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Analysis of phacoemulsification parameters and anterior segment parameters in cataract patients with different blood glucose levels

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不同血糖水平白内障患者超声乳化手术参数和眼前节参数的相关性分析

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摘要

目的:探讨不同血糖水平白内障患者超声乳化手术参数与眼前节参数及其相关性。

方法:选取2023年3月至2024年4月我院收治的2型糖尿病性白内障患者45例45眼,根据糖化血红蛋白(HbA1c)水平分为A、B两组,A组18例18眼,HbA1c<7%;B组27例27眼,7%≤HbA1c<8.5%;同时选取年龄相关性白内障患者94例94眼作为对照组C组。三组患者均接受白内障超声乳化吸除联合人工晶体植入手术治疗,记录三组患者的眼前节参数,包括角膜参数、前房参数及晶状体参数,分析三组患者超声乳化手术参数与眼前节参数的相关性,并比较三组患者的超声乳化手术参数的差异性。

结果:在A组和B组糖尿病性白内障患者中,有效超声乳化时间(EPT)与角膜内皮细胞密度(CECD)呈负相关($r=-0.315$,$P=0.035$);平均超声乳化时间(APT)与角膜前表面曲率半径呈正相关($r=0.402$,$P=0.006$),与角膜前表面平坦轴子午线曲率、角膜前表面陡峭轴子午线曲率、角膜前表面平均曲率、晶状体6 mm直径光密度值(PDZ3)呈负相关(均$P<0.05$);平均超声乳化能量(AVE)与晶状体密度平均值(LD-mean)、晶状体2 mm直径光密度值(PDZ1)、晶状体4 mm直径光密度值(PDZ2)、PDZ3呈正相关(均$P<0.05$),与瞳孔直径呈负相关($r=-0.385$,$P=0.009$)。在C组年龄相关性白内障患者中,EPT与Pentacam核分级(PNS)密度分级、PDZ1、PDZ2、PDZ3呈正相关(均$P<0.05$)。AVE与PNS密度分级呈正相关($r=0.246$,$P=0.018$),与CECD呈负相关($r=-0.245$,$P=0.018$)。A组和B组患者的EPT显著大于C组($P<0.05$),且B组的EPT和APT显著大于A组($P<0.05$)。糖尿病性白内障患者的CECD、角膜密度(CD)、角膜后表面高度与糖尿病病程呈正相关($P<0.05$);角膜后表面平坦轴子午线曲率、角膜后表面曲率半径与HbA1c呈正相关($P<0.05$),角膜总散光与HbA1c、早餐后2 h血糖、空腹胰岛素呈负相关($P<0.05$);CD值、晶状体厚度与空腹胰岛素值呈正相关($P<0.05$)。

结论:不同血糖水平白内障患者的超声乳化手术参数和血糖相关指标与眼前节参数具有不同程度的相关性。糖尿病性白内障患者术中EPT显著大于年龄相关性白内障患者,且血糖控制较差组的EPT和APT显著大于血糖控制较好组。

关键词:糖尿病性白内障;有效超声乳化时间;平均超声乳化能量;平均超声乳化时间;眼前节参数

Abstract

• AIM: To analyze the characteristics and correlation of phacoemulsification parameters and anterior segment parameters in cataract patients with different blood glucose levels.

• METHODS: A total of 45 type 2 diabetic cataract patients (45 eyes) treated in our hospital from March 2023 to April 2024 were stratified into two groups based on glycosylated hemoglobin (HbA1c) levels: group A: HbA1c <7% (n=18) and group B: 7%≤HbA1c<8.5% (n=27); a total of 94 age-matched age-related cataract patients (94 eyes) were enrolled as the control group (group C). All underwent phacoemulsification with intraocular lens implantation. Anterior segment parameters, including corneal, lens and anterior chamber measurements, were recorded. Correlations between phacoemulsification parameters and anterior segment parameters were analyzed, and differences among groups were compared.

• RESULTS: In groups A and B, effective phacoemulsification time (EPT) negatively correlated with corneal endothelial cell density (CECD) (r=-0.315, P=0.035). Average phacoemulsification time (APT) positively correlated with the anterior corneal surface radius of curvature (Rm; r=0.402, P=0.006) and negatively correlated with the flat axis meridian curvature (K_1), steep axis meridian curvature (K_2), mean curvature (Km) of the anterior corneal surface, and lens density at 6 mm zones (PDZ3; all P<0.05). Average phacoemulsification energy (AVE) positively correlated with mean lens density (LD-mean), lens density at 2 mm zones (PDZ1), lens density at 4 mm zones (PDZ2), and PDZ3 (all P<0.05), and negatively with pupil diameter (r=-0.385, P=0.009). In the group C, EPT showed a positive correlation with Pentacam nucleus staging (PNS) density grade, PDZ1, PDZ2, and PDZ3 (all P<0.05). A positive correlation was observed between AVE and PNS classification (r=0.246, P=0.018). Conversely, AVE exhibited a negative correlation with CECD (r=-0.245, P=0.018). EPT in groups A and B was higher than that in the group C (P<0.05). Both EPT and APT in the group B were higher than those in the group A (P<0.05). In diabetic cataract patients, CECD, corneal density (CD), and posterior corneal surface height positively correlated with diabetes duration (P<0.05). Posterior corneal surface K_1 and Rm positively correlated with 7%≤HbA1c<8.5% (P<0.05). Total corneal astigmatism negatively correlated with HbA1c, 2-hour post-breakfast blood glucose (2hPBG), and fasting insulin (FINS; P<0.05). CD and lens thickness (LT) positively correlated with FINS (P<0.05).

• CONCLUSION: Phacoemulsification parameters and blood glucose-related indices exhibited varying degrees of correlation with anterior segment parameters in cataract patients with different blood glucose levels. EPT in diabetic cataract patients was higher than that in age-related cataract patients, while EPT and APT in diabetic cataract patients with poor glycemic control were higher than those with good glycemic control.

• KEYWORDS: diabetic cataract; effective phacoemulsification time; average phacoemulsification energy; average phacoemulsification time; anterior segment parameter

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INTRODUCTION

Diabetes mellitus (DM) is a systemic metabolic disease characterized by chronically elevated blood glucose levels[1]. Over the past 30 years, the prevalence of diabetes in China has increased significantly, with type 2 DM accounting for more than 90% of cases[2]. Ocular complications resulting from diabetes are among the leading causes of blindness[3]. Notably, diabetes significantly accelerates the development of cataracts; studies have demonstrated that cataracts develop earlier in diabetic patients compared to non-diabetic individuals[4]. Currently, phacoemulsification has become the primary surgical technique for cataract treatment. The ultrasonic energy employed during this procedure is a critical factor influencing patients' postoperative visual recovery[5]. Some studies have identified a positively correlation between lens density and thickness and the effective phacoemulsification energy used in cataract surgery patients[6]. However, beyond these two parameters, limited research has explored the relationship between other anterior segment parameters and phacoemulsification parameters. In this study, cornea, anterior chamber, lens and other anterior segment parameters of cataract patients with different blood glucose levels were collected, aiming to observe their correlation with phacoemulsification parameters and blood glucose related parameters of cataract patients with different blood glucose levels, so as to provide scientific reference for individual treatment of cataract patients with different blood glucose levels.

