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Analysis of influencing factors of corneal edema after phacoemulsification for diabetic cataract

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ABSTRACT

The paper aimed to explore the influence factors of corneal edema after phacoemulsification for diabetic cataracts. For this aim, 80 patients (80 eyes) with senile cataracts who underwent phacoemulsification implantation in our hospital from August 2021 to January 2022 were included in this study, including 39 males (48.75%) and 41 females (51.25%), with an average age of 70.35±5.22 years. The OCT system during ophthalmology was used to capture corneal OCT images in the center of the cornea in real time before the phacoemulsification (the phacoemulsification probe just entered the anterior chamber after the balanced saline left the separated nucleus), at the end of phacoemulsification (when the phacoemulsification ultrasound probe was still in the anterior chamber and the perfusion pressure did not change compared with that in the previous step), at the end of perfusion aspiration (after the perfusion aspiration probe left the anterior chamber), and after surgery (after the watertight incision is closed). The corneal thickness was measured at each time point using Photoshop software. AL, curvature and ACD were measured using IOL-Master bio-measurement technology, and ACD referred to the distance between the front surface of the cornea and the front surface of the lens. Endothelial cell density was measured using CIM-530 non-contact mirror microscope. A handheld rebound tonometer was used to measure intraocular pressure and optical coherence tomography was used to assess the macular area of the fundus. Fundus photography was performed with a non-diffuse fundus camera. The results indicated that the preoperative corneal thickness was 514.35±29.62 μm, and the average corneal thickness at the end of the operation was 535.26±30.29μm, which was increased by 20.91±1.67 μm compared with that before operation (P<0.05), and the increase rate of corneal thickness was 4.07%. The corneal thickness of patients tended to increase with the increase in operation time and intraocular operation time (P<0.05). The distribution of corneal edema-related features showed that 42.50% of patients had persistent edema at the time of cataract surgery. The median onset time of corneal edema in the remaining patients was 5.44 years (1.96-21.35 years for 90% CR). The higher the nuclear hardness, the more severe the cataract, and the higher APT, EPT, APE, and TST (P<0.05). The older the patient, the higher the grade of cataract nucleus, and the higher EPT, APE, and TST, the greater the intraoperative corneal thickening (P<0.05). The higher the maximum area of endothelial cells, the greater the intraoperative corneal thickness increase, the lower the corneal endothelial cell density and the greater the intraoperative corneal thickness increase (P<0.05). It was concluded that postoperative corneal edema in phacoemulsification surgery for diabetic cataracts is closely related to intraocular perfusion pressure, nuclear hardness of lens, the density of corneal endothelial cells, the energy of phacoemulsification and duration.

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Introduction

Cataract is the main cause of blindness all over the world. According to the World Health Organization, the number of people with visual impairment in the world is 2.2 billion, of which 46% are caused by cataracts (1). Diabetes is one of the most common chronic diseases in the world. Diabetic patients are at risk of developing cataracts, and the age of surgery is earlier than that of non-diabetic patients. Corneal complications of diabetic patients include delayed wound healing, the risk of epithelial defect or recurrent erosion due to epithelial basement membrane injury and epithelial-matrix interaction (2). The density of endothelial cells in diabetic patients is low, and their endothelial cells are more susceptible to trauma related to cataract surgery. Cataracts can't be cured by drugs, and surgery is the only effective treatment. Phacoemulsification has become the most commonly used surgical method in the world (3,4). Corneal edema is one of the most common early complications after phacoemulsification. It is an important manifestation of corneal endothelial dysfunction, which can lead to corneal endothelial decompensation in severe cases (5). Risk factors of corneal edema after phacoemulsification include pre-existing corneal endothelial dystrophy, iris corneal endothelial syndrome, glaucoma, uveitis and so on. Complications such as operator's experience, instrument trauma, irrigation solution, operation time and vitreous loss can lead to corneal

