Article

The Impact of Preoperative Blood Glucose Control on Corneal Recovery and Visual Function After Phacoemulsification in Diabetic Cataract Patients

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AIM: Diabetic patients are at an increased risk for cataract and may experience delayed postoperative recovery due to diabetes-related ocular tissue vulnerability. However, the impact of preoperative glycemic control on early surgical outcomes and quality of life remains to be fully elucidated. This study aimed to investigate the effects of preoperative fasting blood glucose (FBG) control on postoperative corneal recovery, visual function, and vision-related quality of life in type 2 diabetic patients undergoing phacoemulsification.

METHODS: In this retrospective analysis, 197 cataract patients with type 2 diabetes who underwent phacoemulsification between March 2023 and March 2025 were included. Based on their preoperative FBG levels, they were divided into a well-controlled group (FBG <6.1 mmol/L, n = 83) and a poorly controlled group (FBG $\geq$6.1 mmol/L, n = 114). National Eye Institute Visual Function Questionnaire-25 (NEI-VFQ-25), mean corneal astigmatism, corneal edema recovery, and best corrected visual acuity (BCVA) were compared between the two groups.

RESULTS: Postoperatively, the well-controlled group had significantly higher total scores and scores on all dimensions of the NEI-VFQ-25 scale than the poorly controlled group (all $p < 0.05$). Regarding corneal recovery, the group with better control showed greater changes in mean corneal astigmatism on postoperative days 7 and 30 ($p < 0.001$). The corneal transparency ratio was higher on postoperative day 7 ($p = 0.006$), while there was no significant difference between the two groups on postoperative day 30. On postoperative day 7, the logarithm of the minimum angle of resolution (logMAR) BCVA of the well-controlled group was also significantly better than that of the poorly controlled group ($p < 0.001$). By postoperative day 30, the differences in corneal transparency and BCVA between the two groups became non-significant ($p > 0.05$).

CONCLUSIONS: Good preoperative glycemic control in diabetic patients undergoing phacoemulsification is associated with faster early corneal edema resolution, better early visual recovery, and clinically meaningful improvements in vision-related quality of life. These findings underscore the importance of enhanced perioperative glycemic management to optimize short-term surgical outcomes and health-related quality of life in this population.

Keywords: diabetes mellitus; cataract; phacoemulsification; corneal recovery

Introduction

Diabetes mellitus (DM) is a complex chronic metabolic disease characterized by persistently elevated blood glucose levels [1]. The disease can have a profound long-term impact on multiple organ systems, leading to a series of serious microvascular and macrovascular complications [2]. In recent years, with the profound changes in the global population structure driven by population growth and accelerated aging, a shift toward urban lifestyles marked by reduced physical activity, and changes in dietary structure accompanied by social environmental changes, the prevalence of diabetes has shown a continuous and significant upward trend worldwide [3]. According to epidemiological data, the global prevalence of diabetes is projected to increase from about 9.3% in 2019 to 10.2% by 2030, with a further increment to 10.9% by 2045 [4]. This serious situation makes the prevention and treatment of diabetes and its complications a major challenge in the field of global public health. Among the many complications of diabetes, ocular complications are particularly prominent, with cataracts being one of the most common complications [5]. Poor long-term blood sugar control and advanced age are recognized as two core risk factors for the occurrence and development of cataracts [6]. Cataracts are medically defined as a condition in which the natural lens of the eyeball becomes less transparent or changes color due to various reasons, including congenital, metabolic, traumatic, and especially age-related factors, resulting in one or more opacities of varying sizes [7]. This opacity prevents light from focusing normally on the retina, resulting in a progressive decline in visual quality, including blurred vision, glare, and decreased contrast sensitivity [8]. Currently, cataracts have become

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the leading cause of visual impairment and even blindness worldwide, especially among middle-aged and elderly people over 50 years of age, accounting for about 45% of all cases of blindness worldwide [9]. For cataracts that have already formed, drug treatment cannot reverse or eliminate lens opacity. Surgical removal of the opaque lens and implantation of an artificial lens is currently the only proven effective radical treatment [10].

