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Article

Corneal Endothelial Changes After Phacoemulsification Cataract Surgery Using the Eight-Chop Technique in Diabetic Eyes

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Abstract: Objectives: To investigate corneal endothelial changes and intraocular pressure (IOP) after phacoemulsification using the eight-chop technique and intraoperative parameters in patients with diabetes. **Methods:** Eyes of patients with cataracts who underwent phacoemulsification were included in this study. Cataract surgery was performed using the eight-chop technique. The operative time, phaco time, aspiration time, cumulative dissipated energy, and volume of fluid used were measured. The best-corrected visual acuity, IOP, corneal endothelial cell density (CECD), central corneal thickness (CCT), coefficient of variation (CV), and percentage of hexagonal cells (PHC) were measured pre- and post-operatively. **Results:** Overall, 181 eyes of 138 patients with cataracts were evaluated. In the diabetes group, the CECD loss rates were 5.1%, 3.9%, and 2.1% at 7 weeks, 19 weeks, and 1 year post-operatively, respectively. In the control group, the CECD loss rates were 2.8%, 2.6%, and 1.2% at 7 weeks, 19 weeks, and 1 year postoperatively, respectively. Significant differences in the CV and PHC were observed preoperatively and postoperatively between the diabetes and control groups ($p < 0.01$ or $p = 0.01, 0.02$). Significant differences were also observed between CV and PHC preoperatively, 19 weeks, and 1 year postoperatively in the diabetes and control groups ($p < 0.01$). At 1 year postoperatively, IOP reduction rates were 8.0% and 11.2% in the diabetes and control groups, respectively. **Conclusions:** CECD loss in the eight-chop technique was minimal. The repair and healing mechanisms of the endothelium may have increased by phacoemulsification using the eight-chop technique postoperatively. The IOP reduction was maintained in both groups postoperatively.

Keywords: cataract surgery; corneal endothelial cell; diabetes mellitus; eight-chop technique; phacoemulsification

1. Introduction

Patients with diabetes develop cataracts at a high rate; moreover, diabetes also results in additional complications [1,2]. Particularly in patients with diabetes, high blood sugar is associated with an increase in the accumulation of TGF- β -induced proteins and the formation of advanced glycation end products in the corneal endothelial cells [3]. Furthermore, components of the extracellular matrix such as vitronectin and fibronectin are markedly increased along the Descemet membrane-stromal interface [3]. In addition, the activity of Na⁺/K⁺-ATPase, which plays an important role in the maintenance of the cornea, is reduced and corneal endothelial cells in patients with diabetes are structurally and functionally impaired [4].

Patients with diabetes have higher intraocular pressure (IOP) than do healthy participants [5,6] and are more likely to develop glaucoma than do normal individuals [5]. Therefore, it is important to investigate changes in IOP after cataract surgery in patients with diabetes who have a high incidence of glaucoma. However, many studies have shown that IOP decreases after cataract surgery in patients with and without diabetes, though the results varied.

Although advances in phacoemulsification have improved the safety and efficiency of cataract surgery, there remains a need to work on protecting corneal endothelial cells. Even now, cataract surgery reduces corneal endothelial cell density (CECD) [7–10]. However, results regarding the

reduction of CECD after surgery are inconsistent [11–15], and the phacoemulsification techniques used in surgery are mixed. In addition, intraoperative measurement of parameters is an important indicator for analysis of the effects of surgery; however, only few studies that have investigated the relationship between these parameters and postoperative CECD loss.

Manual nucleus division under an ophthalmic viscosurgical device precedes phacoemulsification in the eight-chop technique [16,17]. The eight-chop technique reduces total ultrasound energy, aspiration time, and fluid volume compared to conventional grooving, divide-and-conquer, and phaco-chop techniques. [16,17]. Furthermore, the CECD loss after cataract surgery is 0.9–1.0% if the nucleus is not hard [16]. From the perspective of corneal endothelial cell protection, the eight-chop technique is an ideal surgical method.

Although cataract surgery alone does not cause corneal endothelial cell dysfunction, the CECD loss after cataract surgery needs to be minimized considering the effects of potential complications such as glaucoma and vitreous surgery.