PARTICIPANTS AND METHODS

Ethical Approval The study methods and protocols were approved by the Medical Ethics Committee of Anhui No.2 Provincial People's Hospital (Hefei, China): (R) 2023-014. The study followed the principles of the Declaration of Helsinki. All subjects were notified of the objectives and content of the study and latent risks, and then provided written informed consent to participate.

Inclusion and Exclusion Criteria These patients were divided into two groups based on glycosylated hemoglobin (HbA1c) levels: group A, comprising 18 cases (18 eyes) with HbA1c<7%, and group B, comprising 27 cases (27 eyes) with 7%≤HbA1c<8.5%. Recruitment criteria for diabetic cataract patients included: 1) Met diagnostic criteria for diabetes (fasting plasma glucose ≥7.0 mmol/L and/or 2-hour plasma glucose ≥11.1 mmol/L during oral glucose tolerance test). Had established diabetes diagnosis confirmed by endocrinology specialists; 2) Received ophthalmological confirmation of diabetic cataract through: Slit-lamp examination documenting lens opacities and exclusion of other cataract etiologies; 3) An axial length of 22-24 mm and central corneal curvature of 42-44 D. Additionally, 94 age-related cataract patients (94 eyes) were served as the control group (group C). Recruitment criteria for age-related cataract patients included: 1) Age ≥50 years (matching typical onset age for age-related cataract); 2) Received ophthalmological confirmation of age-related cataract through: Slit-lamp examination documenting lens opacities and absence of systemic/metabolic disorders affecting lens transparency; 3) An axial length of 22–24 mm and central corneal curvature of 42–44 D. Exclusion criteria for all groups included: 1) Current pregnancy; 2) A history of ocular surgery or contact lens use; 3) A history of severe refractive error (astigmatism greater than 1.5 D, hyperopia exceeding 3 D, or myopia exceeding 3 D), corneal diseases, glaucoma, uveal diseases, or systemic connective tissue diseases.

Baseline Data and Clinical Data Patients diagnosed with diabetic cataract or age-related cataract who met the inclusion criteria were enrolled. Baseline demographic and clinical data were retrieved from the electronic medical record system and laboratory information management system. The collected parameters included: 1) Demographics: name, sex, and age; 2) Anthropometric measurements: height, weight and blood pressure (systolic/diastolic); 3) Lifestyle factors: smoking and alcohol consumption history; 4) Comorbidities: hypertension, hyperlipidemia, and cardiovascular/cerebrovascular diseases; 5) Laboratory parameters: total cholesterol, triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), alanine aminotransferase (ALT), aspartate aminotransferase (AST), blood urea nitrogen (BUN) and serum creatinine. For diabetic cataract patients, additional metabolic parameters were documented, including disease duration, HbA1c, fasting blood glucose (FBG), 2-hour post-breakfast blood glucose (2hPBG), and fasting insulin (FINS).

Preoperative Cataract Examinations All patients underwent preoperative cataract examinations prior to the operation, which included the following assessments: 1) Measurement of best corrected visual acuity: the best corrected distance visual acuity was measured at a distance of 5 m using a standard logarithmic visual acuity chart; 2) Refractive examination: the spherical and cylindrical powers were recorded; 3) Intraocular pressure examination: intraocular pressure was measured using a non-contact tonometer; 4) Anterior chamber depth and anterior chamber volume were measured using anterior segment optical coherence tomography; 5) Corneal endothelial cell density was assessed using corneal endothelial microscopy. Additionally, pupil diameter, corneal refractive parameters, corneal density (Figure 1) and thickness, as well as lens density (Figure 2) and thickness were measured using Pentacam in a darkroom environment.

Surgical procedures All cataract surgeries were performed by the same experienced ophthalmologist. Following anesthesia and disinfection of the operative eyes, a 2.2 mm clear corneal incision was made at the 11:00 position of the corneal limbus, with a corresponding side incision at the 3:00 position. A viscoelastic agent was injected into the anterior chamber. Continuous curvilinear capsulorhexis was then performed, followed by hydrodissection and hydrodelineation. Phacoemulsification of the lens was carried out using a Bausch & Lomb phacoemulsification machine. Residual cortex was thoroughly aspirated through irrigation and aspiration (I/A). Subsequently, the viscoelastic agent was injected into the capsular bag, and intraocular lens implantation was performed. The remaining viscoelastic agent was aspirated, and the clear corneal incision was hydrated until it sealed. Tobramycin dexamethasone eye ointment was applied to the eye, and a dressing was utilized to cover and protect the operative eye.

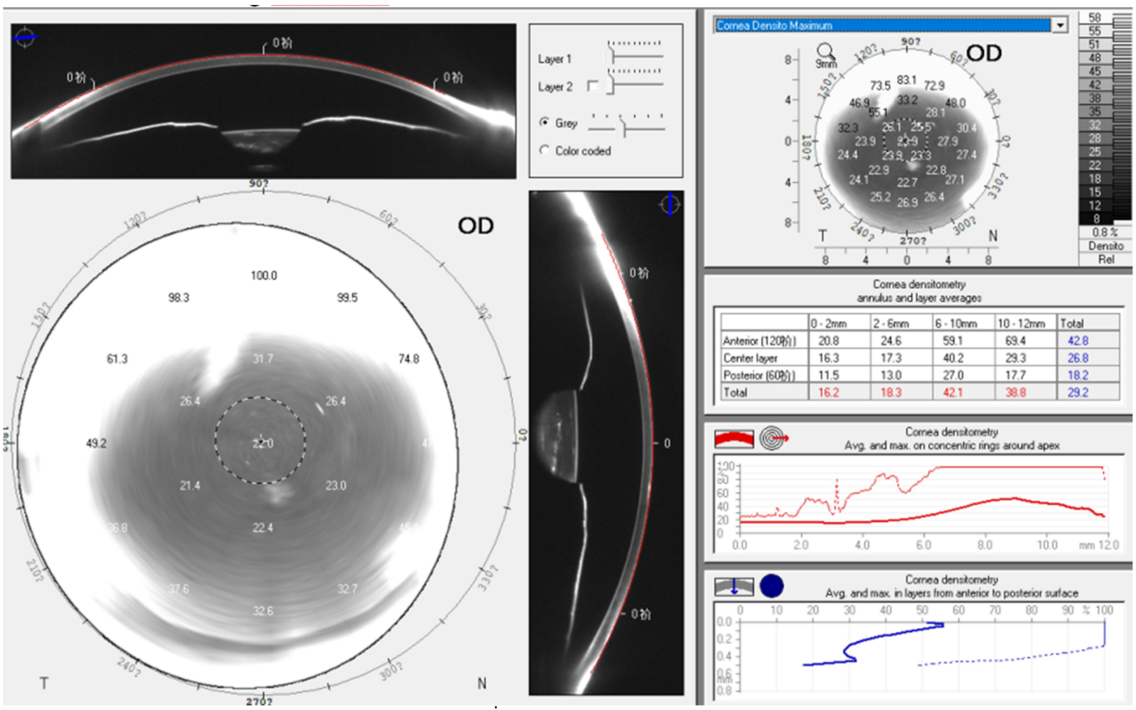

Figure 1 Corneal optical density under Pentacam HR Scheimpflug rotating camera system.