Modern cataract surgery techniques have made revolutionary progress over the past few decades. Among them, phacoemulsification combined with intraocular lens implantation has become the mainstream treatment method in clinical practice due to its significant advantages, such as small incision, minimal invasiveness, good anterior chamber stability during surgery, fast postoperative visual recovery, and minimal astigmatism [11]. This technique involves insertion of a phacoemulsification probe into the eye through a tiny corneal or corneal-scleral incision, pulverization of the cloudy lens nucleus into an emulsion using high-frequency ultrasound, simultaneous aspiration of the emulsion, and implantation of a foldable intraocular lens [12]. At present, phacoemulsification techniques are highly mature, with a low overall complication rate and a high safety profile. Nevertheless, as an invasive procedure, phacoemulsification surgery could be a source of physiological stress to the patients and cause mechanical disturbance to the intraocular tissues. Ultrasound energy generated during the procedure, the impact of perfusion fluid flow on intraocular structures, and the inflammatory response may all contribute to damage of the corneal endothelial cells, a key structure responsible for maintaining corneal transparency [13]. Patients with diabetes face a more complex situation and higher postoperative risks than non-diabetic patients when undergoing cataract surgery. A study has shown that a long-term hyperglycemic environment can have a direct adverse effect on the structure and function of corneal endothelial cells through a variety of pathophysiological mechanisms, such as activating the polyol pathway, promoting the production of advanced glycation end-products, aggravating oxidative stress, and inducing chronic low-grade inflammation [14]. This includes impairing the pump function and barrier integrity of endothelial cells, weakening the cells' tolerance to surgical stress, and possibly increasing the permeability of the blood-aqueous barrier. Therefore, diabetes is widely regarded as an important risk factor for complications such as aggravated corneal endothelial damage, prolonged corneal edema, aggravated inflammatory response, and secondary macular edema after cataract surgery [15,16]. These complications are directly related to the speed of postoperative visual recovery, the final best corrected visual acuity level, and the overall visual-related quality of life. With the increasing prevalence of diabetes, the number of diabetic patients undergoing cataract surgery is growing, making the optimization of surgical prognosis for this population a clinical issue of great practical significance. Therefore, among the prognostic factors of diabetic patients undergoing phacoemulsification, the long-term preoperative blood glucose level is considered to be a crucial and theoretically modifiable and quantifiable key variable [17]. However, the detailed and specific relationship between different levels of blood glucose control and the degree of improvement in patients' postoperative quality of life and visual recovery has never been examined in past studies. In view of the above research and the key issues in clinical practice, in order to explore the association between preoperative blood glucose status and surgical prognosis and plug the research gap, this study adopted a retrospective analysis method to systematically evaluate the impact of different fasting blood glucose (FBG) levels on corneal recovery and visual function after phacoemulsification in diabetic patients. By collecting and analyzing the clinical data of diabetic patients who have previously undergone surgery, and grouping them according to their preoperative FBG values, the study depicts the corneal recovery and visual function levels at multiple time points after surgery among different blood glucose level subgroups. The results of this study are expected to provide more specific reference for clinical practice regarding preoperative blood glucose management in diabetic patients undergoing cataract surgery. Clarifying the correlation between preoperative FBG levels and key postoperative outcome indicators would provide crucial clues for developing more refined and individualized surgical risk assessment and preoperative preparation strategies. This not only assists ophthalmologists in better balancing surgical timing and safety in clinical decision-making and optimizing surgical plans, but also has practical significance in promoting multidisciplinary collaborative management during the perioperative period. Ultimately, it aims to improve the overall efficacy of cataract surgery in diabetic patients and enhance their postoperative visual quality and quality of life.