In this study, we aimed to measure the changes in corneal endothelial cells, IOP, and intraoperative parameters using the eight-chop technique in patients with diabetes.

2. Materials and Methods

2.1. Ethical Considerations

The protocol was approved by the institutional review board and adhered to the tenets of the Declaration of Helsinki. After explaining the nature and possible consequences of the study, informed consent was obtained from each patient to participate in the study.

2.2. Study Population

This study enrolled the eyes of patients with cataract who underwent phacoemulsification and posterior chamber intraocular lens (IOL) implantation between June 2019 and July 2022, and visited our clinic. Exclusion criteria were corneal disease or opacity, uveitis, diabetic retinopathy, poorly dilated pupils (< 5.0 mm), white cataracts, preoperative CECD < 2,000 cells/mm², severely weak zonules, and past ocular trauma or surgery.

2.3. Preoperative Assessment

Slit-lamp and retinal examinations and measurements of best corrected visual acuity (BCVA) and IOP were performed preoperatively in all patients. The patients were diagnosed with diabetes based on the Hemoglobin A1c level within 6 months prior to surgery. The CECD (cells/mm²), central corneal thickness (CCT), coefficient of variation (CV), and percentage of hexagonal cells (PHC) were analyzed with a non-contact specular microscope (EM-3000; Topcon Corporation, Tokyo, Japan). The firmness of the nucleus was graded classified according to the Emery classification [18]. All patients were operated by the same surgeon experienced in the eight-chop technique using the phacoemulsification device (Centurion®; Alcon Laboratories, Inc., Irvine, CA, USA).

2.4. Surgical Instruments

To perform the eight-chop technique, new surgical instruments were constructed and developed [16]. Our research team designed eight choppers and had them manufactured by a manufacturing company. The Eight-Chopper I (SP-8193; ASICO, Parsippany, NJ, USA) has a smaller tip than the conventional prechopper. The tip is 3.2 mm long and 1.4 mm wide and has a sharper leading edge. The Eight-Chopper II (SP-8402; ASICO) has a smaller angled tip (2.5 mm long and 0.8 mm wide). It can be inserted vertically into the lens nucleus.

2.5. Surgical Technique

A temporal clear corneal incision was made with a 3.0 mm steel keratome in all surgeries. A 6.2–6.5 mm continuous curvilinear capsulorhexis was created with capsule forceps after injection of sodium hyaluronate into the anterior chamber. In the Grade III group, the soft-shell [7] technique was used. Hydrodissection was performed with a 27-G cannula; however, no hydrodelineation was performed. In the grade II and III groups, the lens nucleus was divided into eight segments using an Eight-chopper I or II. At the depth of the iris plane, the eight segments were phacoemulsified and aspirated. The capsular bag was aspirated with an irrigation/aspiration tip to remove the cortical materials. The ophthalmic viscosurgical device was injected and a foldable IOL (Acrysof® MN60AC; Alcon Laboratories, Inc., Fort Worth, TX, USA) with polymethyl methacrylate haptics was placed into the capsular bag by injection. Consequently, the ophthalmic viscosurgical device was removed.

The phacoemulsification unit was utilized in all cases, with a flow rate of 32 mL/min, a maximum ultrasound power of 80%, and a 1.1-mm tip. A balanced salt solution containing moxifloxacin (0.5 mg/mL) was used to replace the anterior chamber postoperatively.

Intraoperative outcome measures consisted of operative time (min), phaco time (s), aspiration time (s), cumulative dissipated energy (CDE), volume of fluid used (mL), and intraoperative complication rate. From the beginning of the corneal incision to the end of aspiration of the ophthalmic viscosurgical device, the operative time was calculated. All of the surgeries were recorded with a camera (MKC-704KHD, Ikegami Tsushinki co., Ltd., Tokyo, Japan), and the video images were saved on a hard disk.

2.6. Data Collection and Statistical Analysis

Patients were followed at postoperative days 1 and 2, weeks 1, 3, 7, and 19, and year 1. Postoperative outcome measures included BCVA, IOP, CCT, CV, PHC, and CECD at 7 weeks, 19 weeks, and 1 year postoperatively.