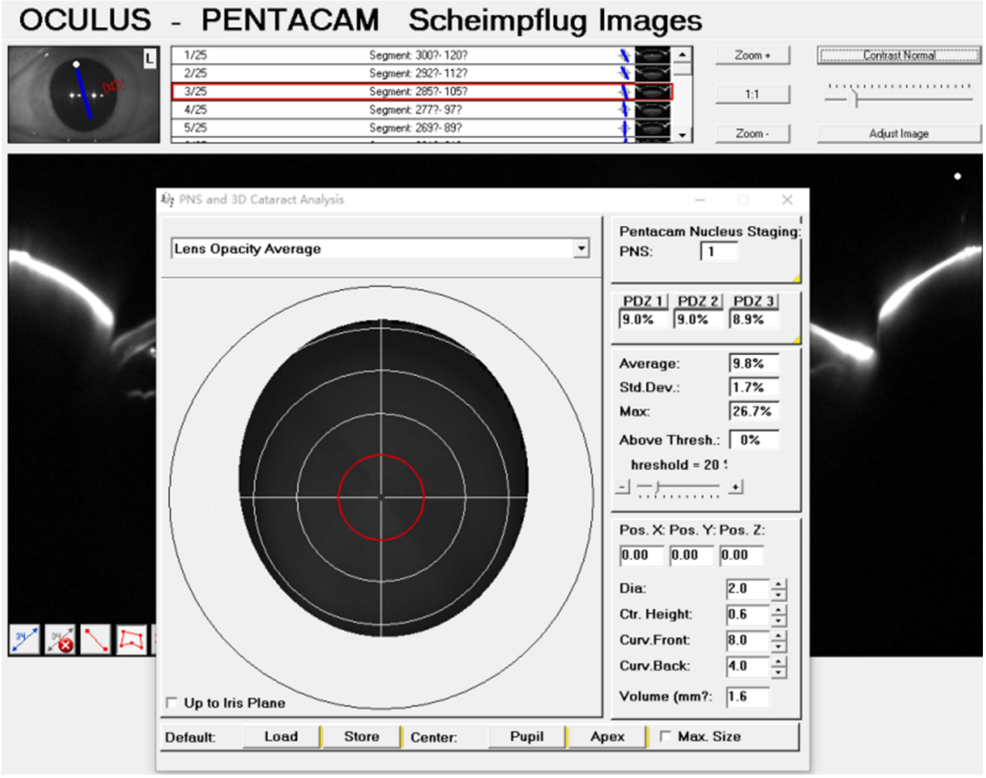

Figure 2　The lens density measurement with Pentacam HR Scheimpflug rotating camera system.

Phacoemulsification parameters　The parameters of phacoemulsification, including effective phacoemulsification time (EPT), average phacoemulsification time (APT), and average phacoemulsification energy (AVE), were meticulously recorded during the operation[7]. EPT is defined as the product of APT and AVE.

Statistical Analysis　Statistical analysis was conducted using one-way analysis of variance or independent samples t-test for between-group comparisons. For severely skewed data, the rank sum test was employed. Count data or graded data were expressed as rates (percentages), with between-group comparisons performed using the Chi-square test or Fisher's exact test. Correlation analysis was carried out using the Pearson test. All tests were two-sided, and $P<0.05$ was considered statistically significant.

RESULTS

No statistically significant differences were observed in baseline characteristics between patients with diabetic cataracts and those with age-related cataracts ($P>0.05$; Table 1). Furthermore, no statistically significant differences were noted in baseline characteristics among the various blood glucose level groups within the diabetic cataract patient cohort ($P>0.05$; Table 2).

Comparison of Blood Test Results　The HDL-C and BUN levels in patients from the groups A and B were significantly higher than those in the group C ($P<0.05$). No statistically significant differences were observed in total cholesterol, triglyceride, LDL-C, ALT, AST, and serum creatinine between diabetic cataract patients and age-related cataract patients. Among patients with diabetic cataract, the group B exhibited significantly higher values for duration of diabetes, FBG, 2hPBG, and FINS compared to the group A ($P<0.05$).

Correlation between phacoemulsification parameters and anterior segment parameters　In patients from groups A and B, APT exhibited a negative correlation with lens density at 6 mm zones (PDZ3) ($r=-0.435$, $P=0.016$). Additionally, AVE showed a positive correlation with the mean lens density (LD-mean) ($r=0.329$, $P=0.027$). In group C patients, EPT positively correlated with the Pentacam nucleus staging (PNS) density grade, lens density at 2 mm zones (PDZ1), lens density at 4 mm zones (PDZ2), and PDZ3 ($P<0.05$). AVE in all patients was positively correlated with PDZ1, PDZ2, and PDZ3 ($P<0.05$; Figure 3).

In patients from groups A and B, EPT was negatively correlated with total corneal astigmatism and corneal endothelial cell density (CECD; $r=-0.315$, $P=0.035$; Figure 4A); APT was positively correlated with corneal anterior surface radius of curvature (Rm; $r=0.402$, $P=0.006$), and negatively correlated with flat axis meridian curvature (K_1), steep axis meridian curvature (K_2) and mean curvature (Km) of anterior corneal surface ($P<0.05$); AVE was negatively correlated with pupil diameter ($r=-0.385$, $P=0.009$). In group C patients, AVE was negatively correlated with CECD ($r=-0.245$, $P=0.018$; Figure 4B).

Comparison of phacoemulsification parameters　EPT was significantly higher in the groups A and B than in the group C ($P<0.05$; Figure 5A). Furthermore, among patients with diabetic cataracts, both EPT and APT in the group B were significantly greater than those in the group A ($P<0.05$; Figure 5B).