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edema (6,7). Studies have shown that the production of free radicals during phacoemulsification leads to corneal endothelial cell damage. Some studies have emphasized the protective effects of various free radical scavengers, such as reduced glutathione, calcium, adenosine, sodium hyaluronate, superoxide dismutase and ascorbic acid (8,9). Endothelial cells are interconnected by discontinuous tight junctions, mainly relying on calcium. The use of calcium-free irrigation solution during surgery can reduce the barrier function and lead to corneal edema (10,11). Corneal edema and corneal thickness increase after cataract surgery are related to many factors, including time and energy of phacoemulsification, hardness of lens nucleus, corneal endothelial cell count, depth of anterior chamber, eye trauma, mechanical and thermal injury, phacoemulsification technology, surgeon experience and use of viscoelastic materials (12,13). Corneal edema, mainly manifested as increased corneal thickness and decreased corneal transparency after the operation, can be diagnosed by slit lamp examination, ultrasound or optical coherence tomography after the operation, which is the most direct manifestation of judging the state and prognosis of eyes in the recovery period (14,15). In this study, the intraoperative real-time optical coherence tomography (OCT) technique was used to measure the changes in corneal thickness at different time points in phacoemulsification for diabetic cataract patients and to creatively clarify the changes of corneal thickness at different surgical steps in diabetic cataract surgery. This will provide a good basis for exploring the influencing factors of corneal edema caused by phacoemulsification and is of great significance for guiding the clinical diagnosis and treatment of diabetic cataracts.

Materials and Methods

General information

This study included 80 cases (80 eyes) of senile cataracts who underwent phacoemulsification implantation in our hospital from August 2021 to January 2022, including 39 males (48.75%) and 41 females (51.25%), with an average age of 60.35 5.22 years.

Admission criteria

Patients diagnosed with diabetic cataracts; were 45 ~ 75 years old; According to cataract turbidity grading system III (LOCS III), senile cataract patients were divided into II-IV grades. The density of corneal endothelial cells was more than 1500 cells /mm^2, which reduced corneal edema caused by endothelial dysfunction; Pupils with a diameter greater than or equal to 6 mm; The images of every step during the operation were completely captured.

Exclusion criteria

Having eye diseases other than diabetic cataracts, such as corneal diseases, high myopia fundus, retinopathy, glaucoma, uveitis, etc. Have a history of eye surgery or oral steroid drugs; Preoperative unfavorable factors such as shallow anterior chamber depth (ACD≤2mm), short axial length (AL≤20 mm) or poor pupil dilation (maximum pupil diameter ≤4 mm).

Medical ethics issues

This study was approved by the hospital ethics committee and followed the principles of the Helsinki Declaration. All participants obtained written informed consent.

Methods

Operation process

Before the operation, tropicamide phenylephrine eye drops (mydrin-p, Santen Pharmaceutical, Japan) were given every 20 minutes three times until the pupil dilated to 6 mm. Paracaine hydrochloride eye drops (Alcaine, Alcon, USA) were used for topical anesthesia. After aseptic disinfection, it was hung by operation (Bo 'an, Tianjin, China), and the eyelids were opened with a speculum (Mingren, Suzhou, China). Before the operation, povidone-iodine (Shanghai Likang, China) was used to flush the conjunctival sac. A 2.65 mm conventional corneal transparent incision was made with a disposable corneal puncture knife, and the incision was made beside the cornea. A viscoelastic agent was injected into the anterior chamber, and a 5.5 mm continuous circular capsulorhexis was made with capsulorhexis forceps. After dissection with a balanced saline solution, the lens nucleus was removed by the ultrasonic probe of the Stellaris ultrasonic emulsification machine in Bausch & Lomb, USA. The ultrasonic negative pressure was 15-360 mmHg, the perfusion height was 100 cm H_2O, and the ultrasonic power was 0-30%. The lens cortex in the anterior chamber was removed by washing and suction (the height was 80 cm H_2O, and the negative pressure was 0-550 mmHg). A viscoelastic agent was injected into the anterior chamber and folded intraocular lens was implanted in the capsular bag. Rinse the viscoelastic agent in the anterior chamber, seal the incision with water, and complete the operation. Record the time and energy required for ultrasonic emulsification. All cataract operations were performed by the same experienced surgeon according to standard procedures.

