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Article

Cataract Surgery in Microcornea Eyes Using the Eight-Chop Technique

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Abstract

Objectives: To evaluate the safety and efficacy of the eight-chop technique in cataract surgery for microcornea eyes, we aimed to investigate intraoperative parameters, changes in corneal endothelial cells, intraocular pressure, and intraoperative complications. **Methods:** Phacoemulsification cataract surgery was performed using the eight-chop technique. Preoperative and postoperative evaluation parameters included best-corrected visual acuity, intraocular pressure, corneal endothelial cell density (CECD), central corneal thickness, coefficient of variation, and percentage of hexagonal cell. Intraoperative parameters measured were operative time, phaco time, aspiration time, cumulative dissipated energy (CDE), and fluid of volume used. **Results:** We analyzed 104 eyes from 104 patients (mean age 76.2 ± 4.8 years; 40 males, 64 females). In the microcornea group, the operative time, phaco time, aspiration time, CDE, and fluid of volume used were 5.9 min, 17.9 s, 77.0 s, 7.06 μ J, and 31.1 mL, respectively, showing favorable measurements. In contrast, the control group, the operative time, phaco time, aspiration time, CDE, and fluid of volume used were 4.5 min, 14.7 sec, 64.3 sec, 6.44 μ J, and 25.0 mL, respectively. Furthermore, CECD loss in the microcornea group was 3.6% at 7 weeks and 1.5% at 19 weeks, compared to 2.3% and 1.4%, respectively, in the control group. Significant reductions were observed in both the microcornea and control groups at 7 and 19 weeks postoperatively. No cases of intraoperative complications occurred in either group. **Conclusion:** The eight-chop technique in cataract surgery demonstrates excellent intraoperative parameters for microcornea eyes and may offer reduced surgical impact even in cases with low anterior chamber volume. This technique is expected to contribute to establishing individualized treatment strategies and improving cataract management and treatment.

Keywords: cataract surgery; corneal endothelial cell; eight-chop technique; microcornea; personalized treatment; phacoemulsification

1. Introduction

Cataract surgery is the most frequently performed ophthalmic surgery worldwide [1]. Currently, phacoemulsification is employed, enabling significant improvement in visual function [2,3]. However, cataract extraction and intraocular lens (IOL) implantation in small eyes remains one of the most challenging procedures for cataract surgeons [4]. Parameters for diagnosing small eye include axial length, corneal diameter, and anterior chamber depth. Based on axial length, it is classified as microphthalmos, nanophthalmos, or relative anterior microphthalmos [4]. The axial length of eyes with microphthalmos is defined as less than 21.0 mm for adults in epidemiological studies [5]. There is currently no consensus on the axial length value defining nanophthalmos, but it is at most 20.5 mm [5]. Relative anterior microphthalmos is defined as axial length exceeding 20.5 mm, with anterior chamber depth of 2.2 mm or less and corneal diameter of less than 11.0 mm [6]. The corneal diameter of 11 mm or 10 mm and below is defined as microcornea [6]. Microcornea can be hereditary, involve morphological abnormalities of the eyeball, or present without morphological abnormalities other than corneal diameter [6,7]. Microcornea without morphological abnormalities may not be diagnosed prior to cataract surgery because axial length and anterior chamber depth

appear normal. However, surgeries for microcornea eyes with small anterior segment are challenging due to the physical and space limitations of the small eye [4].

Corneal endothelial cell density (CECD) serves as a primary biomarker for evaluating surgical trauma to the cornea [8–10]. Furthermore, it is crucial to protect corneal endothelial cells because they lack regenerative capacity. Corneal endothelial cells are unique in that they do not proliferate, which distinguishes them from other cell types. Therefore, when corneal endothelial cells are lost, compensation occurs through cell migration, cell enlargement, and increased pleomorphism, leading to cellular heterogeneity [11]. When cell density falls below 400/mm², corneal endothelial dysfunction occurs, resulting in impaired corneal dehydration function and subsequent swelling. The clinical manifestations of this process include corneal edema, corneal stroma thickening, bullous keratopathy, and corneal scarring, which can ultimately result in irreversible vision loss [8–10]. Bullous keratopathy following IOL implantation remains a significant complication, with an incidence rate reported to be approximately 1 to 2% [12].

