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Association Between Patient-Reported Disease Perception and Objective Glaucoma Progression During the COVID-19 Pandemic

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Abstract

Purpose:

The COVID-19 pandemic has significantly limited glaucoma patients' access to regular check-ups and diagnostic tests, which may have affected the progression of the disease. The aim of the study was to assess the relationship between patients' subjective perception of glaucoma and the results of objective ophthalmological examinations during the COVID-19 pandemic, and to analyze the condition of the eye surface.

Methods:

The cohort study included 137 patients (274 eyes) with glaucoma who were treated and followed between 2019 and 2021. The results of studies conducted before and during the COVID-19 pandemic were compared, including best-corrected visual acuity (BCVA), intraocular pressure (IOP), c/d index, and OCT parameters: RNFL, GCC, and VCD. Patients completed the POEM and PSS-10 questionnaires to assess subjective perceptions of the disease and stress levels. Statistical analysis was performed using non-parametric tests.

Results:

Between the pre-pandemic and 2021 assessments, statistically significant changes were observed in several structural and functional parameters, including reductions in mean RNFL and GCC thickness and deterioration in BCVA. Patient-reported worsening of glaucoma and interference with daily functioning frequently co-occurred with deterioration in OCT parameters. More than half of the patients reported fear of vision loss, while signs of ocular surface disease were observed in approximately one-third of participants.

Conclusion:

The COVID-19 pandemic has been associated with a deterioration in structural and functional parameters in glaucoma patients. Subjective patient feelings correlated with objective study results, highlighting the importance of assessing patients' quality of life and experiences in monitoring the disease. Regular eye check-ups, OCT examinations, and comprehensive care, including education and psychological support, remain crucial in the treatment of glaucoma.

1. Introduction

Glaucoma is a progressive optic neuropathy characterized by irreversible damage to retinal nerve fibers, leading to a gradual loss of visual field [1]. It is one of the most common causes of irreversible blindness

worldwide. According to the European Eye Epidemiology Consortium, around 12.3 million people in Europe suffer from glaucoma, and this number is constantly growing [2]. Depending on the anatomical characteristics of the anterior chamber angle, glaucoma can be classified as open-angle glaucoma (OAG) or angle-closure glaucoma (ACG). Moreover, glaucoma may be primary or secondary to other ocular diseases [3]. Regardless of its etiology, the most important risk factor for the development and progression of glaucoma remains elevated intraocular pressure (IOP) [4].

Glaucomatous damage is irreversible – currently, the only effective therapeutic approach is to slow progression of the disease. The mainstay of treatment is lowering IOP through pharmacotherapy, primarily eye drops and laser therapy; in cases where these methods fail to achieve the target IOP, surgical intervention is also considered.[5] Regular follow-up of patients with glaucoma is essential and includes the measurement of the IOP, evaluation of compliance to the implemented treatment, and monitoring of potential disease progression using imaging techniques such as optical coherence tomography (OCT) and visual field testing (perimetry) [6]. During ophthalmic examination, special attention is also paid to the cup-to-disc (c/d) ratio of the optic nerve head. Physiologically, this ratio is approximately 0.3–0.4. The vertical c/d ratio increases as glaucomatous damage progresses - as optic nerve axons degenerate, an increasingly larger portion of the optic disc head becomes occupied by hollow excavation, while the neuroretinal rim gradually decreases [7]. A major current problem is the limited availability of glaucoma specialists and insufficient frequency of follow-up visits [8].

OCT is currently one of the most important imaging techniques for diagnosing and monitoring glaucoma progression [9]. It enables noninvasive visualization and quantitative assessment of the retinal nerve fiber layer (RNFL), the ganglion cell complex (GCC), and the optic nerve head (ONH). OCT allows detection of structural damage before functional changes appear in visual field testing [9, 10]. The parameters most indicative of progression include average and sectoral RNFL thickness, GCC changes, and vertical c/d (Vc/d) ratio. Routine OCT examinations in glaucoma patients allow for better monitoring of the disease course [11].

The COVID-19 pandemic significantly affected the functioning of healthcare systems, limiting access to follow-up visits and diagnostic examinations [12]. In many patients, regular follow-up visits during this period were impossible due to restrictions, which frequently resulted in poorer control of chronic diseases, including glaucoma [13].