Measurement method

All patients underwent a comprehensive eye examination before the operation, and their vision was measured by using the internationally recognized standard logarithmic vision roll E-picture. AL, curvature and ACD were measured using IOL-Master bio-measurement technology (Master700, Zeiss, Germany), and ACD referred to the distance between the front surface of the cornea and the front surface of the lens.CEM-530 (Nidek Co Ltd, Gamagori, Aichi, Japan) was used to measure the density of endothelial cells. Intraocular pressure was measured with a handheld rebound tonometer (SW-500, Solvay, China), and the macular area was evaluated with optical coherence tomography (OV-RIVE-100-7, Optovue, USA). Fundus photography was performed with a non-diffuse fundus camera (AFC-210, Nidek, Japan). The central corneal thickness was measured by OCT before operation (RTVue100-2, Optovue, USA). Corneal OCT images were taken in real time by the same surgeon at the same position in the center of each patient's cornea using an ophthalmic OCT operating microscope (Rescan 700, Zeiss, Germany) during the operation, before and after phacoemulsification, at the end of irrigation and aspiration and at the end of the operation.

Measurement and comparison of corneal thickness during operation

The central corneal thickness was measured with OCT as the initial thickness before operation. During the process, iOCTwas used for tracking, and images were taken when the central light spot of the cornea was located in the center of the viewfinder, so as to ensure that the scanning was always in the same position in the center of the cornea. Photoshop 2021 was used to collect intraoperative iOCT and preoperative corneal OCT images and videos and compare them. The central scan line images derived from iOCT were 454 × 308 pixels (160.16 mm × 108.66 mm, resolution 96 dpi). All the images were measured by the same observer (Y.D.) using the ruler tool in Photoshop (Adobe) and compared with the central corneal thickness. Corneal thickness was measured 3 times at each time point, and the average value was taken.

Statistical analysis

The data of this study were summarized and analyzed by SPSS statistical software (SPSS 25.0, IBM, USA). The Shapiro-Wilk test was used to evaluate the normal distribution of all data. When the variables were normal or nearly normal, the clinical characteristics were expressed as the mean (standard deviation), and when the variables were non-normal, the clinical characteristics were expressed as the median (interquartile interval). One-way analysis of variance (ANOVA) was used to analyze the demographic characteristics and clinical indicators of the patients in the group. The changes in corneal thickness at different time points during the operation were compared by repeated measures of one-way ANOVA. Pearson correlation analysis was used to test the correlation between the indicators. $P < 0.05$ was statistically significant.

Results

Clinical data statistics

The baseline data of patients were statistically analyzed. There were 80 subjects, including 39 males and 41 females, with an average age of 70.35±5.22 years. There were 41 cases of right eye surgery and 39 cases of left and right surgery, with an average operation time of 10.67±2.45 min, of which 5 cases needed sutures. (Table 1)

Changes of corneal thickness in patients during operation

The results showed that the corneal thickness was 514.35 29.62 μ m before operation and 517.85±30.45 μm at the beginning of phacoemulsification, which increased by 3.50±0.83 μ m (P<0.05), and the growth rate of corneal thickness was 0.68%. At the end of phacoemulsification, the corneal thickness was 520.30±38 μ m, which was 5.95±1.76 μ m higher than that before operation (P<0.05), and the growth rate of corneal thickness was 1.16%. At the end of irrigation and aspiration, the corneal thickness was 526.37±30.66 μ m, which was 12.02±2.04 μ m higher than that before operation (P<0.05), and the growth rate of corneal thickness was 2.34%. At the end of the operation, the average corneal thickness was 535.26±30.29 μ m, which was 20.91±1.67 μ m thicker than that before the operation (P<0.05), and the growth rate of corneal thickness was 4.07%. With the increase in operation time and intraocular operation time, the corneal thickness of patients tended to increase (P<0.05). (Figure 1, Table 2)