Methods

Patient Inclusion and Exclusion Criteria

In this retrospective study, data were obtained from type 2 diabetic patients who underwent phacoemulsification combined with intraocular lens implantation at the Cataract Treatment Center of The Second Affiliated Hospital of Guangdong Medical University between March 2023 and March 2025. The study aimed to evaluate the impact of preoperative FBG control on postoperative corneal recovery and visual function. The inclusion criteria for patients included: (1) age $\leq$85 years; (2) confirmed diagnosis of type 2 diabetes; (3) confirmed diagnosis of cataract and selected to undergo phacoemulsification; and (4) complete preoperative and postoperative follow-up data, completion of 1-month follow-up after surgery, and completion of indicator testing during follow-up. The exclusion criteria were: (1) presence of other ocular diseases that may affect visual function assessment, including but not limited to diabetic retinopathy requiring active treatment, clinically significant macular edema, or any other retinal or optic nerve pathology that could independently impair visual acuity; (2) previous ocular surgery; (3) serious systemic diseases (such as late-stage heart and kidney failure) or cognitive impairment that prevented completion of the quality of life questionnaire; and (4) serious complications during or after surgery (such as posterior capsule rupture, fulminant suprachoroidal hemorrhage, and endophthalmitis). A total of 197 patients were ultimately included. Based on their last preoperative fasting blood glucose level, all eligible patients were divided into two groups: well-controlled group (FBG $<$6.1 mmol/L group, n = 83) and poorly controlled group (FBG $\geq$6.1 mmol/L, n = 114) [18]. The cutoff value of 6.1 mmol/L was selected based on the diagnostic criteria for impaired fasting glucose recommended by the American Diabetes Association (ADA) and the Chinese Diabetes Society, which is a commonly used threshold in clinical practice to differentiate between adequate and inadequate glycemic control prior to surgery. While alternative stratification methods, such as using glycated hemoglobin (HbA1c) levels or a higher FBG cutoff (e.g., 7.0 mmol/L), could provide additional perspectives on long-term or more severe glycemic dysregulation, these were not feasible in the current retrospective design due to the unavailability of uniform HbA1c data and the need to maintain adequate sample sizes in each subgroup for statistical power. The chosen dichotomization based on the 6.1 mmol/L FBG threshold represents a pragmatic and clinically relevant approach to assess the impact of preoperative glycemic status on early postoperative recovery, aligning with routine clinical assessments where FBG is the most readily available metric. The study protocol was approved by the Ethics Committee of The Second Affiliated Hospital of Guangdong Medical University (ethics number: PJKT2026-005), and all aspects of this study were designed and conducted in adherence to the Declaration of Helsinki.

Baseline Data Collection

Baseline data for all included patients were collected by reviewing the electronic medical record system, including age, sex, body mass index (BMI), diabetes course, complications, eye(s) operated (left, right, bilateral), and education level. Cataract nuclear hardness was graded according to the Lens Opacity Classification System III (LOCS III) [19], and the distribution of each grade was recorded.

Outcome Evaluation Indicators

Quality of Life Level

This study used the Chinese version of the National Eye Institute Visual Function Questionnaire-25 (NEI-VFQ-25) to assess the visual-related quality of life of the study subjects [20]. The NEI-VFQ-25 was simplified and revised by the National Eye Institute (NEI) based on the original NEI-VFQ-51. It is one of the most widely used visual function and visual-related quality of life assessment tools in the world. It has been widely used in clinical research and efficacy evaluation of various ophthalmic diseases and conditions, such as cataracts, glaucoma, retinal diseases, and refractive surgery.

This scale contains 25 items covering 12 visual function-related dimensions: general health, general vision, near vision activities, distance vision activities, ocular pain, social functioning, mental health, role difficulties, dependency, driving difficulties, color vision, and peripheral vision. Each dimension consists of a different number of items to assess the patient's visual function status and its impact on quality of life from multiple perspectives. The scale uses a standardized scoring method to convert each item. Each item is converted to a standardized score of 0–100 based on its original response options, where 0 represents the worst visual function status and 100 represents the best status. The score for each dimension is the average score of all items within that dimension; therefore, the score range for each dimension is 0–100. The total score of NEI-VFQ-25 is the average of the scores of the other 11 dimensions except for the overall health dimension. The total score ranges from 0 to 100. A higher score indicates a better level of visual-related quality of life [21]. The NEI-VFQ-25 questionnaire was administered at two standardized time points: within 3 days before surgery (preoperative baseline assessment) and at 1 month after surgery during routine postoperative follow-up. The preoperative assessment was used to evaluate baseline vision-related quality of life before surgical intervention, while the 1-month postoperative assessment was intended to reflect early visual rehabilitation status after stabilization of corneal edema and refractive recovery.

Corneal Recovery Assessment

The mean corneal astigmatism power was used to assess the anterior corneal morphological parameters of patients. Anterior corneal morphological parameters were measured using corneal topography at different time points before and after surgery, including preoperatively, at 1 week postoperatively, and at 1 month postoperatively. All examinations were performed by the same experienced technician under identical conditions to minimize measurement bias. Subjects avoided wearing contact lenses for at least 2 weeks before the examination to rule out potential influences of contact lenses on corneal morphology. Simulated keratometry (SimK) readings were used to measure corneal curvature, recording flat principal meridian curvature (K1) and steep principal meridian curvature (K2), both in diopters (D). SimK values were obtained by analyzing the anterior corneal curvature of a central 3.0 mm region. The mean corneal astigmatism power was obtained by calculating the absolute difference between K1 and K2 ($|K1 - K2|$).

