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ORIGINAL RESEARCH ARTICLE

Improvement of dynamic pupillary function after cataract surgery in eyes with pseudoexfoliation syndrome: a six-month longitudinal pupillometry study

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Abstract
Purpose Impaired pupillary dynamics are a well-recognized feature of pseudoexfoliation syndrome (PXF), yet little is known about how cataract surgery influences postoperative iris function in these eyes. This study aimed to determine the longitudinal effects of cataract surgery on static pupil diameters and dilation velocity in eyes with pseudoexfoliation syndrome compared with age-matched controls.
Methods This longitudinal study included 166 eyes of 166 patients undergoing cataract surgery, comprising 91 eyes with pseudoexfoliation syndrome and 75 control eyes without pseudoexfoliation. Pupillary parameters were measured preoperatively and at six months postoperatively using automated pupillometry. Static pupil diameters were assessed under scotopic (0.04 lx), mesopic (4 lx), and photopic (40 lx) illumination conditions. Dynamic pupillary function was evaluated by measuring dilation velocity (DVel, mm/s) following a standardized light stimulus. Postoperative changes (Δ) were calculated as the difference between preoperative and postoperative measurements.
Results Static pupil diameters remained stable in the PXF group across all illumination conditions ($p > 0.05$). In contrast, the control group demonstrated a significant reduction in scotopic pupil diameter after surgery ($p = 0.008$), while mesopic and photopic diameters remained unchanged. The most notable finding was observed in pupillary kinetics: dilation velocity significantly increased in the PXF group from 0.13 ± 0.04 mm/s to 0.17 ± 0.05 mm/s ($p < 0.001$), whereas no significant change was detected in the control group. Between-group comparison showed a significantly greater improvement in dilation velocity in PXF eyes ($p < 0.001$). Cataract morphology was not associated with postoperative pupillary changes.
Conclusion These findings suggest that cataract surgery may be associated with measurable changes in dynamic pupillary behavior in PXF eyes, particularly in dilation velocity, while static pupil diameter remains largely unchanged.

Keywords Pseudoexfoliation syndrome · Pupillometry · Cataract surgery · Pupil dynamics · Dilation velocity · Static pupillary parameters

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Introduction

Pseudoexfoliation syndrome (PXF) is a common age-related systemic disorder characterized by the progressive accumulation of abnormal fibrillar

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extracellular material in ocular tissues. This pseudoexfoliative material is deposited in several anterior segment structures, including the iris, anterior lens capsule, trabecular meshwork, and zonular fibers, resulting in a wide spectrum of ocular complications such as elevated intraocular pressure, zonular instability, and secondary open-angle glaucoma [1, 2]. Due to these structural alterations, eyes with PXF often present unique surgical challenges, particularly during cataract extraction, where insufficient pupillary dilation and zonular weakness may increase the risk of intraoperative complications [2, 3].

Among the ocular manifestations of PXF, abnormalities in pupillary behavior represent an important yet relatively underexplored aspect of the disease. The accumulation of pseudoexfoliative material within the iris stroma is thought to cause structural rigidity and progressive degeneration of the iris dilator muscle. Histopathological and clinical observations suggest that these changes impair the normal biomechanical properties of the iris, leading to reduced pupillary mobility and inadequate pharmacologic or physiologic dilation [3, 4]. In addition to mechanical factors, alterations in autonomic innervation of the iris have also been proposed as contributing mechanisms underlying the impaired pupillary responses observed in PXF eyes.

The development of automated infrared pupillometry has enabled quantitative evaluation of pupillary function with high precision and reproducibility. Unlike traditional clinical assessments, modern pupillometry systems allow simultaneous measurement of static pupil diameters and dynamic pupillary responses under controlled illumination conditions. These measurements provide valuable insights into both structural and functional aspects of iris physiology [4, 5]. Several studies employing automated pupillometry have demonstrated that eyes with pseudoexfoliation syndrome exhibit significantly smaller pupil diameters and reduced pupillary responsiveness compared with healthy controls [5, 6]. In particular, decreased dilation velocity and impaired dynamic pupillary responses have been consistently reported, suggesting compromised function of the iris dilator muscle in PXF [6, 7].

Cataract surgery itself may influence pupillary characteristics through multiple mechanisms. Mechanical manipulation of the iris during phacoemulsification, intraoperative inflammatory responses, and exposure to ultrasound energy may all contribute to postoperative changes in pupil diameter and iris dynamics [8]. Previous studies have shown that cataract surgery can lead to measurable alterations in both static and dynamic pupillary parameters in the postoperative period. However, the extent to which these changes differ between eyes with pseudoexfoliation syndrome and those without pseudoexfoliation remains unclear.