Postoperative endothelial cell density analysis

The density of endothelial cells was measured by CEM-530 non-contact mirror microscope. The results showed that the density of endothelial cells was 2467.27±38.49/mm^2 before operation and 2348.66±34.39/mm^2 at the beginning of phacoemulsification, which decreased by 118.61/mm^2 (P<0.05). At the end of phacoemulsification, the density of endothelial cells was 2234.82±24.19/mm^2, which was decreased by 232.45/mm^2 (P<0.05). At the end of irrigation and aspiration, the density of endothelial cells

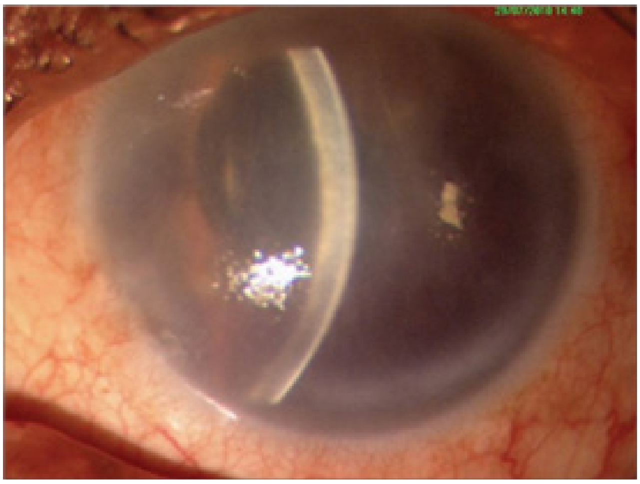

Figure 1. Corneal edema and increased corneal thickness.

Table 1. Analysis of Baseline Data (S).

factor		Patient (n)
n		80
gender	man	39 (48.75%)
	woman	41 (51.25%)
Age (years)		70.35±5.22
position	right eye	41 (51.25%)
	left eye	39 (48.75%)
Surgical technique	divide and rule	37 (46.25%)
	semiluxation	43 (53.75%)
Operation time (min)		10.67±2.45
Final suture		5 (6.25%)
Ultrasonic time (s)		43.55± 9.97
Effective phacoemulsification time (s)		72.79±8.43

Table 2. Intraoperative changes of corneal thickness (s).

time	CCT (μm)	Δ /μm (%)	*P value*
Preoperative corneal thickness	514.35±29.62		
At the beginning of phacoemulsification	517.85±30.45	3.50±0.83 (0.68%)	0.014
At the end of phacoemulsification	520.30±30.38	5.95±1.76 (1.16%)	0.002
At the end of irrigation and suction	526.37±30.66	12.02±2.04 (2.34%)	0.003
At the end of the operation	535.26±30.29	20.91±1.67 (4.07%)	0.001

was 2219.65±29.57/mm^2, which was decreased by 247.62/mm^2 (P<0.05). At the end of the operation, the density of endothelial cells was 2177.67±26.44/mm^2, which was decreased by 289.60/mm^2 (P<0.05). (Table 3)

Distribution of characteristics related to corneal edema

The distribution of corneal edema-related characteristics showed that 42.50% of patients had persistent edema during cataract surgery. The median onset time of corneal edema in other patients was 5.44 years (90% CR was 1.96-21.35 years). (Table 4)

Relationship between different nuclear hardness and corneal thickness during operation

According to the hardness of the lens nucleus, all patients were graded. The results showed that the higher the hardness of the lens nucleus, the more serious the cataract was, and the higher the APT, EPT, APE and TST were (P<0.05). The degree of corneal thickening during the operation was positively correlated with nuclear hardness (Table 3). (Table 5)