The CECD loss after phacoemulsification can be attributed to several factors, such as direct trauma from instruments, exposure to ultrasonic energy, oxidative stress caused by free radicals, mechanical contact with the IOL or lens nucleus fragments, and the stream of irrigation fluid [13–17]. Moreover, given that surgery is performed within the confined intraocular space, ensuring an adequate surgical extent may mitigate the risk of endothelial impairment. However, microcornea eyes encounter physical and structural limitations within the anterior chamber, which may result in more invasive surgical interventions [4]. Therefore, to improve surgical outcomes, it is necessary to investigate the intraoperative parameters that affect CECD loss, even in microcornea eyes. To comprehensively evaluate this factor, it is necessary to investigate corneal diameter, anterior chamber depth, axial length, lens hardness, operative time, phaco time, aspiration time, cumulative dissipated energy (CDE), volume of fluid used, and CECD loss.

Compared to other surgical techniques, cataract surgery using the eight-chop technique has been reported to result in reduced operative time, phaco time, aspiration time and CDE, as well as volume of fluid used [18–23]. The objective of this study was to evaluate the efficacy of the eight-chop technique in microcornea eyes. In this study, cataract surgery was performed using this technique, and intraoperative parameters and postoperative CECD loss were analyzed. Furthermore, since initial research findings on microcornea eyes no longer reflect current surgical outcomes due to advances in phacoemulsification cataract surgery, this study attempted to elucidate changes in corneal endothelial cells in microcornea eyes using the state-of-the-art phacoemulsification cataract surgery system.

2. Materials and Methods

2. Ethical Considerations

The research protocol was reviewed and approved by the ethics review committee. Approval was granted in accordance with the principles of the Declaration of Helsinki. The purpose of the study was explained to each patient prior to surgery, after which consent was obtained for the provision of surgical records (approval number 20250701).

2. Study Population

This study included 1,917 patients (3,507 eyes) who underwent phacoemulsification and IOL implantation between March 2020 and February Subsequently, these patients visited Sato Eye Clinic in Matsudo City, Chiba Prefecture, Japan. Microcornea eyes were selected as those with a corneal diameter of 10 mm or less [6]. The control group was selected to include eyes with a corneal diameter of 11 mm or more, in order to distinguish them clearly from those with microcornea and relative anterior microphthalmos [6]. The age and gender distribution of the control group was matched to that of the microcornea group. Individuals with corneal disease or opacity, uveitis, diabetic retinopathy, cataracts, morphological malformations, or a history of ocular trauma or eye surgery were excluded from the study. Additionally, patients classified as Grade IV or higher for lens nucleus in the Emery Little classification [24] and cases requiring the use of iris retractor hooks were excluded due to their significant impact on surgical duration and invasiveness. Furthermore, we excluded patients for which follow-up could not be maintained until 19 weeks postoperatively. Patients with microcornea in both eyes were randomly selected for analysis using only one eye. The control group was randomly selected from patients undergoing surgery during the same period as the microcornea group, except for age and gender distribution.

2. Preoperative Assessment

All patients underwent detailed evaluation via slit-lamp examination and fundus examination. Best-corrected visual acuity (BCVA) and intraocular pressure (IOP) were measured preoperatively. CECD, central corneal thickness (CCT), coefficient of variation (CV), and percentage of hexagonal cells (PHC) were measured using a non-contact corneal endothelium microscope (EM-3000; Topcon Corporation, Tokyo, Japan). Axial length and anterior chamber depth were measured using a 1060 nm wavelength sweep-source optical coherence tomography device (OA-2000; TOMEY, Tokyo, Japan).