Although numerous studies have examined pupillary characteristics in PXF using cross-sectional designs, longitudinal investigations evaluating pupillary function before and after cataract surgery are scarce. In particular, little is known about whether surgical removal of the cataractous lens and restoration of the optical pathway may influence the dynamic behavior of the iris in eyes affected by pseudoexfoliation syndrome. Understanding these postoperative changes is clinically relevant, as pupillary dynamics may influence visual quality, light adaptation, and overall functional visual outcomes.

Therefore, the aim of the present study was to evaluate longitudinal changes in both static and dynamic pupillary parameters following cataract surgery in patients with pseudoexfoliation syndrome compared with age-matched controls. By assessing pupil diameters under different illumination conditions and analyzing dilation velocity as an indicator of pupillary kinetics, this study sought to provide further insight into the functional behavior of the iris in PXF eyes after cataract surgery.

Material and methods

Study population

The present longitudinal research was conducted at the Department of Ophthalmology, Niğde Ömer Halisdemir University. The local ethics committee accepted the study protocol, and all subjects provided written informed permission prior to assessment. The research followed the principles mentioned in the Declaration of Helsinki. The study included 166 eyes from 166 patients who had undergone cataract surgery. Participants were divided into two groups: individuals diagnosed with Pseudoexfoliation Syndrome (PXF) (n = 91) and an age-matched control group without pseudoexfoliation (n = 75).

All subjects had a complete ophthalmologic examination, which included slit-lamp biomicroscopy, intraocular pressure measurement, and a dilated fundus exam. Pseudoexfoliation was diagnosed by identifying typical pseudoexfoliative material on the anterior lens capsule or pupillary edge during a slit-lamp examination. Eyes with ocular diseases known to affect pupillary function (including previous intraocular surgery, uveitis, glaucoma requiring topical treatment, neuro-ophthalmic disorders, or significant retinal pathology) were excluded from the study. In addition, none of the participants were using topical medications known to directly influence pupillary responses at the time of pupillometric assessment.

Preoperative pupillary measurements were performed prior to cataract surgery, and postoperative measurements were obtained during the six-month follow-up visit. Pupillary characteristics were measured under various lighting circumstances (scotopic, mesopic, and photopic), as well as the velocity of dilation.

Cataract morphology has been categorized as nuclear, cortical, or posterior subcapsular, with subgroup analysis performed accordingly.

Surgical procedure

All cataract surgeries were performed by a single experienced surgeon using a standardized phacoemulsification technique under topical anesthesia. A clear corneal incision was created in all cases, followed by continuous curvilinear capsulorhexis, phacoemulsification of the crystalline lens, cortical aspiration, and implantation of a foldable posterior chamber intraocular lens into the capsular bag.

No iris hooks or pupil expansion devices were used during surgery. Eyes with significant intraoperative complications that could potentially affect postoperative pupillary behavior were excluded from the study.

Postoperatively, all patients received a standardized topical treatment regimen routinely used after cataract surgery, including topical antibiotic and corticosteroid therapy according to institutional clinical practice.

To minimize procedural variability, the same surgical and postoperative follow-up protocols were applied to all participants throughout the study period.

Measurements

Pupillary measurements were performed using an automated infrared pupillometry system integrated into an anterior segment diagnostic platform (Sirius+, CSO, Florence, Italy). All measurements were obtained in a darkened examination room under standardized illumination conditions. To ensure stable pupil size, participants were allowed to adapt to the dark environment for approximately five minutes before measurements were taken. During the examination, subjects were instructed to fixate on a distant target to minimize accommodative effects.

Static pupil diameters were recorded under three different illumination levels representing physiological lighting conditions: scotopic (0.04 lx), mesopic (4 lx), and photopic (40 lx). These light levels were selected in accordance with commonly used pupillometry protocols to evaluate pupil behavior across a range of luminance conditions.

Dynamic pupillary assessment was performed following exposure to a light stimulus of 500 lx. After the stimulus was discontinued, the dilation phase of the pupil was recorded and analyzed. Dilation velocity (DVel) was calculated as the rate of pupil enlargement over time and expressed in millimeters per second (mm/s). This parameter reflects the kinetic response of the iris dilator muscle and provides an objective assessment of pupillary dynamics.

All measurements were performed monocularly and repeated to ensure reproducibility, with the average values used for statistical analysis. The same measurement protocol and device settings were applied for both preoperative and postoperative evaluations to maintain consistency across visits. Similar pupillometry protocols using standardized illumination levels and automated infrared recording have been described previously in studies evaluating pupillary dynamics in pseudoexfoliation syndrome and cataract surgery populations.