Corneal edema was assessed using slit-lamp biomicroscopy, which remains a widely accepted clinical method for evaluating postoperative corneal transparency in routine ophthalmic practice. All examinations were performed under uniform lighting conditions and interpreted by the same experienced ophthalmologist who was blinded to patients' glycemic status to minimize observer bias and improve assessment consistency. The assessment focused on corneal transparency and the presence and distribution of Descemet's membrane folds, which are commonly used clinical criteria for assessing corneal endothelial function and the degree of postoperative corneal edema. Based on the slit-lamp examination results, corneal edema was classified into the three types [22]:

(1) Clear cornea: The cornea is completely transparent, and no corneal stromal opacity or Descemet's membrane folds were observed, indicating good corneal endothelial function and no clinically significant corneal edema.

(2) Focal corneal edema: Mild edema appears in a local area of the cornea, with visible Descemet's membrane folds, but the number of folds is less than 10 and the distribution is limited.

(3) Diffuse corneal edema: The corneal edema is diffuse, with markedly reduced corneal transparency and numerous folds (>10) in Descemet's membrane, indicating severe impairment of corneal endothelial pump function.

Assessment of Visual Function

Best corrected visual acuity (BCVA) was measured by an experienced optometrist under standardized lighting conditions using the Snellen chart. All measurements were performed after the patient's refractive error was fully corrected, and were taken preoperatively, in the first week postoperatively, and in the first month postoperatively. For ease of statistical analysis, Snellen visual acuity results were uniformly converted to logarithm of the minimum angle of resolution (logMAR) values. After conversion, a logMAR value of 0.0 corresponds to a Snellen visual acuity of 20/20 (i.e., decimal visual acuity of 1.0), with higher values indicating poorer visual acuity.

Statistical Analysis

This study used SPSS 26.0 (IBM Corp., Armonk, NY, USA) software for statistical analysis of all data. Continuous variables were first tested for normality using the Kolmogorov–Smirnov test. Data conforming to a normal distribution were expressed as mean ± standard deviation and analyzed using independent samples *t*-tests for intergroup comparisons. Data not conforming to a normal distribution were expressed as median (interquartile range) and analyzed using Mann–Whitney *U* tests for inter-group comparisons. Categorical variables were expressed as frequency (percentage), and chi-square tests or Fisher's exact tests were used for comparisons between groups. All statistical tests were two-tailed, and a $p < 0.05$ was considered statistically significant. For outcome measures assessed at multiple postoperative time points (corneal astigmatism, corneal edema, and BCVA), between-group comparisons were performed separately at each time point using the appropriate tests (independent *t*-tests for normally distributed continuous variables, Mann–Whitney *U* tests for non-normally distributed continuous variables, and chi-square tests for categorical variables). These analyses are descriptive in nature, aligning with the exploratory objective of examining the trajectory of between-group differences at specific clinically relevant time points, rather than testing a single global hypothesis of change over time.

Results

Patient Demographic and Sociological Characteristics

This study included 197 patients with type 2 diabetes and cataracts. Based on their preoperative FBG levels, they were divided into a well-controlled group (FBG <6.1 mmol/L, n = 83) and a poorly controlled group (FBG ≥6.1 mmol/L, n = 114). There were no statistically significant differences between the two groups in age, BMI, gender distribution, diabetes course, complications, eye(s) operated, education level, occupation type, and LOCS III nuclear hardness grade distribution (all $p > 0.05$), indicating that the baseline characteristics of the two groups were balanced and comparable (Table 1).

Comparison of Vision-Related Quality of Life

As shown in Table 2, there were no significant differences between the two groups of patients before surgery in the scores of 12 dimensions (general health, general vision, near vision activities, distance vision activities, ocular pain, social functioning, mental health, role difficulties, dependency, driving difficulties, color vision, and peripheral vision) and the total score (all $p > 0.05$). Postoperative follow-up questionnaires showed that the well-controlled group had significantly higher scores in all dimensions and the total score than the poorly controlled group (all $p < 0.05$). Notably, the between-group difference in the composite score at 1 month postoperatively was 13.00 points (84.69 ± 7.62 vs 71.69 ± 10.12), which exceeded the commonly accepted minimal clinically important difference (MCID) threshold of approximately 4–6 points for the NEI-VFQ-25 [21], suggesting that the observed improvement was not only statistically significant but also clinically meaningful. This indicates that preoperative blood glucose control is a potentially important factor influencing the degree of vision-related quality of life (VR-QOL) recovery after surgery, with those who have good control benefiting more significantly. Given the comparability at baseline, these postoperative differences directly reflect the superior magnitude of improvement achieved by patients with good glycemic control.