2. Surgical Technique

All cases were performed by the same surgeon. This surgeon is highly skilled in the eight-chop technique using the phacoemulsification system (Centurion®; Alcon Laboratories, Inc., Irvine, CA, USA). In each case, a 3.0 mm wide lateral clear corneal incision was created using a steel keratome. Next, sodium hyaluronate was injected into the anterior chamber. Subsequently, a continuous curvilinear capsulorhexis measuring 6.2 to 6.5 mm was created using a capsule forceps (F-2055; M.E.Technica, Tokyo, Japan). Hydrodissection was performed using a 27G cannula (AMO Japan, Inc., Tokyo, Japan). On the iris plane, the eight-segmented lens nucleus was phacoemulsified and aspirated, and the cortical lens material was removed using an irrigation/aspiration tip. After injecting intraocular viscoelastic, a foldable three-piece IOL (Acrysof® MN60AC; Alcon Laboratories, Inc., Fort Worth, TX, USA) with polymethyl methacrylate haptics was carefully inserted into the capsular bag, and the intraocular viscoelastic was removed. During the final stage of the surgery, the anterior chamber was replaced with a balanced salt solution containing moxifloxacin (0.5 mg/ml).

During surgery, the following were measured: operative time (min), phaco time (s), aspiration time (s), CDE (μJ), and volume of fluid used (mL). Intraoperative complications were also recorded. The operative time was strictly measured from the initiation of the corneal incision to the completion

of intraocular viscoelastic aspiration. All surgeries were documented using a camera (MKC-704KHD, Ikegami Tsushinki Co., Ltd., Tokyo, Japan). The video data was stored on a hard disk.

2. Measurements of Corneal Diameter and Pupil Size

The corneal diameter was calculated by measuring the horizontal white-to-white distance of the cornea on the recorded surgical video and correcting the value using measurements from a 3.0 mm steel keratome. Additionally, pupil size was calculated by measuring the horizontal pupil size on the monitor and correcting it using the measured value of the optical section of the 6.0 mm IOL. The magnification of the microscope was kept constant during surgery to ensure the accuracy of measurements on the monitor during the procedure.

2. Literature Review of the Eight-chop Technique and Other Surgical Techniques

We searched for papers on phacoemulsification cataract surgery over the past five years. We selected papers that clearly described the surgical technique and included at least two of the following items: operative time, phaco time, aspiration time, CDE, fluid of volume used, and CECD loss. For CECD loss, we used data from 3 weeks to 6 months postoperatively.

2. Data Collection and Statistical Analysis

Examinations of the anterior segment, BCVA, and IOP were performed on the target patients at 1 day, 2 days, 1 week, 3 weeks, 7 weeks, and 19 weeks postoperatively. Additionally, measurements of CECD, CCT, CV, and PHC were performed at 7 weeks and 19 weeks postoperatively.

Statistical analysis was performed using the Mann-Whitney U test for comparing results between the microcornea group and control group. Paired *t*-tests were used to analyze preoperative and postoperative BCVA, IOP, CV, PHC, CCT, and CECD values. The chi-square test was used to determine whether gender differences existed between the microcornea group and control group. Sample sizes were determined using G-Power software (version 3.1.9.7) [25] to ensure sufficient statistical power to detect significant differences in the study results. Calculation parameters were based on the data from our paper [18]. A *p*-value < 0.05 was considered statistically significant.

Results

3. Characteristics of the Participants

Of the 3,507 eyes analyzed in this study, 89 (2.54%) had a corneal diameter of 10 mm or less. Of these, there were no cases of nanophthalmos [26] with an axial length under 20.5 mm, but three eyes exhibited microphthalmos [5] with an axial length under 21.0 mm. Additionally, there were 9 eyes with relative anterior microphthalmos [26] exhibiting an anterior chamber depth of 2.2 mm or less. Seven eyes had lens nucleus hardness of Grade IV or higher, and seven cases required the use of iris retractor hooks; these cases were excluded from the analysis. The examination of 52 eyes in the microcornea group and 52 eyes in the control group was conducted in detail, both meeting the specified criteria. Table 1 shows patient characteristics and intraoperative parameters. No significant differences were observed between the microcornea group and control group regarding mean age, gender distribution, lens hardness, phaco time, aspiration time, or CDE ($p = 0.86$, $p = 1.00$, $p = 0.48$, $p = 0.29$, $p = 0.06$, $p = 0.71$, respectively). However, significant differences were observed between the two groups regarding corneal diameter, anterior chamber depth, axial length, preoperative pupil size, operative time, and volume of fluid used ($p < 0.01$, $p = 0.04$, $p < 0.01$, $p < 0.01$, $p < 0.01$, $p = 0.03$, respectively). In the microcornea group, glaucoma was observed in 5 eyes (9.6%).