Correlation analysis of corneal thickness changes during phacoemulsification

Multivariate logistic regression was used to analyze the influencing factors of corneal thickness changes in diabetic cataract patients during phacoemulsification. Logistic regression analysis showed that the changes in corneal thickness were related to age, cataract lens nuclear grade, APT, EPT, APE and TST (P<0.05), indicating that the higher the age of patients, the higher the cataract nuclear grade, the higher the EPT, APE and TST, and the greater the corneal thickening during operation (*P*< 0.05). In addition, the increase in corneal thickness during the operation was related to the maximum area of corneal endothelial cells (MAX) and the density of endothelial cells (CD), indicating that the higher the maximum area of endothelial cells, the greater the increase of corneal thickness during operation, and the lower the density of corneal endothelial cells, the greater the increase of corneal thickness during operation (P < 0.05). (Figure 2, Table 6)

Discussion

Corneal endothelium plays a key role in maintaining corneal clarity. With the growth of age and diseases, cell density is expected to decrease, so it is important to maintain the health of this layer of cells because corneal endothelial cells are usually amitotic in vivo (16,17). Diabetes is a very common disease that damages the corneal endothelium. Diabetes leads to the damage of corneal endothelial

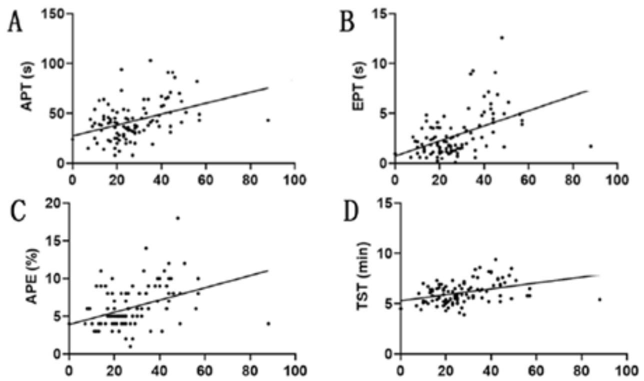

Figure 2. Correlation analysis of corneal thickness after operation.

Table 3. Endothelial cell density (s).

Time	Cells /mm2	*P value*
Preoperative	2467.27±38.49	
At the beginning of phacoemulsification	2348.66±34.39	<0.001
At the end of phacoemulsification	2234.82±24.19	<0.001
At the end of irrigation and suction	2219.65±29.57	<0.001
At the end of the operation	2177.67±26.44	<0.001

Table 4. Distribution of characteristics related to corneal edema.

factor	Degree/case
Time to start edema	
Immediate onset	Yes 34 (42.50%)
	No 46 (57.50%)
Late-onset (median)	5.44 years (90%CR1.96-21.35)
Duration of edema (median)	Overall 1.36 years (90% CR 0.34-6.45)
	Immediate onset was 1.13 years (90% CR 0.47-5.89)
	1.71 years after onset (90% CR 0.33-11.12)

Table 5. Relationship between the hardness of lens nucleus and corneal thickness (S).

index	II	III	IV	*P value*
Δ (μm)	19.45±5.38	26.37±7.66	38.52±8.36	0.001
APT (s)	24.79±6.34	43.57±10.23	66.14±12.05	0.003
EPT (s)	1.15±0.37	2.85±1.25	6.77±2.42	0.006
APE (%)	4.53±1.26	6.22±2.69	10.32±3.42	0.011
TST (min)	5.31±0.59	6.18±0.66	7.95±0.70	0.001

Table 6. Correlation analysis of corneal thickness after operation (S).