Unpaired *t*-tests were used for statistical analyses to compare results between the diabetes and control groups. A paired *t*-test was used to compare the preoperative BCVA, IOP, CV, PHC, CCT, and CECD values with the values at each postoperative time point. The level of statistical significance was set at $p < 0.05$. Chi-squared test was used to determine whether there were differences between the diabetes and control groups by sex.

3. Results

3.1. Characteristics of the Participants

This study investigated 181 eyes of 138 cataract patients undergoing phacoemulsification and IOL implantation. Patient characteristics and intraoperative parameters are shown in Table 1. Mean age ($p = 0.71$) and sex ($p = 0.12$) were not significantly different between the diabetes and control groups. In addition, no significant differences were observed between the diabetes and control groups in terms of operative time, phaco time, aspiration time, CDE, and volume of fluid used ($p = 0.14, 0.15, 0.83, 0.14, \text{ and } 0.65$, respectively).

Table 1. Preoperative Characteristics and Intraoperative Parameters.

Characteristics/Parameters	Diabetes Group	Control Group	p-Value
Number of eyes	94	87	
Age (years)	74.6 ± 6.8	74.3 ± 5.5	0.71 ^a
Sex Male	43 (46%)	30 (34%)	0.12 ^b
Female	51 (54%)	57 (66%)	
Operative time (minutes)	4.63 ± 1.24	4.91 ± 1.38	0.14 ^a
Phaco time (s)	15.5 ± 6.0	14.2 ± 6.3	0.15 ^a
Aspiration time (s)	68.1 ± 16.7	67.6 ± 20.4	0.83 ^a
CDE	6.45 ± 2.30	5.91 ± 2.61	0.14 ^a
Volume of fluid used (mL)	27.0 ± 7.7	26.5 ± 8.1	0.65 ^a

Values are expressed as mean ± standard deviation or as percentages, unless otherwise noted. ^a No significant differences were found between the groups by unpaired *t*-test. ^b No significant differences were found between the groups by Chi-square test. CDE, cumulative dissipated energy.

3.2. Changes in CECD

Preoperative and postoperative changes in CECD are shown in Table 2. There was no significant difference in CECD between diabetes and control groups preoperatively and at 7 weeks, 19 weeks and 1 year postoperatively (*p* = 0.61, 0.24, 0.73 and 0.99, respectively). Significant differences were observed between preoperative and 7-week postoperative CECD, preoperative and 19-week postoperative CECD, and preoperative and 1-year postoperative CECD in the diabetes and control groups (all *p* < 0.01).

Table 2. Pre- and postoperative CECD values.

Mean CECD ± SD (% Decrease)					
Time period	Diabetes group		Control group		<i>p</i> -Value
	(n = 94)		(n = 87)		
Preoperatively	2670 ± 294	-	2652 ± 211	-	0.61 ^b
7 weeks postoperatively	2533 ± 272 ^a	5.1	2576 ± 207 ^a	2.8	0.24 ^b
19 weeks postoperatively	2570 ± 294 ^a	3.9	2583 ± 221 ^a	2.6	0.73 ^b
1 year postoperatively	2620 ± 306 ^a	2.1	2620 ± 214 ^a	1.2	0.99 ^b

Values represent mean ± standard deviation. ^aSignificant differences were found between the preoperative and respective time values by paired *t*-test. ^b No significant differences were found between the groups by unpaired *t*-test. CECD, corneal endothelial cell density; SD, standard deviation.