During the pandemic, many individuals worked remotely, which was associated with prolonged screen time [14]. In some individuals, this led to the development of dry eye syndrome, manifested by a foreign body sensation, burning, and redness of the eyes. Prolonged use of electronic devices leads to less frequent blinking and, consequently, faster tear film evaporation [15]. This problem is particularly significant in patients using antiglaucoma drops, as a common adverse effect of long-term and multidrug therapy is the development or exacerbation of dry eye syndrome [16].

The primary aim of the present study was to evaluate whether patient-reported worsening of glaucoma was associated with objectively observed structural and functional changes during the follow-up period

encompassing the COVID-19 pandemic. We hypothesized that patients reporting subjective disease worsening or greater interference of glaucoma with daily functioning would be more likely to demonstrate deterioration in OCT parameters and/or visual acuity.

As secondary objectives, we assessed changes in structural and functional ophthalmic parameters between the pre-pandemic and pandemic-period examinations, perceived stress, and ocular surface status. Given the observational single-cohort design, the study was not intended to establish a causal effect of the COVID-19 pandemic on glaucoma progression.

2. Materials and Methods

This ambispective observational cohort study was conducted between January 2021 and July 2021 at the Department of Ophthalmology, the Medical University of Warsaw, in the Ophthalmic Public Hospital in Warsaw. All study protocols were reviewed and approved by the Bioethics Committee of the Medical University of Warsaw, Poland. The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. Informed consent was obtained from all participants prior to their inclusion in the study. The datasets used and analysed during the current study available from the corresponding author on reasonable request.

2.1 Subjects

Eligible participants were adults aged ≥ 18 years with a diagnosis of glaucoma established at least two years before the 2021 study visit. Patients with OCT results from 2019 or 2020 (before the pandemic) and from 2021 (during the pandemic) of sufficient quality for reliable analysis were included in the study. Inclusion criteria also required complete ophthalmological documentation from 2019 or 2020 and from 2021.

Patients with severe ophthalmic diseases that could independently affect visual function assessment (age-related macular degeneration, a history of optic neuritis, diabetic retinopathy) and monocular patients were excluded from the study.

Based on the vc/d ratio, patients were classified into three groups: early (vc/d < 0.6), moderate (vc/d = 0.7–0.8), and advanced glaucoma (vc/d ⩾ 0.9). In cases of interocular differences in vc/d, patients were assigned to the group according to the eye with the higher vc/d ratio.

2.2 Examination

On the visit in 2021, participants underwent a comprehensive ophthalmic examination, including best-corrected visual acuity (BCVA), IOP measurement, Tear Break Up Time (TBUT), and c/d ratio. Optical coherence tomography (OCT) was obtained using a spectral-domain OCT (SD-OCT) RTVue XR 100 Avanti Edition (Optovue, Fremont, CA, USA). The OCT parameters analyzed included RNFL, GCC, and vc/d.

The results were compared with data obtained in 2019 and 2020, prior to the COVID-19 pandemic.

The physician completed a questionnaire regarding the number of antiglaucoma medications the patient was using, the stage of cataract or post-cataract status, and the presence of risk factors for glaucoma development, such as arterial hypertension, diabetes, and cardiac arrhythmias.

Each participant was asked to complete a glaucoma patient-reported outcome and experience measure (POEM) and Perceived Stress Scale 10 (PSS-10) questionnaires regarding their perception of their underlying disease. POEM was developed from the National Glaucoma Think Tank event in the UK in 2012 [17]. It consists of 6 questions regarding understanding of the disease, disease management, acceptance of treatment, perceived deterioration, functioning with the disease, and fear of vision loss [18]. PSS-10 consists of 10 questions designed to assess the extent to which the patient experiences stress related to the disease, treatment process, and daily functioning [19].

2.3 Statistical analysis

The data analysis was conducted using Statistica TMv. 13.2, TIBCO Software Inc., Palo Alto, CA, USA, 2017. Continuous variables, presented as means with their standard deviations (SDs), were compared before and after the pandemic using the Wilcoxon signed-rank test. The Shapiro-Wilk test was used to determine the normality of each variable. The Kruskal–Wallis and chi-square tests were used to compare changes in BCVA, c/d and vc/d ratio, IOP and OCT parameters (RNFL, GCC, vc/d) between glaucoma advancement groups. Statistical significance was defined as $p < 0.05$. Descriptive statistics were used to analyze POEM and PSS in each glaucoma advancement group.