Statistical analysis

R software (*version 4.5.2* [9]) was used to conduct statistical analyses. Using the *pwr* package for R, an a priori power analysis was carried out to calculate the sample size necessary to identify significant variations in pupillary parameters [10]. The study was powered to identify a medium effect size (Cohen's

$d = 0.50$) for the comparison between patients with pseudoexfoliation syndrome (PXF, n = 91) and controls (n = 75). A minimum of 64 subjects per group were needed with a two-tailed α level of 0.05 and 80% power; our overall sample (N = 166) exceeded this requirement, preserving adequate power despite slightly unbalanced groupings. For paired comparisons (pre- vs. post-operative), power analysis indicated that 34 subjects were required to detect a medium effect size ($d = 0.50$, $\alpha = 0.05$).

The primary objectives were postoperative changes (Δ) in pupil diameter (mm) at three light levels (scotopic: 0.04 lx, mesopic: 4 lx, photopic: 40 lx) and dilation velocity (mm/s at 500 lx). Δ values were calculated as the difference between preoperative and postoperative measures. Between-group comparisons of postoperative change (Δ) values were performed using the Mann–Whitney U test. The Shapiro–Wilk test was used to assess the data distribution. Continuous variables were presented using mean ± standard deviation for normally distributed data, and median and interquartile range (IQR) for non-normally distributed data. Normally distributed variables were examined using independent and paired t-tests. For non-normal data, the Mann–Whitney U test was employed for between-group comparisons, whereas the Wilcoxon signed-rank test was utilized for paired longitudinal analyses. Categorical variables were compared using the Chi-square or Fisher exact tests. Subgroup analysis according to cataract morphology (nuclear, cortical, and posterior subcapsular) was performed using the Kruskal–Wallis test. All statistical tests were two-tailed, and a p-value < 0.05 was considered statistically significant.

Results

The primary outcome of the present study was the postoperative change in dilation velocity (DVel), while secondary outcomes included changes in static pupil diameters measured under scotopic, mesopic, and photopic illumination conditions. The PXF and control groups were selected to be comparable in terms of demographic and ocular features (Table 1). Both groups had similar mean age (63.54 ± 6.74 vs. 64.05 ± 7.03 years; $p = 0.6$), gender composition (male: 47% vs. 52%; female: 53% vs. 48%; $p = 0.5$), and did not differ in the distribution of right and left eyes (right: 51% vs. 52%; left: 49% vs. 48%; $p = 0.9$). The distribution of cataract types was likewise similar between the two groups (nuclear: 35% vs. 28%; cortical: 35% vs. 35%; posterior subcapsular: 30% vs. 37%; p = 0.5), as well as the mean axial length (22.98 ± 0.58 vs. 22.94 ± 0.57 mm; $p = 0.8$) and the mean intraocular lens power (21.41 ± 2.19 vs. 21.08 ± 2.14 D; $p = 0.3$).

Table 1 Demographic and ocular characteristics of the study group

Parameter	PXF n = 91[1]	Control n = 75[1]	p-value[2]
Age	63.54 ± 6.74	64.05 ± 7.03	0.6
Gender			0.5
Male	43 (47%)	39 (52%)	
Female	48 (53%)	36 (48%)	
Cataract			0.5
Nuclear	32 (35%)	21 (28%)	
Cortical	32 (35%)	26 (35%)	
Posterior Subcapsular	27 (30%)	28 (37%)	
AL	22.98 ± 0.58	22.94 ± 0.57	0.8
IOL	21.41 ± 2.19	21.08 ± 2.14	0.3
Side			0.9
Right	46 (51%)	39 (52%)	
Left	45 (49%)	36 (48%)	

[1]Mean ± SD; n (%) [2]Wilcoxon rank sum test; pearson's Chi-squared test. PXF: Pseudoexfoliation syndrome, AL: axial length, IOL: intraocular lens power

The analysis of static pupillary diameters revealed different response patterns between groups (Table 2). The pupil size in the PXF group remained stable across all illumination conditions, with no significant changes in scotopic ($p = 0.441$), mesopic ($p = 0.506$), or photopic ($p = 0.865$) measurements. In contrast, the control group demonstrated a significant reduction in scotopic pupil diameter (5.51 ± 1.01 mm to 5.06 ± 1.00 mm; $p = 0.008$). As shown in Table 3, there were no significant differences in static pupil diameters between the two groups (scotopic $p = 0.188$, mesopic $p = 0.707$, photopic $p = 0.426$). These findings suggest that although the control group showed a tendency toward scotopic miosis, the overall effect of surgery on static pupil diameter was comparable between the two groups.