3.3. Changes in CCT, CV, and PHC

Preoperative and postoperative changes in the CCT, CV, and PHC are shown in Table 3. There were no significant differences in the CCT preoperatively and at 7 weeks, 19 weeks and 1 year postoperatively between the diabetes and control groups (*p* = 0.59, 0.09, 0.26, and 0.24, respectively). There were significant differences between the CCT preoperatively and that at 7 weeks postoperatively and between the CCT preoperatively and that at 19 weeks postoperatively in the diabetes group (*p* < 0.01 and *p* = 0.03, respectively); however, there were no significant differences between the CCT preoperatively and that at 1 year postoperatively in the diabetes group (*p* = 0.38). There were no significant differences between the CCT preoperatively and that at 7 weeks postoperatively and between the CCT preoperatively and that at 19 weeks postoperatively in the control group (*p* = 0.27 and 0.86, respectively); however, there were significant differences between

the CCT preoperatively and that at 1 year postoperatively in the control group ($p < 0.01$). There were significant differences in the CV preoperatively and at 7 and 19 weeks and 1 year postoperatively between the diabetes and control groups ($p < 0.01$ or $p = 0.01$). No significant differences were observed between the CV preoperatively and that at 7 weeks postoperatively in the diabetes ($p = 0.13$) and control ($p = 0.43$) groups; however, significant differences were observed between the CV preoperatively and that at 19 weeks postoperatively and between the CV preoperatively and that at 1 year postoperatively in the diabetes and control groups (all $p < 0.01$). Significant differences were observed in the PHC preoperatively and at 7 weeks, 19 weeks, and 1 year postoperatively between the diabetes and control groups ($p < 0.01$ or $p = 0.02$). No significant differences were observed between the PHC preoperatively and that at 7 weeks postoperatively in the diabetes ($p = 0.11$) and control ($p = 0.34$) groups; however, significant differences were observed between the PHC preoperatively and that at 19 weeks postoperatively and between the PHC preoperatively and that at 1 year postoperatively in the diabetes and control groups (all $p < 0.01$).

Table 3. Pre- and postoperative endothelial CCT, CV, and PHC.

Time period	Diabetes group (n = 94)	Control group (n = 87)	p-Value
CCT	Mean ± SD		
Preoperatively	538 ± 34.0	536 ± 34.1	0.59 ^a
7 weeks postoperatively	547 ± 36.2 ^c	537 ± 34.0 ^d	0.09 ^a
19 weeks postoperatively	542 ± 33.3 ^c	536 ± 32.7 ^d	0.26 ^a
1 year postoperatively	537 ± 35.0 ^d	531 ± 33.6 ^c	0.24 ^a
CV	Mean ± SD		
Preoperatively	42.3 ± 5.5	39.8 ± 6.9	< 0.01 ^b
7 weeks postoperatively	41.3 ± 5.6 ^d	39.1 ± 5.2 ^d	< 0.01 ^b
19 weeks postoperatively	39.3 ± 6.0 ^c	36.4 ± 4.9 ^c	< 0.01 ^b
1 year postoperatively	37.6 ± 5.0 ^c	35.7 ± 4.9 ^c	0.01 ^b
PHC	Mean ± SD		
Preoperatively	39.7 ± 6.9	44.7 ± 5.6	< 0.01 ^b
7 weeks postoperatively	41.0 ± 6.5 ^d	45.5 ± 6.7 ^d	< 0.01 ^b
19 weeks postoperatively	44.5 ± 7.1 ^c	48.1 ± 6.2 ^c	< 0.01 ^b
1 year postoperatively	46.4 ± 6.7 ^c	48.8 ± 7.0 ^c	0.02 ^b

Values represent mean ± standard deviation. ^aNo significant differences between the groups by one-way analysis of variance. ^bSignificant differences between the groups by one-way analysis of variance. ^cSignificant differences between the preoperative and respective time values by paired *t*-test. ^dNo significant differences between the preoperative and respective time values by paired *t*-test. CCT, central corneal thickness; CV, coefficient of variation; PHC, percentage of hexagonal cells; SD, standard deviation.

3.4. Changes in IOP

Changes in IOP are shown in Table 4. There were no significant differences in IOP preoperatively and at 7 weeks, 19 weeks, and 1 year postoperatively between the diabetes and control groups ($p = 0.06, 0.49, 0.20$, and 0.36 , respectively). There were significant differences between IOP preoperatively and that at 7 weeks, 19 weeks, and 1 year postoperatively in the diabetes and control groups (all $p < 0.01$).

Table 4. Mean IOP (mmHg) and mean decrease (%) in the IOP (mmHg) over the course of time.