3. Results

3.1 Characteristics of the entire study group

The study included 274 eyes of 137 patients. The most common type of glaucoma was primary open-angle glaucoma (POAG), diagnosed in 101 patients (73.7%). Primary angle-closure glaucoma (PACG) was diagnosed in 26 patients (19.0%), and secondary glaucoma in 10 patients (7.3%).

The largest group consisted of patients with advanced glaucoma (43.8%), followed by moderate glaucoma (38.7%) and early glaucoma (17.5%). The number of patients in each group and their age are presented in Table 1. The percentage of glaucoma types in each group is presented in Table 2.

Table 1
Number of patients with each glaucoma stage and their mean age

Glaucoma stage	Number of patients	Age (mean + SD)
early	24	63,9 ± 14,8
moderate	53	70,7 ± 12,6
advaced	60	72,1 ± 11,8

Table 2
Type of glaucoma in each group

Glaucoma type	POAG (n = 101)	PACG (n = 26)	Secondary glaucoma (n = 10)
Early Glaucoma	10,89%	34,62%	40%
Moderate Glaucoma	41,58%	34,62%	20%
Advanced Glaucoma	47,52%	30,77%	40%

In the study group, 16 individuals (11.7%) had COVID-19, and 33 patients (24.1%) had follow-up visits canceled or did not attend scheduled follow-up visits over 1 year.

The most used treatment method was multidrug pharmacotherapy. In the POAG group, 34.65% of patients used two or more antiglaucoma medications. A history of surgical treatment was reported in approximately 30% of patients (Table 3).

Table 3
Characteristics of glaucoma treatment

Treatment	POAG	PACG	Secondary glaucoma
Without medications	7,92%	8,23%	10%
1 medication	26,73%	42,31%	40%
2 or more medications	34,65%	18,69%	30%
After glaucoma surgery, without medications	6,93%	7,69%	10%
After glaucoma surgery, with medications	23,76%	23,08%	10%

3.2 c/d ratio

The c/d ratio assessed during ophthalmic examination changed in the right eye in 34 individuals (25%) and increased on average from 0.675 to 0.691 (p = 0.01). A change in the left eye occurred in 39 individuals (28%) and increased from 0.68 to 0.698 (p = 0.0085).

3.3 Dry eye syndrome

Data regarding the number of patients with dry eye syndrome are presented in Table 4.

Table 4
Percent of patients with dry eye syndrome in each glaucoma group

Dry eye syndrome	Early glaucoma	Moderate Glaucoma	Advanced Glaucoma	Total
Right eye	37,5%	30,2%	36,7%	34,3%
Left eye	37,5%	34,0%	38,3%	36,5%

3.4 Changes in OCT parameters

Each enrolled patient underwent OCT examination, in which RNFL, GCC, and vc/d were assessed. RNFL in the right eye decreased from 84.05 ± 15.33 to 83.01 ± 14.64 ($p = 0.001$), and in the left eye from 85.37 ± 16.42 to 84.22 ± 16.59 ($p < 0.001$). The change in GCC in the right eye was from 85.29 ± 14.4 to 83.85 ± 14.59 ($p < 0.001$), and in the left eye from 86.62 ± 15.9 to 85.7 ± 17.51 ($p < 0.001$). Both results were statistically significant. An increase in Vc/d indicates a reduction in the neuroretinal rim and, therefore, glaucoma progression. Vc/d increased in the right eye from 0.715 ± 0.16 to 0.73 ± 0.16 ($p = 0.002$). Vc/d in the left eye changed from 0.708 ± 0.179 to 0.716 ± 0.184 ($p = 0.2$).

3.5 BCVA

BCVA for distance changed in 42.3% of individuals in the right eye and in 49.6% in the left eye. It decreased from 0.767 ± 0.219 in the right eye to 0.726 ± 0.221 ($p < 0.05$). In the left eye, visual acuity also decreased from 0.766 ± 0.239 to 0.751 ± 0.217, and this decrease was also statistically significant ($p < 0.05$).

3.6 IOP

IOP decreased in the right eye from 12.79 ± 2.65 to 12.52 ± 2.55 ($p = 0.06$), whereas in the left eye it decreased from 13.06 ± 2.66 to 12.59 ± 3.4 ($p = 0.045$).

3.7 Characteristics of subgroups

3.7.1 Early glaucoma

The early glaucoma group included 24 individuals. The characteristics of the group are presented in Table 5.