Table Preoperative characteristics and intraoperative parameters.

Characteristic/Parameter	Microcornea Group	Control Group	p-value
Number of eyes	52	52	
Age (y)	76.2 ± 5.4	76.1 ± 4.1	0.86 ^a
Gender: Men	20 (38.5%)	20 (38.5%)	1.00 ^b
Women	32 (61.5%)	32 (61.5%)	
Coneal diameter (mm)	9.80 ± 0.26	11.48 ± 0.24	<0.01 ^c
Anterior chamber depth (mm)	3.12 ± 0.46	3.32 ± 0.41	0.04 ^c
Axial length (mm)	23.41 ± 1.74	24.42 ± 1.57	<0.01 ^c
Preoperative pupil size (mm)	6.30 ± 0.60	7.05 ± 0.50	<0.01 ^c
Lens hardness	2.5 ± 0.5	2.4 ± 0.3	0.48 ^a
Operative time (min)	5.9 ± 2.4	4.5 ± 0.7	<0.01 ^c
Phaco time (s)	17.9 ± 8.9	14.7 ± 3.7	0.29 ^a
Aspiration time (s)	77.0 ± 27.2	64.3 ± 10.7	0.06 ^a
CDE (μJ)	7.06 ± 3.97	6.44 ± 1.96	0.71 ^a
Volume of fluid used (mL)	31.1 ± 11.6	25.0 ± 4.9	0.03 ^c

Values are expressed as mean ± standard deviation or percentages. ^a No significant differences were found between the groups using the Mann–Whitney U test. ^b No significant differences were found between the groups using the chi-square test. ^c Significant differences were found between the groups using the Mann–Whitney U test. CDE, cumulative dissipated energy.

3.Changes in CECD

Table 2 shows the preoperative and postoperative measurements of CECD and their changes. There was no significant difference in CECD between the microcornea group and control group at preoperative and postoperative 7 weeks and 19 weeks ($p = 0.20$, $p = 0.09$, $p = 0.14$, respectively). In both the microcornea group and control group, a significant decrease was observed at 7 weeks and 19 weeks postoperatively compared to preoperative values (all $p < 0.01$). Regarding the CECD loss, no significant difference was observed between the two groups at 7 weeks and 19 weeks postoperatively ($p = 0.52$, $p = 0.41$, respectively).

Table Pre- and postoperative CECD values.

Time period	Mean CECD ± SD (% Decrease)		p-value
	Microcornea group (n = 34)	Control group (n = 52)	
Preoperatively	2650 ± 271	2753 ± 236	0.20 ^a
7 weeks postoperatively	2558 ± 305 ^b	2689 ± 239 ^b	0.09 ^a
% Decrease	3.6 ± 4.5	2.3 ± 2.1	0.52 ^a
19 weeks postoperatively	2610 ± 250 ^b	2714 ± 244 ^b	0.14 ^a
% Decrease	1.5 ± 2.4	1.4 ± 1.6	0.41 ^a

Values are presented as mean ± standard deviation. ^a No significant differences were found between the groups using the Mann–Whitney U test. ^b Significant differences were found between the preoperative and respective time values using a paired *t*-test. CECD, corneal endothelial cell density; SD, standard deviation.

3.Changes in CCT, CV, and PHC

Table 3 shows the preoperative and postoperative measurements of CCT, CV, and PHC and their changes. No significant difference in CCT was observed between the microcornea group and control group at preoperative and 7 weeks postoperatively, but a significant difference was noted at 19 weeks postoperatively ($p = 0.08$, $p = 0.12$, $p = 0.03$, respectively). Additionally, it showed a significant increase at 7 weeks postoperatively compared to preoperative values in the control group ($p < 0.03$). No significant differences were observed between the microcornea group and control group in CV values at preoperative, 7 weeks postoperatively, and 19 weeks postoperatively ($p = 0.52$, $p = 0.21$, $p = 0.25$, respectively). However, the control group showed a significant decrease in CV at 19 weeks postoperatively compared to preoperative values ($p < 0.01$). No significant difference in PHC was observed between the microcornea group and control group at preoperative or 7 weeks postoperatively, but a significant difference was noted at 19 weeks postoperatively ($p = 0.22$, $p = 0.21$, and $p = 0.02$, respectively). Furthermore, the control group showed a significant increase at 19 weeks postoperatively compared to preoperative values ($p = 0.02$).