Time period	Mean IOP ± SD (% Decrease)				p-Value
	Diabetes group (n = 94)		Control group (n = 87)		
Preoperatively	14.0 ± 1.9	-	14.5 ± 2.0	-	0.06 ^a
7 weeks postoperatively	11.9 ± 2.3 ^b	13.2	12.1 ± 1.8 ^b	16.1	0.49 ^a
19 weeks postoperatively	12.3 ± 2.2 ^b	10.7	12.6 ± 1.8 ^b	12.4	0.20 ^a
1 year postoperatively	12.6 ± 2.1 ^b	8.0	12.9 ± 1.9 ^b	11.2	0.36 ^a

Values represent mean ± standard deviation. ^aNo significant differences between the groups by un paired *t*-test. ^bSignificant differences between the preoperative and respective time values by paired *t*-test. IOP, intraocular pressure; SD, standard deviation.

3.5. Changes in BCVA over the Course of Time

Changes in BCVA are shown in Table 5. There were significant differences in the preoperative BCVA between the diabetes and control groups (*p* = 0.02). Moreover, there were significant differences in the BCVA at 7 weeks, 19 weeks, and 1 year postoperatively between the diabetes and control groups (all *p* < 0.01). There were significant differences between the BCVA preoperatively and that at 7 weeks postoperatively; between the BCVA preoperatively and that at 19 weeks postoperatively; and between the BCVA preoperatively and that at 1 year postoperatively in the diabetes and control groups (all *p* < 0.01).

Table 5. Changes in best-corrected visual acuity over the course of time.

Time period	Best-corrected visual acuity		p-Value
	Diabetes group (n = 94)	Control group (n = 87)	
Preoperatively	0.031 ± 0.030	0.074 ± 0.011	0.02 ^a
7 weeks postoperatively	-0.040 ± 0.0049 ^c	-0.065 ± 0.00095 ^c	< 0.01 ^b
19 weeks postoperatively	-0.037 ± 0.0038 ^c	-0.0664 ± 0.00086 ^c	< 0.01 ^b
1 year postoperatively	-0.039 ± 0.0042 ^c	-0.064 ± 0.0010 ^c	< 0.01 ^b

Values represent mean ± standard deviation. ^aNo significant differences between the groups by unpaired *t*-test. ^bSignificant differences between the groups by unpaired *t*-test. ^cSignificant differences between the preoperative and respective time values by paired *t*-test.

3.6. Complications

There were no intraoperative complications or capsulorhexis tears in the diabetes or control groups.

4. Discussion

The findings of the study indicated that the eight-chop technique exhibited an operative time of 4.63–4.91 minutes in both the diabetes and control groups. This time frame was found to be significantly less than that of other techniques, which ranged from 10 to 19 min [7,9,19,20]. In addition, the phaco time and CDE were decreased, and the volume of fluid used was reduced to one-third to one-fourth of that used in other techniques [7,9,21]. The eight-chop technique involves the mechanical division of the nucleus into eight pieces preceding phacoemulsification. This results in the reduced use of ultrasonic oscillation energy and an efficient removal of the fragmented nucleus, which can lead to a drastic reduction in the phaco time and CDE. The concept of the eight-chop technique may be analogous to femtosecond laser-assisted cataract surgery in that both procedures involve the division of the lens nucleus without the utilization of ultrasonic oscillation energy.

According to two meta-analyses, the preoperative CECD in patients with diabetes was lower than that in the healthy population [22,23]; conversely, Yang et al. [24] reported that there was no difference and no agreement. In this study, no significant differences were observed in the CECD preoperatively between the diabetes and control groups.