Comparison of Corneal Morphology in Patients

On postoperative days 7 and 30, corneal astigmatism increased in both groups compared to preoperative levels, in-

Table 1. Baseline characteristics of patients.

Variables	Well-controlled group (n = 83)	Poorly controlled group (n = 114)	Statistic	p
Age (years)	62.58 ± 10.92	63.99 ± 9.72	t = –0.96	0.340
BMI (kg/m^2)	25.45 ± 1.00	25.35 ± 1.09	t = 0.68	0.496
Gender, n (%)			χ^2 = 1.25	0.264
Female	46 (55.42)	54 (47.37)		
Male	37 (44.58)	60 (52.63)		
Diabetes course (months)	34.00 (28.00, 38.00)	33.00 (28.00, 40.00)	Z = –0.30	0.761
Diabetes-related complications/comorbidities, n (%)			χ^2 = 0.67	0.858
Microalbuminuria	12 (14.46)	15 (13.16)		
Proteinuria	15 (18.07)	16 (14.04)		
Cardiovascular disease	17 (20.48)	16 (14.04)		
Symptoms related to diabetes	8 (9.64)	6 (5.26)		
Eye(s) operated, n (%)			χ^2 = 0.83	0.661
Left side	18 (21.69)	29 (25.44)		
Right side	24 (28.92)	36 (31.58)		
Bilateral	41 (49.40)	49 (42.98)		
Education level, n (%)			χ^2 = 1.59	0.662
Primary school and below	44 (53.01)	62 (54.39)		
Junior high school	19 (22.89)	30 (26.32)		
High school	14 (16.87)	18 (15.79)		
University and above	6 (7.23)	4 (3.51)		
Occupation type, n (%)			χ^2 = 2.29	0.319
Retired	50 (60.24)	79 (69.30)		
Blue-collar	15 (18.07)	19 (16.67)		
White-collar	18 (21.69)	16 (14.04)		
LOCS III, n (%)			χ^2 = 1.65	0.439
Mild	14 (16.87)	13 (11.40)		
Moderate	53 (63.86)	73 (64.04)		
Severe	16 (19.28)	28 (24.56)		

Abbreviations: BMI, body mass index; LOCS III, Lens Opacity Classification System III.

dicating a shift toward against-the-rule astigmatism. The magnitude of astigmatism was significantly greater in the well-controlled group than in the poorly controlled group on days 7 and 30, suggesting that different blood glucose levels may affect the biomechanical response of corneal incision healing (Table 3).

Postoperative Corneal Edema Recovery

Postoperative corneal edema was assessed using a slit lamp (Table 4). On postoperative day 7, the proportion of patients with clear cornea was significantly higher in the well-controlled group than in the poorly controlled group (69.88% vs. 49.12%), while the proportion with diffuse corneal edema was significantly lower (6.02% vs. 18.42%), with statistically significant differences between groups (p = 0.006). By postoperative day 30, the corneas of most patients had returned to transparency, and the difference between the two groups became non-significant ($p > 0.05$). The results indicate that poor preoperative glycemic control may delay the resolution of early postoperative corneal edema.

BCVA Recovery Status

BCVA was expressed as logMAR values. Preoperatively, there was no significant difference in logMAR between the two groups ($p > 0.05$). On postoperative day 7, the visual acuity of the well-controlled group [0.33 (0.20, 0.46)] was significantly better than that of the poorly controlled group [0.57 (0.34, 0.77)] (Z = –5.80, $p < 0.001$). By postoperative day 30, visual acuity in both groups had recovered to good levels with no conspicuous difference between the groups (median for both groups was 0.00, $p > 0.05$), corresponding to a Snellen visual acuity of 20/20. The absence of dispersion at this time point indicates that most patients achieved optimal measurable visual acuity. This suggests that preoperative blood glucose control may affect the speed of early postoperative visual recovery, with patients exhibiting better glycemic control experiencing faster visual improvement (Table 5).