The most noteworthy finding was observed in dynamic pupillary function. The PXF group demonstrated a significant increase in dilation velocity (DVel), from 0.13 ± 0.04 mm/s to 0.17 ± 0.05 mm/s

Table 2 Longitudinal comparison of pupillary parameters under different lighting conditions between the PXF and control groups before and six months after cataract surgery

Group	Parameter	Mean pre-operative	Mean post-operative	Mean change (Δ)	*p*-value*
PXF	Scotopic (mm)	5.55 ± 1.01	5.42 ± 1.06	− 0.13 ± 1.59	0.441
PXF	Mesopic (mm)	4.51 ± 1.06	4.39 ± 1.06	− 0.12 ± 1.67	0.506
PXF	Photopic (mm)	3.42 ± 0.92	3.44 ± 1.04	0.03 ± 1.49	0.865
PXF	DVel (mm/s)	0.13 ± 0.04	0.17 ± 0.05	0.04 ± 0.07	**< 0.001**
Control	Scotopic (mm)	5.51 ± 1.01	5.06 ± 1.00	− 0.45 ± 1.44	**0.008**
Control	Mesopic (mm)	4.31 ± 1.04	4.09 ± 0.96	− 0.22 ± 1.39	0.175
Control	Photopic (mm)	3.45 ± 0.91	3.27 ± 0.94	− 0.18 ± 1.25	0.221
Control	DVel (mm/s)	0.21 ± 0.06	0.20 ± 0.05	− 0.01 ± 0.08	0.152

Bold values represent statistically significant results ($p < 0.05$)

Table 3 Between-group comparison of postoperative change (Δ)

Parameter	PXF median (IQR)	Control median (IQR)	*p*-value*
Dilation velocity	0.04 (− 0.01–0.09)	− 0.02 (− 0.07–0.03)	< 0.001
Mesopic	− 0.07 (− 1.36–1.16)	− 0.28 (− 1.22–0.80)	0.707
Photopic	0.06 (− 1.12–0.84)	− 0.24 (− 1.15–0.63)	0.426
Scotopic	− 0.17 (− 1.31–0.85)	− 0.51 (− 1.60–0.68)	0.188

*p-values calculated using the Mann–Whitney U test. Significance level: $p < 0.05$

($p < 0.001$, Table 2). Between-group analysis further showed that the improvement in DVel was significantly greater in the PXF group compared with the control group ($p < 0.001$, Table 3). This improvement in pupillary kinetics in the PXF group is also illustrated in Fig. 1.

Figure 1 demonstrates the longitudinal behavior of pupillary parameters in both groups. While static pupil diameters remained largely stable in the PXF group across illumination conditions, the control group exhibited a reduction in scotopic pupil diameter. In contrast, dilation velocity showed a clear postoperative increase in the PXF group, whereas the control group remained relatively stable.

The magnitude of postoperative change (Δ) in pupillary parameters is illustrated in Fig. 2. The dilation velocity shows a substantial difference ($p < 0.001$), with the PXF group having a positive Δ (improvement in velocity) and the control group centering around zero. The Δ values for Mesopic, Photopic, and Scotopic diameters overlap significantly between the two groups. This suggests that the fundamental physiological difference between PXF and healthy eyes six months after cataract surgery is the return of kinetic agility rather than a change in resting pupil size.

Figure 3 investigates whether the type of cataract present pre-operatively influenced the surgical outcome on pupil dynamics. Across all four metrics dilation velocity (DVel), mesopic, photopic, and scotopic changes the Kruskal–Wallis tests resulted in non-significant p-values (ranging from $p = 0.17$ to $p = 0.99$). This demonstrates that the improvements observed (particularly in dilation velocity) are independent of the initial cataract morphology.

Discussion

Pseudoexfoliation syndrome (PXF) is a multifactorial, age-related disorder characterized by the progressive deposition of fibrillar extracellular material within ocular tissues. This pathological process primarily affects structures of the anterior segment, including the iris, zonules, trabecular meshwork, and lens capsule, leading to a wide spectrum of clinical manifestations such as impaired mydriasis, increased intraocular pressure, and zonular instability [11, 12]. Because of these structural alterations, eyes with pseudoexfoliation syndrome frequently exhibit abnormal pupillary responses and are associated with an increased risk of complications during cataract surgery.