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

Time period	Microcornea group (<i>n</i> = 33)	Control group (<i>n</i> = 52)	<i>p</i> -value
CCT	Mean ± SD		
Preoperatively	544 ± 44.4	528 ± 36.0	0.08 ^a
7 weeks postoperatively	545 ± 41.0 ^d	532 ± 35.6 ^c	0.12 ^a
19 weeks postoperatively	545 ± 42.4 ^d	526 ± 38.0 ^d	0.03 ^b
CV	Mean ± SD		
Preoperatively	40.2 ± 4.7	39.8 ± 5.3	0.52 ^a
7 weeks postoperatively	41.4 ± 5.5 ^d	40.1 ± 5.4 ^d	0.21 ^a
19 weeks postoperatively	38.8 ± 4.6 ^d	37.6 ± 4.2 ^c	0.25 ^a
PHC	Mean ± SD		
Preoperatively	43.8 ± 6.5	45.7 ± 5.7	0.22 ^a
7 weeks postoperatively	42.9 ± 7.4 ^d	44.6 ± 6.0 ^d	0.21 ^a
19 weeks postoperatively	44.8 ± 6.3 ^d	47.7 ± 3.9 ^c	0.02 ^b

Values are presented as mean ± standard deviation. ^aNo significant differences were found between the groups using the Mann–Whitney U test. ^bSignificant differences were found between the groups using the Mann–Whitney U test. ^cSignificant differences between the preoperative and respective time values using a paired *t*-test. ^dNo significant differences were found between the preoperative and respective time values using a paired *t*-test. CCT, central corneal thickness; CV, coefficient of variation; PHC, percentage of hexagonal cells; SD, standard deviation.

3.Changes in IOP

Table 4 shows the measured values of IOP and their changes. There were no significant differences in IOP between the microcornea group and control group at preoperative, 7 weeks postoperatively, and 19 weeks postoperatively ($p = 0.42$, $p = 0.38$, and $p = 0.79$, respectively). In the microcornea group and control group, a significant decrease was observed at 7 weeks and 19 weeks postoperatively (both $p < 0.01$). Regarding the rate of IOP reduction, no significant difference was observed between the two groups at 7 weeks and 19 weeks postoperatively ($p = 0.84$ and $p = 0.88$).

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

Time period	Mean IOP ± SD (% Decrease)		
	Microcornea group (n = 34)	Control group (n = 52)	p-value
Preoperatively	14.1 ± 2.4	13.8 ± 1.9	0.42 ^a
7 weeks postoperatively	12.5 ± 2.3 ^b	12.2 ± 1.8 ^b	0.38 ^a
% Decrease	10.8 ± 11.8	11.3 ± 10.5	0.84 ^a
19 weeks postoperatively	12.5 ± 2.5 ^b	12.3 ± 1.9 ^b	0.79 ^a
% Decrease	10.8 ± 14.5	10.3 ± 11.7	0.88 ^a

Values are presented as mean ± standard deviation. ^a No significant differences were observed between the groups using the Mann–Whitney U test. ^b Significant differences were found between the preoperative and respective time values using a paired *t*-test. IOP, intraocular pressure; SD, standard deviation.

3.Changes in BCVA over time

Table 5 shows the measured BCVA values and their changes. Preoperative BCVA showed a significant difference between the microcornea group and control group, but no significant difference was observed at 7 weeks postoperatively and 19 weeks postoperatively (*p* < 0.01, *p* = 0.10, *p* = 0.08, respectively). In both the microcornea group and control group, significant improvement in BCVA was observed at 7 weeks postoperatively and 19 weeks postoperatively (all *p* < 0.01).

Table Pre- and postoperative BCVA values.