Previous studies have reported 10.2–18.5% and 5.0–18.4% decreases in the CECD following cataract surgery in the first few postoperative months in patients with and without diabetes [8–10,22,23]. In this study, however, the decrease was only 5.1%, 3.9%, and 2.1% at 7 weeks, 19 weeks, and 1 year postoperatively in the diabetes group and 2.8%, 2.6%, and 1.2% at 7 weeks, 19 weeks, and 1 year postoperatively in the control group. Diabetes increases the risk of damage and dysfunction of the corneal endothelium following surgical stress [25]. Compared with patients without diabetes, those with diabetes show differences in greater CECD loss following cataract surgery [22,24,26]. However, no significant difference was observed in the postoperative decrease in the CECD between the diabetes and control groups. The low surgical invasiveness of the eight-chop technique may have prevented the fragility of the corneal endothelial cell function of patients with diabetes from causing a difference in the CECD loss.

CECD loss during phacoemulsification is inevitable. This is primarily due to the confined space (anterior chamber) where the surgery is performed. The corneal endothelium comes into direct contact with the instruments several times during the procedure, making it susceptible to damage from the high ultrasound energy of the phaco tip [27]. Despite the potential benefits of phacoemulsification, the CECD after phacoemulsification remains a major concern. Because it represents the true summary of intraocular insult during surgery, CECD assessment is critical for comparing different techniques [7,28]. Our results suggest that minimizing surgical involvement of intraocular tissues, including the trabecular meshwork and Schlemm's canal, may be advantageous with the eight-chop technique. Modern cataract surgery aims not only to improve vision but also to minimize the damage to corneal endothelial cells, especially in patients with cataracts and diabetes. This study revealed that, in patients with diabetes, the CECD loss after cataract surgery is greater than that in normal patients; however, this loss is minimal. Moreover, if the eight-chop technique is used, even in patients with diabetes, the rate of CECD reduction 1 year post-surgery is the same as the average annual rate of decrease over 10 years post-surgery in normal patients, which has been reported at 2.5% [29].

CCT is used as a marker of corneal endothelial function [26]. In this study, preoperative and postoperative CCT were not significantly different between the diabetes and control groups. Nevertheless, significant differences were observed between the CCT preoperatively and that at 7 weeks postoperatively and between the CCT preoperatively and that at 19 weeks postoperatively in the diabetes group, whereas no significant differences were observed in the control group. This result shows that there is a possibility of corneal endothelial cell dysfunction in the diabetes group at 19 weeks postoperatively compared to that in the control group.

The CV is an indicator of the uniformity in the size of endothelial cells, which implies the repair and healing mechanisms of the endothelium after damage. Previous studies have demonstrated significant and non-significant differences in CV changes between patients with and without diabetes after cataract surgery [11,22,24,30]. In this study, the CV in the diabetes group was higher than that in the control group preoperatively and the CVs decreased significantly in both groups at 1 year postoperatively; moreover, there was no significant difference between the two groups.

Hexagonality indicates the variability in hexagonal cell shape, such as the CV, and it represents the healing response after damage [26]. Previous studies have demonstrated significant and non-significant differences in PHC changes between patients with and without diabetes after cataract surgery [11,22,24,30]. In this study, the PHC in the diabetes group was lower than in the control group preoperatively and the PHCs increased significantly in both groups at 1 year postoperatively, there was no significant difference between the two groups. These results of CV and PHC suggest that the repair and healing mechanisms of the endothelium may be reduced in the diabetes group.

preoperatively, although its activity may have increased in both groups postoperatively because of the low surgical invasiveness of the eight-chop technique.

IOP reduction after phacoemulsification, cataract extraction, and IOL implantation in patients with cataracts has been reported by many investigators [31,32]. Previous reports have demonstrated IOP reductions of 4–10% [33–35]. Changes in the postoperative IOP are proportional to the preoperative IOP. However, Poly et al. [35,36] reported an increase in IOP in the primary open-angle glaucoma (POAG) and normal groups at 1 year compared with the preoperative levels. Therefore, there are conflicting perspectives on IOP reduction after phacoemulsification cataract surgery. The study showed an IOP reduction rate of 8.0% and 11.2% for the diabetes and control groups, respectively, at 1 year postoperatively, which was higher than previously reported data in both groups. The greater IOP reduction could be attributed to the superiority of the eight-chop technique over other techniques in decreasing surgical involvement of the intraocular tissues.