Table 5
Characteristics of early glaucoma group

Early glaucoma	Number of patients (%)
Sex	18 (75%)
Women	6 (25%)
Men	
Type of glaucoma	11 (45, 83%)
Primary open-angle	9 (37,5%)
Primary angle-closure	4 (16,6%)
Secondary	
Glaucoma risk factors	14 (58,3%)
Arterial hypertension	3 (12,5%)
Diabetes	3 (12,5%)
Cardiac arrhythmias	
Cataract status	9 (37,5%)
After cataract surgery	5 (20,8%)
Cataract	4 (16,6%)
Clear lens	6 (25%)
Opacifying lens	
Treatment	17 (70,8%)
1 medication	4 (16,7%)
2 medications	3 (12,5%)
> 2 medications	
Dry eye with TBUT < 10 seconds	9 (37,5%)
Changes in OCT	6 (25%)
Right eye	7 (29%)
RNFL deterioration	5 (20,8%)
VC/D deterioration	8 (33,3%)
GCC deterioration	9 (37,5%)
Left eye	4 (16,6%)
RNFL deterioration	

Early glaucoma	Number of patients (%)
VC/D deterioration	
GCC deterioration	

A deterioration of vision by at least 2 lines on the Snellen chart in at least one eye was observed in 10 individuals (41.6%). In 6 individuals (25%), a higher c/d ratio was documented.

Mean RNFL decreased in the right eye from 95.9 to 94.5 and in the left eye from 98.5 to 96.3. VC/d increased in the right eye from 0.502 to 0.528 and in the left eye from 0.497 to 0.515. Total GCC decreased from 93.4 to 93.0 in the right eye and from 93.9 to 93.4 in the left eye.

Questions 4, 5, and 6 of the POEM questionnaire concerned fear of progression, functioning with the disease, and functioning in the disease. For question 4 of the POEM questionnaire - I feel that my glaucoma is getting worse – 9 individuals (37.5%) answered affirmatively. Among these patients, 6 (66.6%) had deterioration in OCT parameters, and 4 (44.4%) had deterioration in BCVA. For question 5 of the POEM questionnaire - My disease interferes with my everyday life 6 individuals (25%) answered affirmatively. In this group, 5 individuals (25%) had deterioration in OCT findings, and 4 individuals (66.6%) had deterioration in BCVA. For question 6 - I am afraid that I will lose my sight/become blind because of glaucoma – 16 individuals (66.6%) answered affirmatively.

3.7.2 Moderate glaucoma

The moderate glaucoma group included 53 individuals. The characteristics of the group are presented in Table 6.

Table 6
Characteristics of moderate glaucoma group

Moderate glaucoma	Number of patients (%)
Sex	40 (75,5%)
Women	13 (24,5%)
Men	
Type of glaucoma	42 (79,2%)
Primary open-angle	9 (17%)
Primary angle-closure	2 (3,7%)
Secondary	
Glaucoma risk factors	26 (49%)
Arterial hypertension	9 (17%)
Diabetes	13 (24,5%)
Cardiac arrhythmias	
Cataract status	24 (45,3%)
After cataract surgery	10 (18,9%)
Cataract	7 (13,2%)
Clear lens	12 (22,6%)
Opacifying lens	
Treatment	11 (20,8%)
1 medication	34 (64,2%)
2 medications	8 (15,1%)
> 2 medications	
Dry eye with TBUT < 10 seconds	19 (35,8%)
Changes in OCT	17 (32,1%)
Right eye	27 (51%)
RNFL deterioration	13 (24,5%)
VC/D deterioration	18 (34%)
GCC deterioration	19 (35,8%)
Left eye	20 (37,7%)
RNFL deterioration	

Moderate glaucoma	Number of patients (%)
VC/D deterioration	
GCC deterioration	

A deterioration of vision by at least 2 or more lines on the Snellen chart in at least one eye was observed in 23 individuals (43.4%). In 19 individuals (35.8%), a higher c/d ratio was documented.

Mean RNFL decreased in the right eye from 86.9 to 86.1 and in the left eye from 87.9 to 86.1. VC/d increased in the right eye from 0.699 to 0.716 and in the left eye from 0.708 to 0.716. Total GCC decreased from 89.4 to 87.5 in the right eye and from 88 to 86.4 in the left eye.