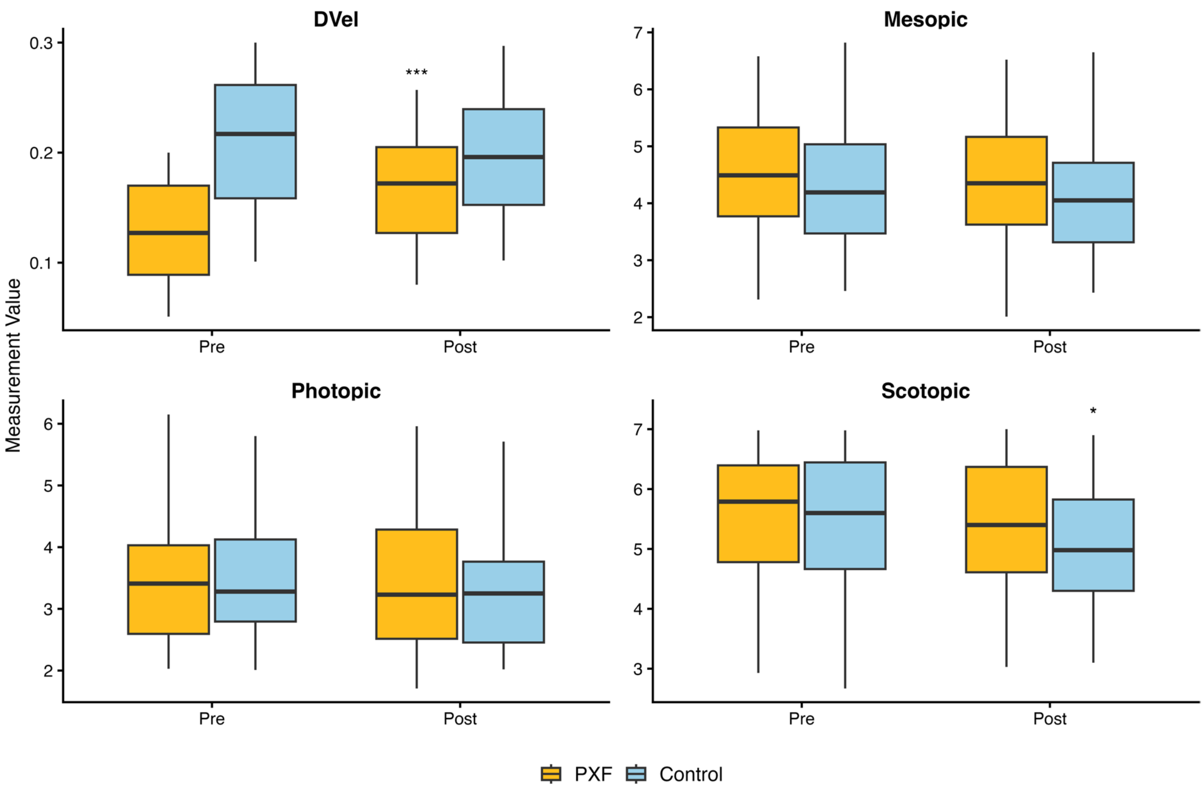

Fig. 1 Preoperative and six-month postoperative pupillary parameters in eyes with pseudoexfoliation syndrome (PXF) and controls. Static pupil diameters were measured under scotopic, mesopic, and photopic illumination conditions, and dynamic pupillary function was evaluated using dilation velocity (DVel). The principal finding of this study was a significant postoperative increase in dilation velocity in PXF eyes, suggesting altered postoperative dynamic pupillary behavior after cataract surgery. Cataract surgery did not significantly alter static pupil diameters in PXF eyes, whereas control eyes demonstrated a reduction in scotopic pupil diameter following surgery. Data are presented as boxplots showing the interquartile range and median values. Statistical significance between preoperative and postoperative measurements is indicated (*$p<0.05$, **$p<0.01$, ***$p<0.001$). PXF, pseudoexfoliation syndrome; DVel, dilation velocity

Alterations in pupillary dynamics in PXF have been well documented in the literature. Several studies using automated pupillometry have demonstrated that eyes with pseudoexfoliation syndrome show smaller static pupil diameters and impaired dynamic responses compared with healthy individuals [13, 14]. These abnormalities have been attributed to the infiltration of pseudoexfoliative material within the iris stroma and dilator muscle, which results in mechanical rigidity and progressive functional impairment of the iris [15]. Histopathological studies have further suggested that degeneration of the iris dilator muscle and disruption of autonomic innervation may contribute to the reduced pupillary responsiveness observed in PXF eyes [16].

Previous clinical investigations have consistently reported reduced pupillary mobility in patients with pseudoexfoliation syndrome. Tekin et al. demonstrated that both static and dynamic pupillary parameters were significantly lower in PXF eyes compared with controls, including decreased scotopic and mesopic pupil diameters as well as reduced contraction and dilation velocities [6]. Similarly, Yasar et al. reported that pupillary dynamics are altered in pseudoexfoliation syndrome and suggested that pupillometry may serve as a useful tool for detecting functional iris abnormalities in these patients [5]. Other studies have also confirmed that impaired dilation velocity is one of the most characteristic pupillometric findings associated with pseudoexfoliation syndrome [17, 18].