index	β	SE	OR value	95%CI	*P value*
age	2.305	0.693	2.214	0.586-1.336	0.016
Nucleus level of lens	0.217	1.145	0.835	0.107-0.443	0.023
APT	1.583	0.683	1.225	1.505-2.006	0.011
EPT	1.528	2.661	1.974	1.592-2.053	0.017
TST	1.047	0.703	1.463	1.442-1.706	0.005
MAX	0.992	0.516	0.447	1.517-1.886	0.026
CD	0.342	1.445	1.805	1.368-1.694	0.003

structure and function, which reduces cell reserve to cope with stress (18). Compared with non-diabetic patients of the same age, the density of endothelial cells in diabetic patients is lower. The endothelial cell count is negatively correlated with the course of diabetes and glycosylated hemoglobin (HbA1c) level, and the endothelial cell count of type 1 diabetes is lower than that of type 2 diabetes (19). Other studies have reported that compared with non-diabetic patients, the proportion of hexagonal cells and polycystic cells in the cornea of diabetic patients is lower and the central corneal thickness is higher. In diabetic patients, endothelial cells may be more vulnerable to trauma and have a weaker compensatory ability (20). Compared with non-diabetic patients, cataract surgery in diabetic patients leads to more endothelial cell loss. In addition, the glucose concentration in the aqueous humor of diabetic patients may often increase, which leads to metabolic acidosis of corneal stroma and reduces the repair ability (21). Because the density of the basal plexus in diabetic patients is lower than that in non-diabetic patients, cataract surgery further reduces the density of the basal plexus, and diabetic patients are prone to diabetic keratopathy (22).

Cataract surgery improves vision by removing the cloudy lens and then implanting the intraocular lens. The average adult cornea has 2000-2500 cells /mm^2, and the number of cells decreases with age, and the annual loss rate is about 0.3%-0.5%. Long-term corneal transparency after operation depends on the morphological stability and functional integrity of the corneal endothelium. All surgical interventions that need to enter the anterior chamber will cause some damage to the corneal endothelium (23,24). The loss of endothelial cells leads to cell hypertrophy to maintain continuity, which leads to changes in the density and morphology of endothelial cells. Studies have shown that during the 3-month follow-up, the density of endothelial cells is decreased, the variation is increased and the proportion of hexagonal cells is decreased. One of the most serious surgical complications occurs in 1% of postoperative patients, including the loss of endothelial cell density and the pump dysfunction of the remaining cells, which leads to corneal edema and a temporary increase in corneal thickness. Corneal edema is caused by decreased endothelial cell density and dysfunction of the endothelial pump. The endothelial pump is responsible for maintaining matrix and epithelial cells in the state of dehydration induced by surgery. A large number of studies have studied the influencing factors of endothelial cell loss after phacoemulsification. These studies show that elevated intraocular pressure and inflammation are the opposite causes of ion pump failure, and lowering intraocular pressure and introducing anti-inflammatory drugs have been proven to reduce edema and improve corneal transparency (25,26). Phacoemulsification combined with intraocular lens implantation is the main surgical method to treat diabetic cataracts, and most patients have good postoperative visual effects. Corneal edema after phacoemulsification for diabetic cataracts is a common postoperative complication. Most patients with grade I and II diabetic cataracts have mild edema, while some patients with grade III and IV diabetic cataracts may have moderate to severe corneal edema. In this study, intraoperative OCT was used for the first time to show the changes in corneal thickness during phacoemulsification, and the related influencing factors were analyzed, which further enriched the mechanism of corneal edema caused by intraocular surgery and effectively guided the surgical and postoperative clinical treatment of diabetic cataract.