Discussion

Diabetes, as a metabolic disease that can affect the state of other organs in the long term, has a continuously rising prevalence worldwide and has become an important public

Table 2. Patients' quality of life.

Variables	Well-controlled group (n = 83)	Poorly controlled group (n = 114)	Statistic	p
General health				
Preoperative	55.47 ± 10.80	53.81 ± 14.15	t = 0.90	0.372
Postoperative	63.92 ± 11.76	59.74 ± 12.66	t = 2.36	0.019
General vision				
Preoperative	46.74 ± 18.26	48.02 ± 18.34	t = −0.48	0.628
Postoperative	73.18 ± 9.58	60.25 ± 13.63	t = 7.82	<0.001
Near vision activities				
Preoperative	60.77 ± 13.79	61.31 ± 11.27	t = −0.30	0.763
Postoperative	82.14 ± 6.45	71.36 ± 11.23	t = 8.50	<0.001
Distance vision activities				
Preoperative	60.81 ± 9.19	59.29 ± 10.96	t = 1.03	0.304
Postoperative	76.82 ± 8.38	67.80 ± 9.31	t = 7.00	<0.001
Ocular pain				
Preoperative	54.70 ± 17.35	55.09 ± 11.03	t = −0.18	0.857
Postoperative	76.43 ± 11.80	72.90 ± 9.64	t = 2.24	0.027
Social functioning				
Preoperative	74.37 ± 9.11	73.46 ± 8.45	t = 0.73	0.467
Postoperative	91.59 ± 3.65	84.46 ± 5.96	t = 10.37	<0.001
Mental health				
Preoperative	67.88 ± 12.57	69.31 ± 15.55	t = −0.72	0.475
Postoperative	91.66 ± 1.19	79.24 ± 6.19	t = 20.91	<0.001
Role difficulties				
Preoperative	72.25 ± 9.46	74.10 ± 11.14	t = −1.26	0.210
Postoperative	90.83 ± 4.49	79.92 ± 5.36	t = 15.07	<0.001
Dependency				
Preoperative	72.63 ± 10.38	72.44 ± 11.55	t = 0.12	0.907
Postoperative	92.41 ± 3.63	77.96 ± 8.92	t = 15.61	<0.001
Driving difficulties				
Preoperative	64.41 ± 14.08	62.19 ± 10.60	t = 1.21	0.227
Postoperative	84.22 ± 5.03	71.30 ± 13.63	t = 9.29	<0.001
Color vision				
Preoperative	77.77 ± 13.14	76.13 ± 13.02	t = 0.87	0.385
Postoperative	94.24 ± 2.62	81.37 ± 8.79	t = 14.76	<0.001
Peripheral vision				
Preoperative	69.55 ± 14.12	71.60 ± 16.14	t = −0.93	0.353
Postoperative	78.43 ± 5.06	75.20 ± 10.99	t = 2.76	0.006
Composite score				
Preoperative	61.07 ± 9.91	61.66 ± 18.04	t = −0.29	0.770
Postoperative	84.69 ± 7.62	71.69 ± 10.12	t = 10.28	<0.001

Table 3. Mean corneal astigmatism in the two groups of patients.

Variables	Well-controlled group (n = 83)	Poorly controlled group (n = 114)	Effect size	Statistic	p
Preoperative	0.79 ± 0.31	0.82 ± 0.28	0.03 (−0.06, 0.11)	t = −0.64	0.522
Postoperative day 7	1.66 ± 0.78	1.08 ± 0.58	−0.58 (−0.77, −0.39)	t = 5.73	<0.001
Postoperative day 30	1.73 ± 0.52	1.19 ± 0.53	−0.54 (−0.69, −0.39)	t = 7.05	<0.001

health problem that seriously threatens human health [23]. According to existing epidemiological statistics, the number of diabetic patients worldwide is expected to continue to grow in the coming decades, mainly due to the aging population and changes in lifestyle that further aggravate the disease burden [24]. Long-term hyperglycemia will damage the microvessels and nervous system of the patient's body through a variety of mechanisms, leading to various complications, among which ocular complications are particularly common [25]. Cataracts are one of the ocular complications that diabetic patients are more likely to develop early and have a significantly higher incidence rate. They occur

Table 4. Postoperative edema recovery in both groups of patients.