Time period	BCVA logMAR		
	Microcornea group (n = 33)	Control group (n = 52)	p-value
Preoperatively	0.231 ± 0.391	0.093 ± 0.142	<0.01 ^a
7 weeks postoperatively	-0.046 ± 0.046 ^c	-0.060 ± 0.040 ^c	0.10 ^b
19 weeks postoperatively	-0.044 ± 0.046 ^c	-0.064 ± 0.035 ^c	0.08 ^b

Values represented as mean ± standard deviation. ^aSignificant differences were found between the groups using the Mann–Whitney U test. ^b No significant differences were found between the groups using a paired *t*-test. ^c Significant differences were found between the preoperative and respective time values using a paired *t*-test. BCVA, best-corrected visual acuity; logMAR, logarithmic minimum angle of resolution.

3.Intraoperative Parameters and CECD Loss

Table 6 summarizes the intraoperative parameters and CECD loss for various types of phacoemulsification cataract surgery.

Table Results of intraoperative parameters and CECD loss by various phacoemulsification techniques.

CECD, corneal endothelial cell density; CDE, cumulative dissipated energy; VFU, volume of fluid used; NR, not reported.

3. Complications

Study	Year	Eye s	Surgical technique	Operati ve time (min)	Phaco time (s)	Aspira tion- time (s)	CD E (μJ)	VF U (m L)	CECD loss (%)
Sato[20]	2025	75	Eight-chop	4.5	14.3	64.0	5.83	25.5	1.6
Opala[27]	2025	80	Stop-and-chop	NR	NR	NR	4.19	NR	18.8
Spaulding [28]	2025	36	Stop-and-chop	NR	29.5	90.1	5.00	32.8	NR
Wang[29]	2025	123	Phaco-chop	NR	68.9	NR	18.2	NR	10.6
Sato[19]	2024	65	Eight-chop	4.6	16.2	72.1	7.00	28.9	1.2
Kim[30]	2024	94	Prechop	NR	7.05	NR	NR	NR	12.5
Wang[31]	2024	55	Phaco-chop	NR	30.6	NR	5.22	45.1	4.3
Altansuk h[32]	2024	110	Divide-and- conquer	NR	75.1	NR	12.3 1	NR	4.2
Sato[18]	2023	50	Eight-chop	3.7	11.6	NR	5.00	22.9	0.9
Cruz[33]	2023	48	Phaco-chop	NR	NR	NR	6.10	80.8	32.0
Fernández- Muñoz[34]]	2023	30	Phaco-chop	NR	94.0	NR	20.1 1	NR	31.8
Eom[35]	2023	76	Phaco-chop	12.3	25.7	NR	NR	NR	8.1
Sinha[36]	2023	50	Stop-and-chop	NR	122.4	NR	6.9	NR	10.1
Tao[37]	2023	45	Reverse-chop	NR	NR	NR	7.53	NR	15.9
Cyril[38]	2022	82	Phaco-chop	NR	NR	NR	4.80	36.1	NR
Upadhyay[39]	2022	50	Crater-chop	NR	NR	NR	NR	105. 9	4.4
Abdelmot aal[40]	2021	66	Phaco-chop	12.3	NR	NR	19.1 3	NR	15.2
Present	2025	52	Eight-chop	5.9	17.9	77.0	7.06	31.1	1.5

No intraoperative complications such as capsulorhexis tears, posterior capsule rupture, or zonular dialysis were observed in either the microcornea group or the control group.

Discussion

In this study, the operative times for the microcornea group and control group were 5.9 min and 4.5 min, respectively. Other surgical techniques have been reported to require 12.3 min [35,40], demonstrating that the eight-chop technique can significantly reduce operative time even in microcornea eyes. Furthermore, both phaco time and aspiration time were short, and CDE was also low. Previous reports indicated volume of fluid used ranging from 32.8 to 105.9 mL [28,31,33,38,39], whereas in this study, the microcornea group and control group used only 31.1 mL and 25.0 mL, respectively. The eight-chop technique involves mechanically dividing the lens nucleus into eight

segments prior to phacoemulsification. This reduces the amount of ultrasonic energy required and improves the efficiency of lens nucleus removal, thereby shortening the phaco and aspiration times and decreasing CDE [18–23]. However, compared to the control group, the microcornea group showed a 31% longer operative time and a 24% increase in volume of fluid used, representing significant differences. Although no significant difference was observed in aspiration time, it was 20% longer. The primary reason is thought to be the difficulty in surgical manipulation due to the reduced anterior chamber volume. Within the narrow anterior chamber, it becomes extremely difficult to maintain safe distances from the corneal endothelium, iris, and posterior lens capsule while maneuvering ultrasound and irrigation/aspiration tips to effectively aspirate and remove the lens nucleus and cortex. Furthermore, the pupil size was significantly smaller in the microcornea group, likely further complicating the surgery.