Correlation between anterior segment parameters and blood glucose related parameters in patients with diabetic cataract　We investigated the correlation between anterior segment parameters and blood glucose related parameters in

Table 1　Comparison of general clinical data between patients with diabetic cataract and patients with age-related cataract

Data	Diabetic cataract patients (n=45)	Age-related cataract patients (n=94)	χ^2/t	P
Age ($\bar{x}\pm s$, y)	68.33±9.36	69.22±8.95	0.54	0.59
Gender (n, %)				
Male	19 (42.2)	33 (35.1)	0.658	0.417
Female	26 (57.8)	61 (64.9)		
Ocular laterality (n, %)				
Right	24 (53.3)	54 (57.4)	0.209	0.647
Left	21 (46.7)	40 (42.6)		
Weight ($\bar{x}\pm s$, kg)	63.42±8.47	63.32±10.01	−0.06	0.953
Height ($\bar{x}\pm s$, cm)	164.02±7.52	161.84±7.55	−1.6	0.113
Smoking (n, %)				
0	37 (82.2)	80 (85.1)	0.19	0.663
1	8 (17.8)	14 (14.9)		
Drinking (n, %)				
0	35 (77.8)	76 (80.9)	0.179	0.673
1	10 (22.2)	18 (19.1)		
Hypertension (n, %)				
0	22 (48.9)	48 (51.1)	0.058	0.81
1	23 (51.1)	46 (48.9)		
Hyperlipidemia (n, %)				
0	28 (62.2)	70 (74.5)	2.194	0.139
1	17 (37.8)	24 (25.5)		
0-4 PNS assessment (n, %)				
0	17 (37.8)	27 (29.0)	8.142	0.087
1	19 (42.2)	59 (63.4)		
2	6 (13.3)	4 (4.3)		
3	1 (2.2)	2 (2.2)		
4	2 (4.4)	1 (1.1)		

One-way analysis of variance.PNS: Pentacam nucleus staging.

Table 2　Comparison of baseline characteristics among diabetic cataract patients with various blood glucose level

Characteristics	HbA1c<7% (n=18)	7%≤HbA1c<8.5% (n=27)	χ^2/t	P
Age ($\bar{x}\pm s$, y)	67.83±10.67	68.67±8.57	−0.29	0.774
Gender (n, %)				
Male	7 (38.9)	12 (44.4)	0.137	0.711
Female	11 (61.1)	15 (55.6)		
Ocular laterality (n, %)				
Right	10 (55.6)	14 (51.9)	0.06	0.807
Left	8 (44.4)	13 (48.1)		
Weight ($\bar{x}\pm s$, kg)	61.67±6.94	64.59±9.29	−1.14	0.261
Height ($\bar{x}\pm s$, cm)	163.61±6.26	164.3±8.36	−0.3	0.768
Smoking (n, %)				
0	15 (83.3)	22 (81.5)	0.025	0.874
1	3 (16.7)	5 (18.5)		
Drinking (n, %)				
0	14 (77.8)	21 (77.8)	0	1
1	4 (22.2)	6 (22.2)		
Hypertension (n, %)				
0	7 (38.9)	15 (55.6)	1.201	0.273
1	11 (61.1)	12 (44.4)		
Hyperlipidemia (n, %)				
0	12 (66.7)	16 (59.3)	0.252	0.616
1	6 (33.3)	11 (40.7)		
0-4 PNS assessment (n, %)				
0	6 (33.3)	11 (40.7)	1.886	0.757
1	8 (44.4)	11 (40.7)		
2	2 (11.1)	4 (14.8)		
3	1 (5.6)	0		
4	1 (5.6)	1 (3.7)		

One-way analysis of variance.PNS: Pentacam nucleus staging.

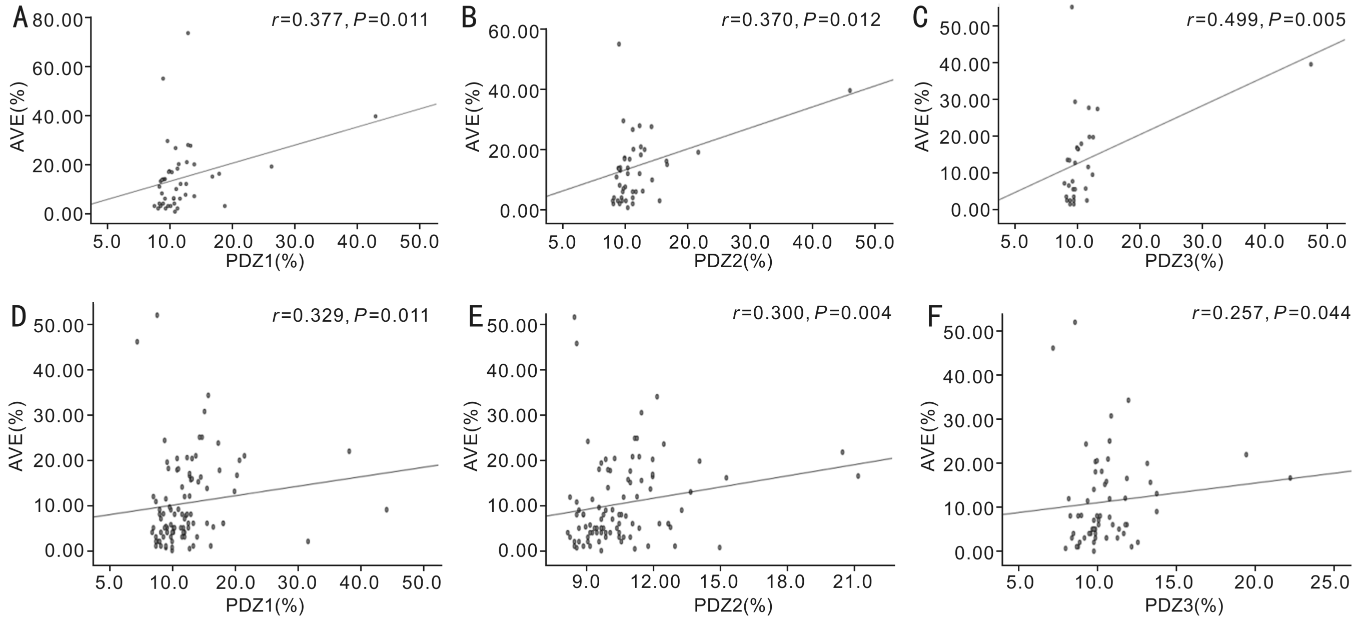

Figure 3　Scatter plots showing the relationship between average phacoemulsification energy and PDZ1, PDZ2, and PDZ3.　A, B and C: Scatter plots showing the relationship between AVE and PDZ1, PDZ2, and PDZ3 in groups A and B; D, E and F: Scatter plots showing the relationship between AVE and PDZ1, PDZ2, and PDZ3 in group C. AVE: Average phacoemulsification energy; PDZ1: Lens density at 2 mm zones; PDZ2: Lens density at 4 mm zones; PDZ3: Lens density at 6 mm zones.