Variables	Well-controlled group (n = 83)	Poorly controlled group (n = 114)	Effect size	Statistic	p
Postoperative day 7, n (%)			Cramér's V = 0.23	$\chi^2 = 10.33$	0.006
Focal corneal edema	20 (24.10)	37 (32.46)			
Diffuse corneal edema	5 (6.02)	21 (18.42)			
Clear cornea	58 (69.88)	56 (49.12)			
Postoperative day 30, n (%)			OR: 1.69 (0.50, 5.71)	$\chi^2 = 0.74$	0.391
Focal corneal edema	4 (4.82)	9 (7.89)			
Clear cornea	79 (95.18)	105 (92.11)			

Abbreviation: OR, odds ratio.

Table 5. Best corrected visual acuity in the two groups.

Variables	Well-controlled group (n = 83)	Poorly controlled group (n = 114)	Effect size	Statistic	p
Preoperative, M (Q_1, Q_3)	1.36 (1.06, 1.59)	1.44 (1.14, 1.72)	r = −0.11	Z = −1.56	0.118
Postoperative day 7, M (Q_1, Q_3)	0.33 (0.20, 0.46)	0.57 (0.34, 0.77)	r = −0.41	Z = −5.80	<0.001
Postoperative day 30, M (Q_1, Q_3)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	r = −0.01	Z = −1.28	0.199

Notes: Median logarithm of the minimum angle of resolution (logMAR) 0.00 corresponds to Snellen visual acuity of 20/20. The absence of dispersion at postoperative day 30 indicates excellent visual recovery in most patients.

earlier and progress faster than in non-diabetic populations, seriously affecting patients' visual function and quality of life [26]. At present, phacoemulsification combined with intraocular lens implantation has become the standard surgical method for treating cataracts. However, diabetic patients treated with this surgical method still face many challenges in terms of postoperative corneal recovery and improvement of visual function, due to the decline in corneal endothelial reserve, the enhancement of inflammatory response, and the impairment of tissue repair capacity [27]. Therefore, exploring the key factors affecting the postoperative recovery of diabetic patients with cataracts is of great clinical significance for optimizing perioperative management and improving surgical outcomes.

The optimal threshold for preoperative glycemic control in diabetic cataract patients remains debated, with substantial variations reported across studies in both the choice of metrics and cutoff values [28–32]. In this context, our use of FBG $\geq$6.1 mmol/L—based on the American Diabetes Association's definition of impaired fasting glucose—represents a pragmatic choice aligned with routine clinical assessment, though alternative thresholds might yield different perspectives [33].

In the present study, the two groups were well-matched at baseline in all NEI-VFQ-25 dimensions, but postoperatively, the well-controlled group demonstrated significantly higher scores across all dimensions, including the composite score, compared to the poorly controlled group. This result suggests that good preoperative blood glucose control not only helps to restore objective visual function but also significantly improves patients' perceived visual quality and social functioning. This aligns with previous work suggesting that chronic hyperglycemia-related visual symptoms and psychological burden may influence postoperative quality of life [34].

Postoperatively, both groups showed increased against-the-rule astigmatism, with significantly greater changes in the well-controlled group at both postoperative days 7 and 30. This finding indicates that preoperative glycemic status influences the corneal wound healing response following phacoemulsification. Several interpretations are possible: it may reflect more robust biomechanical remodeling in healthier corneal tissue, or indicate reduced wound stability. Without direct measurements of corneal biomechanical properties or longer-term refractive data, the clinical significance of this finding remains uncertain.

Previous studies on cataract surgery have shown that corneal incision healing is influenced by multiple factors, including corneal stromal rearrangement, collagen fiber crosslinking, and the recovery of endothelial pump function. Abnormal corneal stromal metabolism and delayed healing in diabetic patients may lead to a weakened corneal biomechanical response. Regarding corneal edema, the well-controlled group demonstrated significantly higher rates of corneal transparency and lower rates of diffuse edema at postoperative day 7, though these differences resolved by day 30. The results suggest that poor preoperative blood glucose control mainly affects the early postoperative corneal recovery process, while its impact on mid- to long-term corneal transparency is relatively limited. The study by Yang *et al*. [13] showed that endothelial cell loss in diabetic patients after successful phacoemulsification was significantly higher than that in their non-diabetic counterparts. This result suggests that the endothelial cells of diabetic patients are more fragile and more prone to damage under surgical stress. The results of this study support the above view to some extent, suggesting that the level of blood glucose control may indirectly affect the postoperative corneal morphology by affecting the quality of corneal healing. However, it should be noted that corneal edema in the present study was assessed using clinical grading criteria with the assistance of slit-lamp biomicroscopy. While this method is widely used in routine practice and was performed by a masked observer under standardized conditions, it remains inherently subjective and may lack sensitivity for detecting subtle differences in corneal recovery. Future studies would benefit from incorporating more objective parameters, such as central corneal thickness measured by pachymetry or endothelial cell density assessed by specular microscopy, to provide quantitative validation of the clinical observations reported here.