In this study, it was found that the corneal thickness at the end of phacoemulsification, after irrigation and aspiration, and at the end of surgery was significantly higher than that before surgery. At the end of the surgery, the corneal thickness increased by 4.07% compared with that before surgery, and the corneal thickness increased with the increase of operation time, operation steps, effective phacoemulsification energy and time. A study showed that the average corneal thickness increased by 45 μm 3 days after phacoemulsification, increased by 13 μm 3 weeks after phacoemulsification, and gradually returned to normal 3 months after phacoemulsification. The increase in corneal thickness is not only related to the surgical trauma of corneal endothelial cells during operation but also related to early anterior chamber inflammation (27,28). Another study reported that the corneal thickness of cataract patients increased by 21.5% on the first day after the operation, and gradually decreased to the baseline level two weeks after the operation. The increase of phacoemulsification power and time leads to an increase in corneal thickness. The study on the change of corneal thickness 7 days after phacoemulsification showed that the corneal thickness of patients increased most significantly on the first day after phacoemulsification, increasing by 25.6% compared with that before the operation, and the corneal thickness increased by 12.9% on the third day after phacoemulsification and gradually recovered to the preoperative level one month after the operation. Compared with the preoperative level, the corneal thickness after simple phacoemulsification increased by 8.4% at 2 hours, 1.8% at 4 days and 0.1% at 15 days. In another study of phacoemulsification for 13 eyes, the corneal thickness was measured at 1 hour, 1 day and 1 week after the operation, which increased by 13.81%, 6.44% and 0.57% respectively.

Different from previous studies that focused on the changes in corneal thickness within days or months after cataract surgery, this study reported the changes in corneal thickness during phacoemulsification for diabetic cataracts for the first time. It was found that the corneal thickness of the patient was slightly thickened before phacoemulsification, that is, it had changed during intraocular perfusion, increasing by about 3.50 μm and the growth rate was 0.68%. Previous studies mainly thought that the energy and time of phacoemulsification had a greater impact on postoperative corneal edema, but this study showed that the corneal thickness changed only under high perfusion pressure, mainly due to the transient high intraocular pressure under high perfusion pressure before the start of ultrasound, which led to the imbalance of the pump function and barrier function of the corneal endothelium, and the destruction of the balance of liquid absorption and output, resulting in a temporary slight increase in corneal thickness. The study on the structure and function of corneal endothelium temporarily damaged by anterior chamber perfusion in the ocular hypertension model shows that the increase of corneal endothelial permeability leads to corneal edema, which further verifies our research results. At the end of phacoemulsification, the corneal thickness increased by 5.95 μm, an increase of 1.16%. At the beginning of the operation, high perfusion pressure and phacoemulsification led to the first increase in corneal thickness. The higher the phacoemulsification energy and the longer the time, the more obvious the increase in corneal thickness. At the end of irrigation and aspiration, the corneal thickness increased by 12.02 μm compared with that before the operation, with an increased rate of 1.16%, which was mainly due to the long-term inhalation of the anterior chamber under high irrigation pressure during the operation, combined with the effect of the intraocular operation, which led to further thickening of the cornea on the basis of phacoemulsification. At the end of the operation, the total corneal thickness increased by 4.07% compared with that before the operation. Intraoperative surgery, such as intraocular lens implantation, repeated entry of instruments and high intraocular pressure environment all lead to the continuous increase of corneal thickness. These results further confirmed that the increase in corneal thickness and corneal edema began at the beginning of the operation and lasted for a while before returning to normal. In this study, the operation time for diabetic cataracts was shorter, the maintenance time of high perfusion pressure was shorter, and the corneal edema after the operation was not serious, which affected the vision of patients.