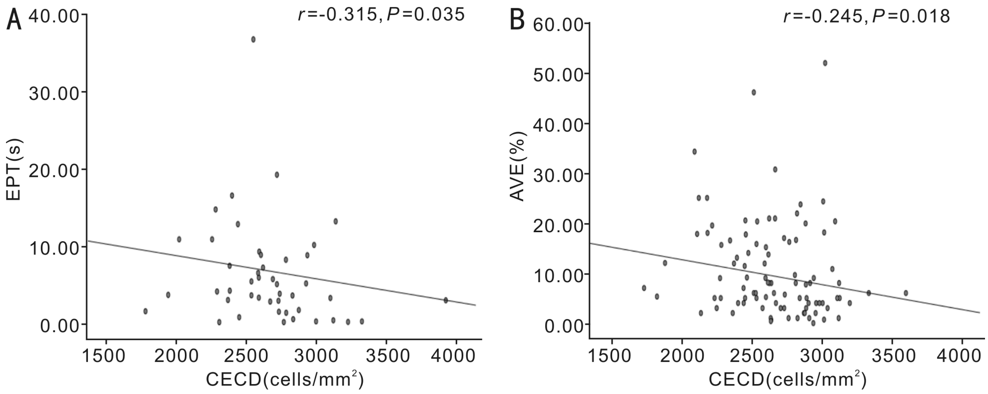

Figure 4　Scatter plots showing the relationships between corneal endothelial cell density and effective phacoemulsification time and between corneal endothelial cell density and average phacoemulsification energy in groups A and B.　A: Scatter plot showing the relationship between the CECD and EPT in groups A and B; B: Scatter plot showing the relationship between the CECD and AVE in groups A and B. CECD: Corneal endothelial cell density; EPT: Effective phacoemulsification time; AVE: Average phacoemulsification energy.

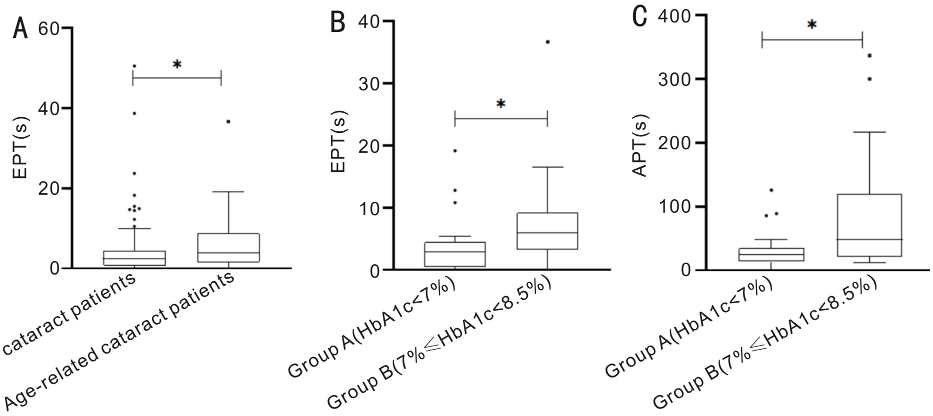

Figure 5　Box plot showing the differences in phacoemulsification parameters among cataract patients with different blood glucose levels.　A: Box plot showing the difference in EPT between diabetic cataract patients (groups A and B) and age-related cataract patients (group C); B: Box plot showing the difference in EPT between group A and group B; C: Box plot showing the difference in APT between group A and group B. EPT: Effective phacoemulsification time; APT: Average phacoemulsification time; HbA1c: glycosylated hemoglobin.

diabetic cataract patients, as summarized in Table 3. The CECD, CD and posterior corneal elevation of diabetic cataract patients were positively correlated with the duration of diabetes ($P<0.05$). K_1 and Rm of posterior corneal surface were positively correlated with HbA1c ($P<0.05$). And total corneal astigmatism was negatively correlated with HbA1c, 2hPBG and FINS ($P<0.05$). CD and lens thickness (LT) were positively correlated with FINS ($P<0.05$; Table 3).

Table 3 Correlation analysis between anterior segment parameters and blood glucose related indexes

Anterior segment parameters	Duration of diabetes	HbA1c	FBG	2hPBG	FINS
Anterior chamber depth					
r	−0.106	−0.040	−0.090	0.195	−0.279
P	0.489	0.796	0.560	0.222	0.073
Anterior chamber volume					
r	−0.064	−0.049	0.021	0.174	−0.263
P	0.676	0.748	0.894	0.277	0.092
Pupil diameter					
r	0.132	−0.078	−0.151	0.030	−0.080
P	0.387	0.609	0.326	0.853	0.616
CECD					
r	0.303[a]	0.076	0.114	−0.101	0.214
P	0.043	0.620	0.460	0.528	0.174
CD					
r	0.329[a]	0.201	0.065	0.270	0.367[a]
P	0.029	0.190	0.679	0.088	0.018
K_1 of anterior corneal surface					
r	0.031	−0.258	−0.081	−0.213	−0.015
P	0.840	0.087	0.599	0.181	0.924
K_2 of anterior corneal surface					
r	−0.047	−0.270	−0.058	−0.194	−0.004
P	0.757	0.073	0.710	0.225	0.981
Rm of anterior corneal surface					
r	0.018	0.260	0.062	0.183	−0.009
P	0.905	0.084	0.687	0.252	0.952
Anterior corneal elevation					
r	0.151	−0.087	0.202	−0.047	−0.025
P	0.321	0.568	0.188	0.771	0.877
K_1 of posterior corneal surface					
r	0.074	0.341[a]	0.187	0.143	0.132
P	0.628	0.022	0.224	0.372	0.404
K_2 of posterior corneal surface					
r	0.083	0.222	0.200	0.162	−0.051
P	0.588	0.143	0.192	0.311	0.748
Rm of posterior corneal surface					
r	0.088	0.300[a]	0.183	0.148	0.021
P	0.564	0.045	0.235	0.356	0.895
Posterior corneal elevation					
r	0.328[a]	0.011	−0.004	−0.081	−0.036
P	0.028	0.944	0.979	0.615	0.823
Central corneal thickness					
r	−0.032	−0.247	−0.221	0.066	−0.035
P	0.832	0.102	0.150	0.683	0.827
Corneal volume					
r	−0.099	−0.293	−0.283	−0.082	−0.108
P	0.519	0.051	0.062	0.608	0.497
LT					
r	0.010	0.161	0.010	−0.179	0.333[a]
P	0.950	0.298	0.951	0.270	0.033

Table 3 Correlation analysis between anterior segment parameters and blood glucose related indexes (continued)

Anterior segment parameters	Duration of diabetes	HbA1c	FBG	2hPBG	FINS
LD-mean					
r	0.152	-0.098	-0.034	-0.091	-0.194
P	0.320	0.524	0.824	0.571	0.218
Total corneal astigmatism					
r	-0.147	-0.307[a]	-0.175	-0.343[a]	-0.315[a]
P	0.336	0.040	0.256	0.028	0.042
PNS assessment (0-4)					
r	0.029	0.033	-0.010	-0.216	0.016
P	0.852	0.831	0.950	0.175	0.917
PDZ1					
r	0.041	-0.067	-0.001	-0.181	-0.053
P	0.790	0.661	0.996	0.257	0.741
PDZ2					
r	-0.070	-0.116	0.028	-0.165	-0.121
P	0.650	0.448	0.859	0.304	0.445
PDZ3					
r	-0.049	-0.075	0.123	-0.030	-0.213
P	0.797	0.694	0.525	0.885	0.275