For question 4 of the POEM questionnaire - I feel that my glaucoma is getting worse – 14 individuals (26.4%) answered affirmatively. Among these patients, 11 (78.6%) had deterioration in OCT parameters, and 6 (42.9%) had deterioration in BCVA. For question 5 of the POEM questionnaire - My disease interferes with my everyday life – 15 individuals (28.3%) answered affirmatively. In this group, 13 individuals (86.6%) had deterioration in OCT findings, and 7 individuals (46.6%) had deterioration in BCVA. For question 6 - I am afraid that I will lose my sight/become blind because of glaucoma – 31 individuals (58.5%) answered affirmatively.

3.7.3 Advanced glaucoma

The advanced glaucoma group included 60 individuals. The characteristics of the group are presented in Table 7.

Table 7
Characteristics of advanced glaucoma group

Advanced glaucoma	**Number of patients (%)**
Sex	44 (73%)
Women	16 (27%
Men	
Type of glaucoma	48 (80%)
Primary open-angle	8 (13,3%)
Primary angle-closure	4 (6,7%)
Secondary	
Glaucoma risk factors	35 (58,3%)
Arterial hypertension	10 (16,6%)
Diabetes	11 (18,3%)
Cardiac arrhythmias	
Cataract status	42 (70,0%)
After cataract surgery	6 (10,0%)
Cataract	3 (5,0%)
Clear lens	9 (15,0%)
Opacifying lens	
Treatment	12 (20,0%)
1 medication	29 (48,3%)
2 medications	8 (31,7%)
> 2 medications	
Dry eye with TBUT < 10 seconds	22 (36,6%)
Changes in OCT	19 (31,6%)
Right eye	20 (33,3%)
RNFL deterioration	26 (43,3%)
VC/D deterioration	21 (35,0%)
GCC deterioration	18 (30,0%)
Left eye	29 (48,3%)
RNFL deterioration	

Advanced glaucoma	Number of patients (%)
VC/D deterioration	
GCC deterioration	

A deterioration of vision by at least 2 or more lines on the Snellen chart in at least one eye was observed in 18 individuals (30.0%). In 12 individuals (20.0%), a higher c/d ratio was documented.

Mean RNFL decreased in the right eye from 76.7 to 75.5 and in the left eye from 77.8 to 77.7. VC/d increased in the right eye from 0.812 to 0.822 and in the left eye from 0.789 to 0.791. Total GCC decreased from 78.1 to 77.1 in the right eye and increased from 81.7 to 81.9 in the left eye.

For question 4 of the POEM questionnaire - I feel that my glaucoma is getting worse – 23 individuals (38.3%) answered affirmatively. Among these patients, 19 (82.6%) had deterioration in OCT parameters, and 8 (35.0%) had deterioration in BCVA. For question 5 of the POEM questionnaire - My disease interferes with my everyday life – 25 individuals (41.6%) answered affirmatively. In this group, 22 individuals (88.0%) had deterioration in OCT findings, and 8 individuals (32.0%) had deterioration in BCVA. For question 6 - I am afraid that I will lose my sight/become blind because of glaucoma – 39 individuals (65.0%) answered affirmatively.

Changes in BCVA, c/d ratio, and OCT parameters (RNFL, GCC, vc/d) are presented in Table 8.

Table 8
Changes of BCVA, c/d ratio and OCT parameters in each glaucoma group

Parameter	Glaucoma		
	early	moderate	advanced
↓ BCVA	41,6%	43,4%	30,0%
↑ c/d ratio	25,0%	35,8%	20,0%
↓ RNFL	33,3%	34,0%	35,0%
↑ vc/d ratio	37,5%	51,0%	33,3%
↓ GCC	20,8%	37,7%	48,3%

3.8 PSS-10 Results

The PSS-10 questionnaire results based on glaucoma stage and glaucoma deterioration were analyzed using descriptive statistics. The results are presented in Table 9. In questions 1–4 and 6–10, the percentage of negatively oriented responses 3 – often and 4 - very often are presented. In question 5, negatively oriented responses were 0 - never, 1 - almost never, and 2 - sometimes.