Preoperatively, BCVA was comparable between groups. At postoperative day 7, the well-controlled group achieved significantly better BCVA, though by day 30, both groups reached a median logMAR of 0.00 (Snellen 20/20), indicating excellent visual recovery in most patients. When a large proportion of participants reach the upper limit of measurable visual acuity, the capacity to detect further between-group differences may be restricted, suggesting the presence of a potential ceiling effect. Therefore, the absence of a statistically significant difference at 1 month postoperatively may reflect a convergence toward optimal visual outcomes rather than a lack of early glycemic influence. This result suggests that the level of preoperative blood glucose control mainly affects the speed of early postoperative visual recovery, while the impact on the final visual outcome is relatively limited. This may be attributable to advances in medical care, which enable most patients to achieve good postoperative recovery. A previous study has suggested that delayed early postoperative visual recovery in diabetic patients is closely related to corneal edema, increased inflammatory response, and abnormal aqueous humor barrier function [16]. Good blood glucose control can reduce postoperative inflammatory response and corneal edema, thereby promoting rapid recovery of visual axis transparency. The findings of this study are consistent with this mechanism hypothesis, suggesting that strengthening preoperative blood glucose management can help improve patients' early postoperative visual experience and satisfaction.

While this study yielded some clinical findings, several limitations remain. First, as a single-center retrospective study with a limited sample size, it is difficult to completely exclude potential selection bias and confounding factors. Additionally, the single-center design limits the generalizability of our findings. All patients were enrolled from a single cataract treatment center, and the surgical procedures were performed by a limited number of surgeons using standardized techniques. Therefore, our results may not be directly applicable to other populations, healthcare settings, or scenarios utilizing surgical approaches with different perioperative management protocols. Multicenter studies involving diverse patient populations and surgical practices are needed to confirm the external validity of our observations. Second, this study only used preoperative FBG as an indicator of glycemic control, omitting indicators reflecting long-term glycemic control, such as glycated hemoglobin, which may underestimate the cumulative impact of chronic hyperglycemia on postoperative recovery. In addition, corneal edema in the present study was primarily evaluated using slit-lamp biomicroscopy coupled with clinical grading criteria—a method that may still involve some degree of subjectivity despite standardized examination procedures. Future prospective, multicenter, large-sample studies incorporating multidimensional glycemic indicators, longer follow-up, and quantitative corneal imaging with endothelial cell analysis would provide more robust evidence to validate our findings and elucidate the underlying mechanisms linking glycemic control to corneal recovery.

Conclusions

In conclusion, this study suggests that preoperative glycemic control may be closely related to early corneal recovery, visual function improvement, and vision-related quality of life in diabetic patients after phacoemulsification. Good glycemic control helps accelerate postoperative corneal edema resolution, promotes visual recovery, and significantly improves patients' subjective visual experience. These findings provide evidence-based support for developing more refined perioperative management strategies for diabetic cataract surgery and underscore the importance of standardized preoperative glycemic management, alongside surgical safety, to achieve better surgical outcomes and greater patient benefits.

Availability of Data and Materials

The data analyzed are available from the corresponding author upon reasonable request.

Author Contributions

QYY and XDL designed the research study. XL and QG performed the research. ZBL and YNT analyzed the data. XDL drafted this article. All authors have been involved in revising the manuscript critically for important intellectual content. All authors gave final approval of the version to be published. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

The study protocol was approved by the Ethics Committee of The Second Affiliated Hospital of Guangdong Medical University (ethics number: PJKT2026-005), and all aspects of this study adhered to the Declaration of Helsinki. Given the retrospective nature of this study and the use of de-identified patient data from routine clinical practice, the requirement for informed consent was waived by the Ethics Committee of The Second Affiliated Hospital of Guangdong Medical University.

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Conflict of Interest

The authors declare no conflict of interest.

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