In this study, all patients were graded according to the hardness of the lens nucleus. The results showed that compared with nuclear patients, the corneal thickness of nuclear and nuclear patients increased greatly during phacoemulsification, and the consumption of APT, EPT, APE and TST was significantly higher. Previous studies reported that the ultrasonic time and accumulated dissipated energy required for phacoemulsification of grade IV nuclear were much higher than that of grade I ($P<0.01$), and the more severe corneal edema after the operation, the higher the edema score. In a study of patients with moderate hardness cataract nuclei undergoing phacoemulsification, it was found that the corneal thickness increased by 10.4% one day after the operation. During the ultrasonic examination of cataracts in patients with relatively dense cataracts, it was found that the phacoemulsification time was significantly prolonged and the average energy dissipation was significantly improved. The corneal thickness was 3.13% thicker than that in patients with low-grade cataracts one week after the operation. The results of this study showed that the changes in corneal thickness at different time points during the operation were positively correlated with APT, EPT, APE and TST ($P<0.05$), and the longer the ultrasound time, the longer the operation time and the higher the energy consumption, the more obvious the corneal thickening. A relatively hard and mature nuclear cataract needs more ultrasonic time and energy in phacoemulsification. Ultrasonic power during operation, the vibration of the phacoemulsification probe, turbid fragments of lens nucleus, mechanical damage caused by irrigation solution and surgical instruments may all lead to corneal edema (29-35). The growth rate of the corneal thickness of grade III patients in this study was only 4.07%, which was significantly lower than that of previous studies. With the development of cataract surgical instruments and techniques, more and more attention has been paid to the protection of the cornea during surgery, and the incidence and severity of corneal edema have gradually decreased. Real-time monitoring of the changes in corneal thickness during phacoemulsification can reflect the use of energy and time in time, predict postoperative corneal edema and prognosis, and further guide postoperative drug treatment. According to the change of corneal thickness during operation, the operator can adjust the operation process in time, such as moving gently, reducing time and energy, appropriately reducing the perfusion pressure during operation, or choosing a viscoelastic agent with endothelial protection function to reduce the occurrence of corneal edema after the operation. In addition, for patients with significantly increased corneal thickness during operation, a drug intervention can be carried out in advance, and anti-inflammatory and anterior repair treatment should be strengthened after the operation.

The corneal endothelium is necessary to maintain normal transparency and thickness of the cornea, and corneal thickness is one of the most important indexes of corneal endothelial function. The energy required for phacoemulsification depends largely on the density of the lens nucleus, and the severity of corneal edema depends on the function of corneal endothelial cells. The damage of phacoemulsification to the corneal endothelium can affect its barrier and pump function, resulting in corneal edema. It was found that the loss rate of corneal endothelial cells after phacoemulsification was 8.5 ~ 15.4%. In patients with low density of corneal endothelial cells, cataract surgery leads to greater loss of corneal endothelial cells, and postoperative persistent corneal edema occurs more frequently and lasts longer. A study found that cataract surgery in patients with corneal endothelial dystrophy further accelerated the loss of endothelial cells and made corneal edema worse after surgery. This study showed that the change in corneal thickness during phacoemulsification was negatively correlated with the density of corneal endothelial cells. The lower the density of corneal endothelial cells, the more serious corneal edema during operation.

In addition, for corneal endothelial cells lacking homogeneity, even if there is enough cell density, diabetic cataract surgery will still have a certain impact on corneal thickness. The adhesion of lens fragments to corneal endothelium during operation, mechanical stimulation and local temperature increase can also lead to corneal endothelial damage, which further aggravates corneal edema.

This study found that in patients with decreased corneal endothelial cell count, short-term and low-energy phacoemulsification could reduce the degree of corneal edema during operation. The corneal thickness of some patients did not increase much at the end of the operation, but corneal edema was obvious after the operation, which may be related to the shorter operation time and high perfusion pressure time. Corneal endothelial cells will change in structure and function with the change in osmotic pressure, but this change needs a cumulative effect. When the compensatory function of corneal endothelium exceeds, it will change qualitatively, which will eventually lead to obvious corneal edema.

To sum up, in phacoemulsification for diabetic cataracts, postoperative corneal edema is closely related to intraocular perfusion pressure, lens nucleus hardness, corneal endothelial cell density, phacoemulsification energy and duration. These findings further enrich the mechanism of corneal edema caused by intraocular surgery. Real-time observation of corneal thickness during operation is helpful to predict the severity of corneal edema and corneal endothelial loss after the operation, so as to carry out the corresponding treatment in advance and achieve good surgical results.

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