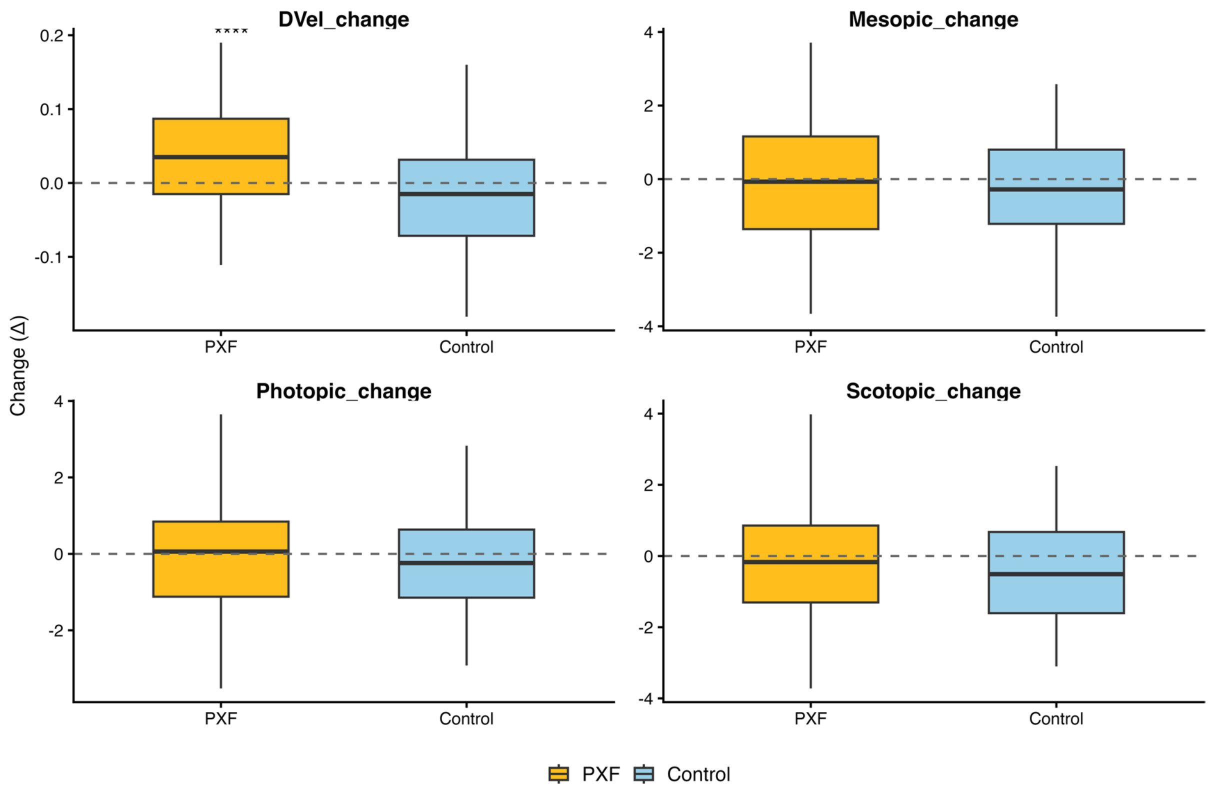

Fig. 2 Between-group comparison of postoperative changes (Δ) in pupillary parameters in pseudoexfoliation (PXF) and control eyes. Δ values represent the difference between postoperative and preoperative measurements for static pupil diameters (scotopic, mesopic, photopic) and dilation velocity (DVel). Eyes with pseudoexfoliation syndrome demonstrated a significantly greater postoperative change in dilation velocity compared with controls, whereas postoperative changes in static pupil diameters were comparable between groups. The dashed horizontal line represents no change from baseline. PXF, pseudoexfoliation syndrome; DVel, dilation velocity

In contrast to these predominantly cross-sectional observations, the present study provides longitudinal data on pupillary changes after cataract surgery in patients with PXF. The most notable finding of our study was the significant postoperative increase in dilation velocity in the PXF group, while static pupil diameters remained largely unchanged. The observed increase in dilation velocity may indicate altered postoperative pupillary dynamics in eyes with pseudoexfoliation syndrome. However, because the PXF group demonstrated lower baseline dilation velocity values than controls, the possibility that regression to the mean may have partially contributed to the observed postoperative increase cannot be excluded.

One potential explanation for this improvement in dilation velocity may relate to biomechanical changes within the anterior segment following lens removal. The aging crystalline lens becomes progressively thicker and more rigid with cataract formation, potentially limiting iris mobility within the posterior chamber. Cataract extraction and intraocular lens implantation may therefore relieve this mechanical constraint, allowing greater freedom of iris movement and resulting in improved dynamic pupillary responses [19]. Similar mechanisms have been suggested in previous studies evaluating pupillary changes after phacoemulsification procedures [20]. However, because structural iris imaging or direct biomechanical assessment was not performed in the present study, these interpretations remain speculative.