Trabecular meshwork cells, which are exposed to the same ultrasonic energy and turbulent currents as corneal endothelial cells during cataract surgery, are expected to decrease in number if the corneal endothelial cells decrease more severely. A decrease in the trabecular meshwork cells is associated with POAG and elevated IOP. POAG eyes contained overall fewer trabecular meshwork cells than did normal eyes, indicating an average cell loss of 17.7% in glaucoma eyes [37]. Furthermore, trabecular meshwork cellularity was highly correlated with the maximum recorded IOP [36], supporting the notion that reduced trabecular meshwork cell density hampers the ability of the tissue to regulate IOP [37]. Therefore, increasing CECD loss may lead to trabecular meshwork cell loss, resulting in increased IOP.

In the eight-chop technique, the low volume of fluid used suggests that the ultrasonic and irrigation/aspiration tips are employed for a shorter period, which may exert a reduced impact on the trabecular meshwork and Schlemm's canal cells, including corneal endothelial cells. Therefore, we speculate that the eight-chop technique may result in less trabecular meshwork cell loss, and as a result, normal trabecular meshwork function may be maintained, leading to long-term IOP reduction.

It is important to note that this study is not without limitations. The initial observation is derived from the absence of outcomes with the prechop, phaco-chop, or divide-and-conquer techniques. This should be taken into full consideration when assessing the present results. However, numerous other studies have been carried out employing the phaco-chop and divide-and-conquer techniques, and it is our belief that the present results can be assessed by comparing them with our results. Second, the correlation between intraoperative parameters, postoperative outcomes, and blood glucose levels, duration of diabetes, and type of diabetes was not investigated. Furthermore, as cases with diabetic retinopathy were excluded, it is unknown how the CECD changes in patients with severe diabetes after cataract surgery.

The prechop technique has the excellent feature of being able to reduce the use of ultrasonic oscillation energy and the surgical invasion of intraocular tissue by mechanically dividing the crystalline lens into four segments before phacoemulsification [38]. This excellent feature is the same as the advantages of femtosecond laser-assisted cataract surgery. However, it is far superior to femtosecond laser-assisted cataract surgery in terms of medical economics.

Although the prechop technique has excellent features, it is rarely used as a surgical technique worldwide [16,39] because the prechopper may not be easy to operate. However, the eight-chop technique, which is an improvement on the prechop technique, has been developed and the eight-chopper has improved usability [16,17]. Furthermore, by using the Lance-chopper, it is possible to perform phacoemulsification surgery on patients with hard nucleus cataracts or weak zonules [16].

The phaco time, aspiration time, CDE, volume of fluid used, and operative time should be thoroughly evaluated when analyzing changes in IOP and CECD following phacoemulsification cataract surgery. To the best of our knowledge, however, few studies have investigated the effects of phacoemulsification cataract surgery on IOP and CECD. To reduce postoperative CECD loss and maintain IOP reduction, surgical invasion of intraocular tissues should be analyzed using

intraoperative parameters, and a phacoemulsification technique should be selected to minimize surgical invasion.

5. Conclusions

The eight-chop technique is a cataract surgery with a shorter operative time, less surgical invasion of intraocular tissues, and less fluid volume used than those in previous techniques. The CECD loss in the present study was minimal compared with that reported in previous studies. The changes in the CV and PHC suggest that the repair and healing mechanisms of the endothelium may have increased postoperatively because of the low surgical invasiveness of the eight-chop technique. The IOP reduction could be explained by the superiority of the eight-chop technique in minimizing surgical involvement of the intraocular tissues.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Sato Eye Clinic (protocol code 190401 and date of approval 1 April 2019).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study for sample collection and subsequent analyses.

Data Availability Statement: The data presented in this study are available on request from the corresponding author due to privacy and ethical restrictions.

Conflicts of Interest: The author declares no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

IOP	Intraocular pressure
CECD	Corneal endothelial cell density
CCT	Central corneal thickness
CV	Coefficient of variation
PHC	Percentage of hexagonal cells
IOL	Intraocular lens
BCVA	Best-corrected visual acuity
CDE	Cumulative dissipated energy
SD	Standard deviation
POAG	Primary open angle glaucoma

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