Similar to the eight-chop technique, femtosecond laser-assisted cataract surgery (FLACS) has the advantage of being able to fragment the lens nucleus without the use of ultrasonic energy. This could lead to a significant reduction in both the amount of ultrasonic energy used and the time it takes to perform the procedure. However, reports indicate that CDE does not decrease compared to conventional phacoemulsification cataract surgery. Furthermore, no statistically significant differences were observed in long-term visual prognosis, corneal endothelial cell preservation, or complication rates. This has led to a lack of consensus [41,42]. Regarding CECD loss, reports indicate values ranging from 12.3% to 14.6% [33,43]. Therefore, it cannot be concluded that the objective of reducing surgical damage through lens nucleus prefragmentation in FLACS has been achieved. However, mechanical octagonal fragmentation of the lens nucleus using the eight-chop technique has resulted in shorter operative time, reduced phaco and aspiration times, lower volume of fluid used and a smaller CECD loss. The concept of lens nucleus prefragmentation was first introduced by the prechop technique [44,45], evolved through FLACS, and has since been adopted by the eight-chop technique.

The anterior chamber, where lens extraction is performed, is a confined space, posing a high risk of corneal endothelial cell damage from intraoperative ultrasonic energy [46–48]. In particular, with small eyes such as microphthalmos, nanophthalmos, relative anterior microphthalmos, and microcornea, the reduced anterior chamber volume may lead to a higher CECD loss compared to normal eyes [4]. However, in this study, no significant difference in CECD loss was observed between the microcornea group and control group at 7 weeks and 19 weeks postoperatively. The reported CECD loss after cataract surgery ranges from 4.2% to 32.0% [29–37,39,40]. In this study, the microcornea group experienced a CECD loss of 3.6% and 1.5% at 7 and 19 weeks postoperatively, respectively. Meanwhile, the control group showed a CECD loss of 2.3% and 1.4% at 7 and 19 weeks postoperatively, respectively. There was no difference in CECD loss between the two groups, and the results were favorable compared to previously reported CECD loss. These results suggest that the minimally invasive nature of the eight-chop technique may have suppressed the CECD loss caused by decreased anterior chamber volume in microcornea eyes. To date, few studies have examined changes in CECD following cataract surgery in small eyes. However, this study demonstrates that the CECD loss is extremely minimal when using the state-of-the-art phacoemulsification cataract surgery system with the eight-chop technique. Therefore, combining this advanced system with the eight-chop technique could make minimally invasive cataract surgery possible for small eyes, comparable to surgery performed on normal eyes.

Despite advances in phacoemulsification cataract surgery systems and techniques, intraoperative CECD loss remains unavoidable and continues to be a significant issue. Furthermore, evaluating the CECD loss is useful for comparing surgical techniques, as it reflects intraoperative damage to ocular tissues [39]. Our studies indicate that the eight-chop technique minimizes surgical damage to corneal endothelial cells and may also reduce surgical invasion of intraocular tissues exposed to similar conditions during surgery, including the ciliary body, trabecular meshwork, and Schlemm's canal. In particular, its low invasiveness to the trabecular meshwork may contribute to maintaining postoperative IOP reduction. Modern cataract surgery often involves patients with

concomitant ocular diseases, necessitating not only visual improvement but also the minimization of corneal endothelial cell damage and the maintenance of reduced IOP. The eight-chop technique may be a highly useful surgical approach in this respect.

CCT serves as a clear indicator of corneal endothelial cell function [27,49]. Our study found a significant difference in CCT at 19 weeks postoperatively between the microcornea group and control group. This result may indicate either a difference in corneal endothelial cell function recovery between the two groups or incomplete recovery of corneal endothelial cell function in the microcornea group. CV indicates the uniformity of endothelial cell size, while PHC indicates the variability of hexagonal cell shape; both are indicators of the healing response following injury [49]. This study found a significant difference in PHC between the microcornea group and control group at 19 weeks postoperatively. Furthermore, the control group showed significant differences in CV and PHC at 19 weeks postoperatively compared to preoperative levels. These results suggest that the postoperative endothelial repair and healing mechanisms may be impaired in the microcornea group compared to the control group.