Another factor that may contribute to improved pupillary kinetics after cataract surgery is the restoration of retinal illumination. Cataracts significantly reduce retinal light transmission, which may alter the afferent limb of the pupillary light reflex pathway. Following cataract removal, increased retinal

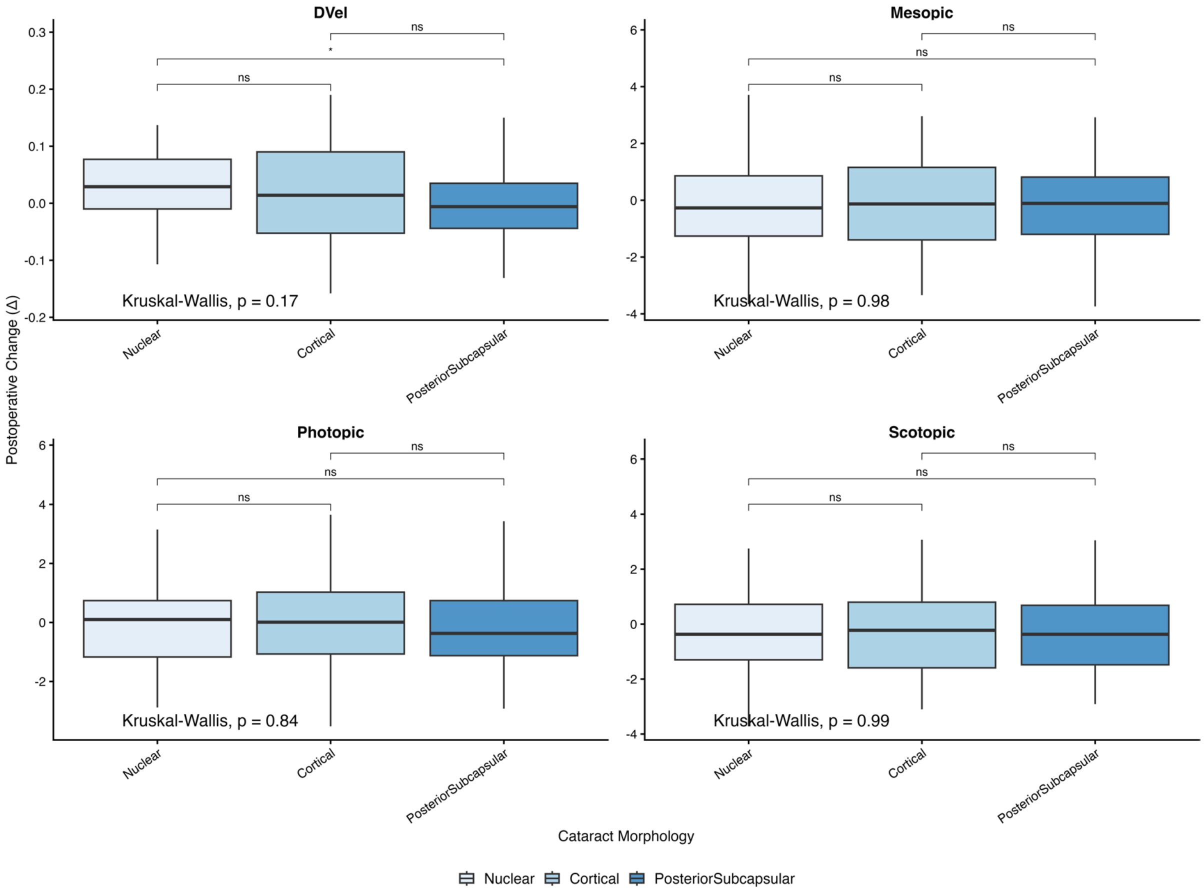

Fig. 3 Subgroup analysis of postoperative changes (Δ) in pupillary parameters according to cataract morphology. Postoperative changes in dilation velocity (DVel) and static pupil diameters under scotopic, mesopic, and photopic illumination were compared among nuclear, cortical, and posterior subcapsular cataracts. No statistically significant differences were observed among cataract morphologies for any pupillary parameter. Statistical comparisons were performed using the Kruskal–Wallis test. DVel, dilation velocity

illumination may enhance neural signaling within the pupillary reflex arc, leading to improved autonomic regulation of iris movement and faster dilation responses [21]. This phenomenon has also been described in studies evaluating postoperative pupillary function in patients undergoing cataract surgery [22].

Interestingly, despite the improvement in dilation velocity, static pupil diameters did not significantly change in the PXF group in our study. This finding may indicate that structural alterations within the iris caused by pseudoexfoliation syndrome are largely irreversible. The accumulation of pseudoexfoliative material within the iris stroma can lead to permanent fibrotic changes that may limit the maximal resting pupil diameter [23]. Therefore, while dynamic parameters such as dilation velocity may improve due to functional changes in iris mobility or neural signaling, the structural characteristics of the iris may remain relatively unchanged.