[a]$P<0.05$ shows the statistical significance; Spearman correlation analysis; *r* correlation coefficient. FBG: Fasting blood glucose; 2hPBG: 2-hour post-breakfast blood glucose; FINS: Fasting insulin; CECD: Corneal endothelial cell density; CD: Corneal density; K_1: Flat axis meridian curvature; K_2: Steep axis meridian curvature; Rm: Radius of curvature; LT: Lens thickness; LD-mean: Mean lens density; PNS: Pentacam nucleus staging; PDZ1: Lens density at 2 mm zones; PDZ2: Lens density at 4 mm zones; PDZ3: Lens density at 6 mm zones.

DISCUSSION

Currently, ocular complications of diabetes are a leading cause of blindness, with chronic hyperglycemia frequently resulting in damage to the structure and function of the anterior segment tissue[1]. Clinical studies have shown that diabetic patients develop cataracts at an earlier age than their non-diabetic counterparts[8]. The precise pathogenesis of diabetic cataracts remains incompletely understood. Existing literature suggests that elevated glucose levels in the aqueous humor, coupled with a depletion of antioxidants in diabetic patients, may contribute to the formation and progression of diabetic cataracts[6,9], Chronic hyperglycemia may impact lens tissue structure and function through the sorbitol pathway, oxidative stress, and the autophagy-lysosome pathway[9].

With the increasing prevalence of type 2 diabetes, there has been a corresponding rise in the incidence of diabetic cataracts[10]. In cataract patients, changes of biochemical indexes are closely related to the occurrence and development of the disease. Studies have shown that there are significant differences in biochemical parameters between diabetic cataract patients and age-related cataract patients. The hyperglycemic state of diabetic patients can lead to increased oxidative stress in ocular tissues, thereby accelerating the formation of cataracts[11]. Prior studies on age-related cataracts have indicated that triglyceride (TG) levels are associated with cataract development. Tomić *et al*[12] reported significantly higher levels of LDL-C and TG in patients with age-related cataracts compared to the control group, establishing serum LDL-C and TG as independent risk factors for age-related cataracts. Paunksnis *et al*[13] and Chen *et al*[14] found that elevated TG levels are positively correlated with the incidence of cataracts and diabetes. Animal studies suggest that hyperlipidemia and low HDL-C may accelerate the development of diabetic cataracts. In our study, we observed that patients with diabetic cataracts had lower HDL-C levels compared to the control group, while serum TG levels were higher; however, this difference was not statistically significant. Research has demonstrated that in diabetic patients with nephropathy, BUN levels frequently increase, suggesting its potential as a significant marker for impaired renal function and disrupted glucose homeostasis[15]. Additionally, elevated BUN and creatinine levels have been linked to a 15-year incidence of posterior subcapsular cataracts[16], which is consistent with our findings of increased BUN levels in diabetic patients. Currently, there is limited research regarding the relationship between HDL-C and BUN levels in relation to the progression of diabetic cataracts; thus, further investigation into the underlying mechanisms is warranted.

During cataract phacoemulsification surgery, the transmission of ultrasound energy and the associated thermal effects inevitably damage the corneal endothelium. Mild to moderate injuries resulting from phacoemulsification are reversible; however, severe injuries can lead to postoperative complications that significantly impair the patient's vision recovery[17]. Previous studies have indicated that corneal endothelial cell loss is one of the primary complications associated with phacoemulsification surgery, with reported losses ranging from 8.0% to 16.7%[18-20]. This loss is attributed to the free heat and oxygen generated during ultrasound-induced base formation[18]. Furthermore, corneal endothelial cells in patients with diabetic cataracts are more vulnerable to damage than those in patients undergoing phacoemulsification for other reasons[21-23]. This study found a negative correlation between CECD and EPT in patients with diabetic cataracts, as well as a negative correlation between CECD and AVE in patients with age-related cataracts. Previous research has established that the damage to the corneal endothelium during cataract phacoemulsification surgery is primarily due to the duration of phacoemulsification, followed by the energy applied[24]. Therefore, it may be beneficial to optimize energy consumption by appropriately increasing ultrasound energy while reducing the duration of phacoemulsification[25].

In this study, EPT of patients with diabetic cataracts was found to be significantly greater than that of patients with age-related cataracts. Furthermore, both the EPT and APT for patients with diabetic cataracts were significantly higher than those for patients with age-related cataracts. Previous research has identified various factors that influence the surgical parameters of cataract phacoemulsification, including surgical methods, surgical techniques, and anterior segment parameters[25-28]. These parameters encompass lens characteristics and pupil dimensions[6,24]. In our study, the surgical methods and the surgeons involved were consistent across both patient groups, and no statistically significant differences were observed in the anterior segment parameters. Nevertheless, the differences in phacoemulsification surgical parameters between the two groups were statistically significant, and there is currently a lack of supportive evidence for similar findings in existing literature. Given that cataract phacoemulsification surgical parameters may be influenced by additional factors, such as the psychological state of the surgeon when treating diabetic cataract patients, further research is warranted to explore this issue.

This study found that AVE in patients with diabetic cataracts was positively correlated with the mean lens opacity. Additionally, AVE and EPT in patients with age-related cataracts were positively correlated with the PNS density rating, consistent with previous research indicating that the mean phacoemulsification energy in patients with age-related cataracts correlates positively with lens density[25]. Furthermore, accumulated ultrasound energy is positively correlated with lens nuclear density grading[28]. Building on prior studies, this research included a correlation analysis of phacoemulsification energy and optical density across lens diameters, revealing that AVE in all patients was positively correlated with PDZ1, PDZ2, and PDZ3. In patients with diabetic cataracts, a negative correlation was observed between APT and PDZ3, while EPT in elderly patients with cataracts was positively correlated with PDZ1, PDZ2, and PDZ3. Given that PDZ1, PDZ2, and PDZ3 represent density parameters of different regions of the lens, it follows that greater lens density corresponds to a more mature lens and higher phacoemulsification parameter values. Moreover, this study identified a negative correlation between AVE and pupil diameter in patients with diabetic cataracts. Previous research indicates that phacoemulsification surgery in diabetic cataract patients has a more significant impact on pupil size compared to elderly patients with cataracts[29]. A smaller pupil diameter is associated with increased ultrasound energy and greater endothelial cell loss[29], which aligns with the findings of this study.

