtained from all subjects.

Conflicts of interest

The authors declare that they have no conflict of interest that could influence their opinion on the subject or materials described and discussed in this manuscript.

Disclaimer

The opinions presented in this article are those of the authors and do not necessary represent that of Kharkiv National Medical University.

Data Availability Statement

The data obtained and/or analyzed during this study are available from the appropriate author upon reasonable request.

Abbreviations

GCC, retinal ganglion cell complex; Inf, inferior retinal nerve fiber layer; MD, mean deviation; mNFL, macular nerve fiber layer; OCT, optical coherence tomography; POAG, primary open-angle glaucoma; RNFL, retinal nerve fiber layer; 7/5, RNFL thickness in the 7/5 clock hour sector.

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