The results of our study also demonstrated that postoperative changes in pupillary parameters were independent of cataract morphology. Subgroup analysis based on nuclear, cortical, and posterior subcapsular cataract types did not reveal significant differences in pupillary outcomes. This suggests that the observed improvement in dilation velocity is more likely related to the surgical intervention itself rather than to the specific morphological characteristics of the cataract. Previous studies investigating the relationship between cataract type and pupillary dynamics have similarly reported no consistent association between cataract morphology and pupillometric parameters [24].

From a clinical standpoint, the improvement in dynamic pupillary function observed in PXF eyes after cataract surgery may have important implications. Pupillary dynamics play a crucial role in visual quality, light adaptation, and contrast sensitivity. Abnormal pupillary responses may contribute to visual symptoms such as glare, halos, and impaired night vision [25]. However, the potential functional implications of these pupillometric changes remain uncertain, since visual quality parameters such as glare symptoms, contrast sensitivity, and patient-reported outcomes were not evaluated in the present study.

The present study has several strengths. First, the longitudinal design allowed direct comparison of pupillary parameters before and after cataract surgery in the same individuals. Second, the use of automated pupillometry provided objective and reproducible measurements under standardized illumination conditions. Third, the relatively large sample size compared with many previous pupillometry studies enhances the robustness of the findings and allows a more reliable evaluation of pupillary behavior in PXF patients [26].

Nevertheless, several limitations should be acknowledged. The follow-up period of six months may not fully reflect long-term changes in pupillary behavior after cataract surgery. Additionally, structural evaluation of the iris using imaging techniques such as anterior segment optical coherence tomography or ultrasound biomicroscopy was not performed in this study. These modalities could provide valuable insights into the relationship between structural iris changes and functional pupillary parameters [27]. In addition, functional visual outcomes such as glare symptoms, contrast sensitivity, or patient-reported visual quality were not evaluated, which limits direct assessment of the clinical significance of the observed pupillary changes. Furthermore, intraoperative parameters such as cumulative phacoemulsification energy, phaco time, and postoperative inflammatory response were not systematically analyzed and may have influenced postoperative pupillary behavior. In addition, systemic medications that may potentially influence pupillary dynamics were not systematically recorded and therefore could not be controlled for in the analysis. Additionally, multivariable longitudinal modelling approaches such as mixed-effects analysis or ANCOVA were not performed, which may limit adjustment for potential baseline differences and perioperative confounding factors. Finally, although the present study included a relatively large cohort, further multicenter investigations may be necessary to confirm the generalizability of these findings across different populations.In conclusion, the present study expands the current understanding of pupillary behavior in pseudoexfoliation syndrome and provides novel longitudinal evidence regarding pupillary changes following cataract surgery. While pseudoexfoliation syndrome is traditionally associated with impaired pupillary dynamics and reduced iris mobility, our findings demonstrate that cataract surgery may lead to a measurable improvement in dynamic pupillary function, particularly dilation velocity. Importantly, this statistically significant increase in dilation velocity occurred without significant alterations in static pupil diameter. However, the clinical significance of this quantitative pupillometric change remains uncertain and should be interpreted cautiously. Further studies incorporating structural iris imaging and functional visual outcome measures are needed to clarify the clinical relevance of these findings. These findings highlight the importance of evaluating dynamic pupillary parameters in addition to static measurements when assessing iris function in patients with pseudoexfoliation syndrome and suggest that automated pupillometry may serve as a valuable tool for understanding postoperative functional changes in iris physiology and visual adaptation in this patient population [18].

Clinical relevance

Pseudoexfoliation syndrome is frequently associated with impaired pupillary dynamics and insufficient dilation, which may complicate cataract surgery and influence postoperative visual function. The present findings suggest that cataract surgery may be associated with improvement in dynamic pupillary responses, particularly dilation velocity, in eyes with pseudoexfoliation syndrome. Evaluation of dynamic pupillary parameters using automated pupillometry may therefore provide valuable information about postoperative iris function and visual adaptation in this patient population.

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Author contributions GA (First Author) contributed to the conceptualization of the study, data collection, statistical analysis, interpretation of the results, and drafting of the manuscript. OO contributed to patient recruitment, clinical examinations, data acquisition, and critical revision of the manuscript for important intellectual content. MK (Corresponding Author) contributed to study design, supervision of the research process, interpretation of the findings, and final review and approval of the manuscript. All authors read and approved the final version of the manuscript.

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Data availability The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest The authors declare that they have no conflicts of interest related to this work.
The study protocol was approved by the Ethics Committee of Niğde Ömer Halisdemir University (Approval No. 2026/51; March 26, 2026). The study was conducted in accordance with the ethical principles of the Declaration of Helsinki.
Written informed consent was obtained from all participants before inclusion in the study.

Statement of human rights All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Written informed consent was obtained from all individual participants included in the study.

Statement on the welfare of animals This article does not contain any studies with animals performed by any of the authors.

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