Chronic elevation of blood glucose often leads to damage in the tissue structure and function of the anterior segment[30]. This study found a positive correlation between the duration of diabetes and the density of corneal endothelial cells[31]. These results differ from those of previous studies, which suggested that, compared to the control group, diabetic patients exhibit a lower density of corneal endothelial cells[32]. Additionally, with increased duration of diabetes, poor blood glucose control, and elevated HbA1c levels, the loss of endothelial cells becomes more pronounced[33]. The discrepancies in study results may be attributed to variations in perioperative glycemic control among patients with diabetic cataracts[34]. Furthermore, this study also identified a positive correlation between the duration of diabetes and corneal optical density. The cornea primarily relies on the epithelial fluid barrier and the endothelial pump mechanism to maintain transparency[35]. Prolonged hyperglycemia impairs the ion pump function of corneal endothelial cells, exacerbating corneal edema, which results in corneal thickening and reduced transparency, thereby increasing corneal optical density[36]. Corneal density is significantly correlated with corneal astigmatism[37], and corneal edema can influence corneal astigmatism[38]. Previous studies have indicated that a long duration of diabetes[39] and higher HbA1c values[40] are significant factors contributing to astigmatism in the corneas of diabetic patients. This study demonstrated that HbA1c and blood glucose levels were negatively correlated with total corneal astigmatism 2 h after breakfast.

This study also found that the posterior surface height of the cornea is positively correlated with the duration of diabetes, while both the posterior surface K_1 and posterior surface Rm of the cornea are positively correlated with HbA1c levels. Currently, the conclusions regarding the correlation between blood glucose-related indicators and corneal parameters are not consistent. Yilmaz *et al*[41] reported a negative correlation between Km and HbA1c on the posterior corneal surface, whereas Rozema *et al*[42] found that LT was positively correlated with the duration of diabetes. They also noted that the curvature of the posterior corneal surface and the length of the eye axis were negatively correlated with the duration of diabetes, and that corneal parameters showed no significant correlation with HbA1c. Some researchers suggest that there is no significant correlation between corneal parameters and blood glucose-related indicators[43]. The discrepancies in study results may be attributed to variations in sample size and the level of blood glucose control among diabetic patients. Furthermore, this study indicates that FINS levels are positively correlated with corneal optical density and LT, while being negatively correlated with total corneal astigmatism and axial length. It is known that serum insulin plays a crucial role in maintaining blood glucose stability[44]. However, there is a scarcity of studies investigating the correlation between FINS levels and anterior segment parameters, highlighting the need for further research to elucidate its mechanism of action. This study found that in patients with diabetic cataract, APT was negatively correlated with PDZ3, EPT was negatively correlated with total corneal astigmatism, and AVE was positively correlated with spherical equivalent. In patients with age-related cataract, APT was negatively correlated with both the standard deviation of average lens opacity and the maximum value of PNS. Although no similar research findings have been reported, these results hold significant implications for future studies. In our study, the limited sample size may have resulted in insufficient representativeness. Future research is planned to expand the sample size, investigate blood sugar control in diabetic patients, and enhance postoperative follow-up studies for patients with both diabetic and age-related cataracts. This will further explore the correlation between phacoemulsification parameters and anterior segment parameters in diabetic cataract patients.

In conclusion, in this study, phacoemulsification parameters, blood glucose related indexes and anterior segment parameters of cataract patients with different blood glucose levels were analyzed. Phacoemulsification parameters and blood sugar-related indices exhibited varying degrees of correlation with anterior segment parameters in cataract patients with different blood glucose levels. EPT in diabetic cataract patients was higher than that in age-related cataract patients, EPT and APT in diabetic cataract patients with poor glycemic control were higher than those with good glycemic control.

Conflicts of Interests: Xu XQ, None; Wang P, None; Liu T, None; Wang L, None; Zhu XS, None; Zhang HW, None; Shi L, None; Gao W, None.

Authors' contributions: Xu XQ initiated the project, designed the data collection tools, monitored the data collection for the whole trial, wrote the statistical analysis plan, cleaned and analyzed the data, as well as drafted and revised the manuscript; Gao W and Shi L initiated the project, designed the data collection tools, monitored the data collection for the whole trial, revised the manuscript, approved the final manuscript prior to journal submission, and supervised the study; Wang P, Liu T, Wang L, Zhu XS and Zhang HW designed the data collection tools.

REFERENCES

[1] Antar SA, Ashour NA, Sharaky M, et al. Diabetes mellitus: Classification, mediators, and complications; A gate to identify potential targets for the development of new effective treatments. Biomedecine Pharmacother, 2023,168:115734.
[2] Chinese Elderly Type 2 Diabetes Prevention and Treatment of Clinical Guidelines Writing Group, Geriatric Endocrinology and Metabolism Branch of Chinese Geriatric Society, Geriatric Endocrinology and Metabolism Branch of Chinese Geriatric Health Care Society, et al. Clinical guidelines for prevention and treatment of type 2 diabetes mellitus in the elderly in China (2022 edition). Chin J Intern Med, 2022, 61(1):12-50.
[3] Ghenciu LA, Haţegan OA, Bolintineanu SL, et al. Immune-mediated ocular surface disease in diabetes mellitus-clinical perspectives and treatment: a narrative review. Biomedicines, 2024,12(6):1303.
[4] Mrugacz M, Pony-Uram M, Bryl A, et al. Current approach to the pathogenesis of diabetic cataracts. Int J Mol Sci, 2023,24(7):6317.
[5] Uyar E. Eye-related factors that can be associated with the plane of phacoemulsification. Cureus, 2022,14(4):e24578.
[6] Shajari M, Rusev V, Mayer W, et al. Impact of lens density and lens thickness on cumulative dissipated energy in femtosecond laser-assisted cataract surgery. Lasers Med Sci, 2019,34(6):1229-1234.
[7] Coco G, Cremonesi P, Menassa N, et al. Changes in pupillometry associated with dissipated energy during phacoemulsification. Eur J Ophthalmol, 2021,31(6):2962-2968.
[8] Mishra D, Kashyap A, Srivastav T, et al. Enzymatic and biochemical properties of lens in age-related cataract versus diabetic cataract: a narrative review. Indian J Ophthalmol, 2023, 71(6): 2379-2384.
[9] Khare K, Mendonca T, Rodrigues G, et al. Aldose reductase and glutathione in senile cataract nucleus of diabetics and non-diabetics. Int Ophthalmol, 2023,43(10):3673-3680.
[10] Chitra PS, Chaki D, Boiroju NK, et al. Status of oxidative stress markers, advanced glycation index, and polyol pathway in age-related cataract subjects with and without diabetes. Exp Eye Res, 2020, 200:108230.
[11] Dolar-Szczasny J, Drab A, Rejdak R. Biochemical changes in anterior chamber of the eye in diabetic patients-a review. J Clin Med, 2024,13(9):2581.
[12] Tomić M, Vrabec R, Raštegorac P, et al. Hypertension and hypercholesterolemia are associated with cataract development in patients with type 2 diabetes. High Blood Press Cardiovasc Prev, 2021,28(5): 475-481.
[13] Paunksnis A, Bojarskiene F, Cimbalas A, et al. Relation between cataract and metabolic syndrome and its components. Eur J Ophthalmol, 2007,17(4):605-614.
[14] Chen ZS, Hu HF, Chen ML, et al. Association of Triglyceride to high-density lipoprotein cholesterol ratio and incident of diabetes mellitus: a secondary retrospective analysis based on a Chinese cohort study. Lipids Health Dis, 2020,19(1):33.
[15] Jeng CJ, Hsieh YT, Yang CM, et al. Diabetic retinopathy in patients with diabetic nephropathy: development and progression. PLoS One, 2016,11(8):e0161897.
[16] Klein BE, Knudtson MD, Brazy P, et al. Cystatin C, other markers of kidney disease, and incidence of age-related cataract. Arch Ophthalmol, 2008,126(12):1724-1730.
[17] Zhai J, Su W, Tang Z, et al. Phacoemulsification cataract surgery with different cumulative energy composite parameters in patients with type 2 diabetes mellitus: therapeutic effect and complications. Nan Fang Yi Ke da Xue Xue Bao, 2019,39(4):500-504.
[18] Khalid M, Ameen SS, Ayub N, et al. Effects of anterior chamber depth and axial length on corneal endothelial cell density after phacoemulsification. Pak J Med Sci, 2019,35(1):200-204.
[19] Jiang Y, Shi WY, Li FJ, et al. Efficacy of double-incision extracapsular cataract extraction in the treatment of hard-nucleus cataract with low corneal endothelial cell density. Zhonghua Yan Ke Za Zhi, 2020,56(2):126-130.
[20] Yang C, An Q, Zhou H, et al. Research progress on the impact of cataract surgery on corneal endothelial cells. Adv Ophthalmol Pract Res, 2024,4(4):194-201.
[21] Lee NS, Ong K. Risk factors for corneal endothelial cell loss after