Table 9
PSS-10 responses and percentage of patients with deterioration in OCT/BCVA in each group

PSS-10	**Glaucoma**		
	early	**moderate**	**advanced**
PSS-1: How often have you been upset in the last month because of something that happened unexpectedly?	33,3% among them: 75,0% OCT deterioration 25,0% BCVA deterioration	24,5% among them: 84,5% OCT deterioration 54,0% BCVA deterioration	33,3% among them: 85,0% OCT deterioration 45,0% BCVA deterioration
PSS-2: How often have you felt in the last month that important things in your life were beyond your control?	12,5% among them: 66,6% OCT deterioration 12,5% BCVA deterioration	18,86% among them: 90,0% OCT deterioration 60,0% BCVA deterioration	20,0% among them: 18,3% OCT deterioration 41,6% BCVA deterioration
PSS-3: How often have you felt nervous and stressed in the last month?	50,0% among them: 66,6% OCT deterioration 41,6% BCVA deterioration	34,0% among them: 57,6% OCT deterioration 39,4% BCVA deterioration	40,0% among them: 36,6% OCT deterioration 92% BCVA deterioration
PSS-4: How often have you felt confident in the last month that you were able to handle your personal problems?	50,0% among them: 75,0% OCT deterioration 41,6% BCVA deterioration	62,3% among them: 75,0% OCT deterioration 25,0% BCVA deterioration	55,0% among them: 25,0% OCT deterioration 6,6% BCVA deterioration
PSS-5: How often have you felt in the last month that things were going your way -	75,0% among them: 50,0% OCT deterioration 11,0% BCVA deterioration	38,0% among them: 88,8% OCT deterioration 22,2% BCVA deterioration	51,6% among them: 40,0% OCT deterioration 25,0% BCVA deterioration

PSS-10	Glaucoma		
	early	moderate	advanced
PSS-6: How often have you found in the last month that you could not cope with all the things you had to do?	41,6% among them: 60,0% OCT deterioration 30,0% deterioration	20,75% among them: 91,0% OCT deterioration 45,5% BCVA deterioration	23,3% among them: 85,7% OCT deterioration 64,3% BCVA deterioration
PSS-7: How often have you been able to control irritations in your life in the last month?	62,5% among them: 60,0% OCT deterioration 40,0% deterioration	41,5% among them: 66,6% OCT deterioration 66,6% BCVA deterioration	45,5% among them: 66,6% OCT deterioration 16,6% BCVA deterioration
PSS-8: How often have you felt in the last month that you were on top of things?	29,0% among them: 12,5% OCT deterioration 8,3% deterioration	47,2% among them: 25,0% OCT deterioration 32,0% BCVA deterioration	33,3% among them: 84,6% OCT deterioration 33,2% BCVA deterioration
PSS-9: How often have you been angered in the last month because of things that were outside your control?	41,6% among them: 60,0% OCT deterioration 10,0% BCVA deterioration	22,6% among them: 92,0% OCT deterioration 50,0% BCVA deterioration	21,6% among them: 92,3% OCT deterioration 23,1% BCVA deterioration
PSS-10: How often have you felt in the last month that difficulties were piling up so high that you could not overcome them?	29,1% among them: 85,7% OCT deterioration 28,6% BCVA deterioration	15,0% among them: 87,5% OCT deterioration 37,5% BCVA deterioration	25,0% among them: 86,6% OCT deterioration 33,3% BCVA deterioration

4. Discussion

Restrictions and the epidemiological situation made it difficult to maintain continuity of care for patients with chronic diseases, including glaucoma [12, 20]. The results of the present study are consistent with previous reports showing that limited access to healthcare negatively affects the course of glaucoma [21]. Since glaucoma is an incurable disease, appropriate care is based on regular monitoring of potential disease progression and intensification of therapy when such progression is detected [22]. The literature has described delays and cancellations of follow-up visits as well as treatment interruptions during the pandemic, which may have contributed to disease progression [21, 23]. In our study, nearly one-quarter of patients reported canceled or missed follow-up visits for at least 1 year, which may partly explain the observed deterioration in OCT parameters. Progression most often occurs slowly and, for a long time, does not produce clear subjective symptoms, resulting only in deterioration of structural parameters on OCT examination [24, 25]. Limited access to follow-up visits, OCT examinations, visual field testing, and IOP measurement may increase the risk of progression and delay its detection [26].

The present study demonstrated that during the COVID-19 pandemic, patients with glaucoma experienced statistically significant deterioration in structural and functional parameters (worsening OCT results, increased vc/d ratio, and decreased BCVA). Progression of structural changes was particularly evident in patients with moderate and advanced glaucoma. Previous studies have shown that RNFL thinning may precede the onset of functional visual field defects, underscoring the importance of OCT in long-term patient monitoring [27, 28].