phacoemulsification. Taiwan J Ophthalmol, 2024,14(1):83-87.
[22] Chaurasia RK, Khasnavis A, Mittal J. Comparison of corneal endothelial changes following phacoemulsification in diabetic and non-diabetic patients. Indian J Ophthalmol, 2022,70(4):1208-1213.
[23] Cornetta P, de Bernardo M, Rosa N. Central corneal thickness and endothelial damage after cataract surgery. Cornea, 2018,37(7):e36.
[24] Hayashi K, Hayashi H, Nakao F, et al. Risk factors for corneal endothelial injury during phacoemulsification. J Cataract Refract Surg, 1996,22(8):1079-1084.
[25] Guedes J, Pereira SF, Amaral DC, et al. Phaco-chop versus divide-and-conquer in patients who underwent cataract surgery: a systematic review and meta-analysis. Clin Ophthalmol, 2024, 18: 1535-1546.
[26] Mackenbrock LHB, Labuz G, Baur ID, et al. Cataract classification systems: a review. Klin Monbl Augenheilkd, 2024, 241(1):75-83.
[27] Feng L, Zhao FK, Ke X, et al. Correlation between degree of lens opacity and the phacoemulsification energy parameters using different imaging methods in age-related cataract. Transl Vis Sci Technol, 2022, 11(3):24.
[28] Saeedi OJ, Chang LY, Ong SR, et al. Comparison of cumulative dispersed energy (CDE) in femtosecond laser-assisted cataract surgery (FLACS) and conventional phacoemulsification. Int Ophthalmol, 2019, 39(8):1761-1766.
[29] Simsek A, Toptan M. The evaluation of pupil diameter by using Sirius before and after phacoemulsification in healthy, diabetic and hypertension patients. Medicine (Baltimore), 2023,102(16):e33223.
[30] Zhou Q, Yang L, Wang Q, et al. Mechanistic investigations of diabetic ocular surface diseases. Front Endocrinol (Lausanne), 2022, 13:1079541.
[31] Papadakou P, Chatziralli I, Papathanassiou M, et al. The effect of diabetes mellitus on corneal endothelial cells and central corneal thickness: a case-control study. Ophthalmic Res, 2020, 63(6): 550-554.
[32] Pandey S, Singh A, Vannadil H, et al. Corneal parameters in diabetics versus non-diabetics and correlation with various blood sugar parameters. Rom J Ophthalmol, 2024,68(2):128-134.
[33] Yusufoğlu E, Güngör Kobat S, Keser S. Evaluation of central corneal epithelial thickness with anterior segment OCT in patients with type 2 diabetes mellitus. Int Ophthalmol, 2023,43(1):27-33.
[34] Go JA, Mamalis CA, Khandelwal SS. Cataract surgery considerations for diabetic patients. Curr Diabetes Rep, 2021,21(12): 67.
[35] Del Buey MA, Casas P, Caramello C, et al. An update on corneal biomechanics and architecture in diabetes. J Ophthalmol, 2019, 2019:7645352.
[36] Güell JL, El Husseiny MA, Manero F, et al. Historical review and update of surgical treatment for corneal endothelial diseases. Ophthalmol Ther, 2014,3(1-2):1-15.
[37] Kai C, Oie Y, Nishida N, et al. Associations between visual functions and severity gradings, corneal scatter, or higher-order aberrations in fuchs endothelial corneal dystrophy. Invest Ophthalmol Vis Sci, 2024,65(6):15.
[38] Kobashi H, Kamiya K, Shimizu K. Factors influencing visual acuity in fuchs' endothelial corneal dystrophy. Optom Vis Sci, 2018,95(1):21-26.
[39] Lin Z, Wen L, Li D, et al. Refractive error in a Chinese population with type 2 diabetes: a report from the Fushun diabetic retinopathy cohort study. Ophthalmic Epidemiol, 2023,30(1):38-45.
[40] Yang M, Liu BH, Sun DJ, et al. Epidemiology of uncorrected refractive errors in type 2 diabetics aged 50 and above in Funing County, China: the Jiangsu Diabetic Eye Study. Zhonghua Yan Ke Za Zhi, 2021, 57(10):757-765.
[41] Yilmaz YC, Hayat SC, Ipek SC. Analysis of corneal and lens densitometry changes in patients with type 1 diabetes mellitus. Am J Ophthalmol, 2023,254:23-30.
[42] Rozema JJ, Khan A, Atchison DA. Modelling ocular ageing in adults with well-controlled type I diabetes. Adv Ophthalmol Pract Res, 2022,2(2):100048.
[43] Okamoto F, Sone H, Nonoyama T, et al. Refractive changes in diabetic patients during intensive glycaemic control. Br J Ophthalmol, 2000,84(10):1097-1102.
[44] Norton L, Shannon C, Gastaldelli A, et al. Insulin: The master regulator of glucose metabolism. Metabolism, 2022,129:155142.