Importantly, the structural and functional deterioration observed between the pre-pandemic and 2021 examinations should not be interpreted as evidence that the COVID-19 pandemic itself caused glaucoma progression. Glaucoma is a chronic progressive optic neuropathy, and some degree of RNFL and GCC thinning may be expected over time as part of the natural course of the disease [27]. Because the present study included a single cohort and did not include a comparable pre-pandemic control period or a control group with uninterrupted follow-up, it is not possible to determine whether the observed rate of change exceeded the expected natural rate of glaucoma progression.

Accordingly, the COVID-19 pandemic should primarily be considered the clinical context in which follow-up occurred rather than a demonstrated causal exposure. The finding that approximately one-quarter of participants experienced canceled or missed follow-up visits for at least one year suggests that disruption of care was clinically relevant; however, the present data do not establish that such disruption caused the observed structural changes. Future studies comparing rates of progression before, during, and after the pandemic, ideally using longitudinal models with multiple measurements per patient, would be required to address this causal question.

An interesting observed finding was that a decrease in intraocular pressure was not always associated with stabilization of the disease course. This confirms previous observations that glaucoma progression may also occur in patients with apparently well-controlled IOP, particularly in more advanced stages of the disease [29]. Additional factors influencing progression may include adherence to therapeutic recommendations, vascular disorders, stress, and comorbidities.

An important element of the study was the comparison of patients' subjective assessment of the disease with objective clinical examination results. Patients reporting subjective worsening of glaucoma or difficulties in daily functioning more often presented deterioration of OCT parameters and visual acuity. This relationship was particularly evident in the groups of patients with moderate and advanced glaucoma. Similar observations have previously been reported in studies evaluating patient-reported outcome measures (PROMs), which demonstrated a correlation between deterioration in quality of life and progression of glaucomatous changes [30, 31].

At the same time, fear of vision loss was very common across all glaucoma severity groups. More than half of patients in each subgroup expressed fear of vision loss. The COVID-19 pandemic may have additionally increased the level of anxiety associated with chronic diseases due to social isolation and limited access to healthcare. High stress levels in patients with glaucoma have previously been associated with poorer quality of life and lower adherence to therapeutic recommendations [32]. Therefore, psychological support and appropriate patient education should constitute an important component of glaucoma treatment.

In approximately one-third of patients across all glaucoma severity groups, tear film instability with a TBUT of less than 10 seconds was observed. Chronic use of topical antiglaucoma medications, especially multidrug therapy and preparations containing preservatives such as benzalkonium chloride, is a recognized risk factor for ocular surface disease [33]. Additionally, increased exposure time to electronic device screens during remote work and pandemic restrictions may have exacerbated dry eye symptoms [34]. Ocular surface discomfort may negatively affect treatment adherence.

The limitations of the present study include the relatively small number of patients, the homogeneity of the group, and the single-center design. Additionally, there is a lack of assessment of visual field parameters, which, despite being a subjective test, is a very useful tool for monitoring glaucoma progression [35].

An important limitation of the study is the potential for selection bias resulting from the requirement for available and sufficiently complete ophthalmological and OCT documentation at both the pre-pandemic and 2021 assessments. Patients who maintained ophthalmological follow-up and underwent repeated imaging may differ systematically from those who did not return for follow-up during the pandemic. Conversely, patients experiencing symptoms or more severe disease may have been more likely to undergo repeated examinations. Therefore, the analyzed cohort may not be fully representative of the overall glaucoma population followed before the pandemic.

5. Conclusion

During the follow-up period encompassing the COVID-19 pandemic, structural and functional deterioration was observed in a proportion of patients with glaucoma. Patient-reported worsening and difficulties in daily functioning frequently co-occurred with deterioration in objective ophthalmic parameters, suggesting that patient-reported experience may provide complementary information during

glaucoma monitoring. However, because of the observational single-cohort design, the observed progression cannot be attributed causally to the COVID-19 pandemic or pandemic-related disruption of care. Regular objective monitoring remains essential, while patient-reported outcomes may provide additional clinically relevant information regarding patients' experience of their disease.

Declarations

Author Contribution

JD and MZ wrote tha main manuscript text and prepared tablesJD and AS were responsible for collecting the dataAZZ and JPS supervisedAZZ was responsible for research planning

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Data Availability

The datasets used and analysed during the current study available from the corresponding author on reasonable request.

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