Regarding IOP, this study showed a 10.8% reduction in the microcornea group and a 10.3% reduction in the control group at 19 weeks postoperatively, indicating favorable pressure reduction. In primary open-angle glaucoma, loss of trabecular meshwork cells occurs [50,51], leading to impaired aqueous outflow [50]. Thus, a reduction in trabecular meshwork cell density may influence IOP after cataract surgery. In this study, we confirmed that the CECD loss after cataract surgery using the eight-chop technique was lower compared to surgery using the divide-and-conquer or phaco-chop techniques. We hypothesize that the eight-chop technique results in less CECD loss and correspondingly less loss of trabecular meshwork cells, thereby preserving normal aqueous outflow function postoperatively and leading to IOP reduction.

The incidence of complications during cataract surgery is high in eyes classified as small eye, including microphthalmos, nanophthalmos, relative anterior microphthalmos, and microcornea. Major complications include posterior capsule rupture, vitreous loss, and zonular dialysis [26,52]. Additionally, while a study reported postoperative CECD loss of 14.2% in nanophthalmos eyes and 11.6% in relative anterior microphthalmos eyes [26], no study has thoroughly examined the relationship between intraoperative parameters and changes in CECD or IOP. Furthermore, while a report exists on cataract surgery for microcornea eyes complicated by morphological malformations [53], no studies have been reported on phacoemulsification cataract surgery for microcornea eyes without morphological malformations. However, simple microcornea eyes without congenital anomalies are frequently encountered clinically and cause difficulties during phacoemulsification cataract surgery. Therefore, findings regarding its surgery are beneficial for ophthalmic surgeons. Consequently, we report for the first time on intraoperative parameters for phacoemulsification cataract surgery in simple microcornea eyes and changes in CECD and IOP.

The prechop technique is an excellent method that reduces the amount of ultrasonic energy and surgical damage to intraocular tissues by mechanically dividing the lens nucleus into four segments prior to phacoemulsification [44]. This characteristic aligns with the advantages of FLACS. However, the prechop technique has not been widely adopted as a phacoemulsification technique due to the difficulty of operating the prechopper [18,54]. Therefore, we devised the eight-chop technique, an improvement on the prechop technique, and have reported on its efficacy and safety [18–23]. As shown in Table 6, the eight-chop technique has the potential to be a less invasive surgical method with high efficiency compared to other techniques. There are differences between the prechop technique and the eight-chop technique. First, while the prechop technique typically divides the lens nucleus into four segments [44,45], the eight-chop technique always divides it into eight segments [18–23]. This is the advantage of the eight-chop technique over the prechop technique, enabling more efficient phacoemulsification of smaller lens nucleus fragments. Additionally, the surgical instruments have been improved. For the eight-chop technique, the Eight chopper I and Eight chopper II have been developed and are used, featuring sharper and more delicate tips. These surgical instruments facilitate the eight-segment division of the lens nucleus. Furthermore, these

instruments reduce the stress on the zonules and lens capsule, making them extremely useful even in difficult cases.

This study has several limitations. First, the surgical outcomes of the eight-chop technique have not been directly compared with those of the stop-and-chop, phaco-chop or divide-and-conquer techniques. This point must be carefully considered when evaluating the present results. Future studies should compare the surgical outcomes of the stop-and-chop, phaco-chop or divide-and-conquer techniques with those of the eight-chop technique to enable more accurate verification. Second, in this study, the corneal diameter of the microcornea group ranged from 9.1 mm to 10.0 mm; eyes with microcornea smaller than 9.1 mm were not included. Therefore, the results of this study cannot be applied to microcornea eyes which have smaller corneal diameters. Third, the postoperative outcomes have only been observed up to 19 weeks postoperatively. Longer-term changes in corneal endothelial cells and IOP require further investigation. Fourth, since three-piece IOLs were used in all cases in this study, differences in IOL fixation status during and after surgery may occur compared to when one-piece IOLs are used. Fifth, small eyes with microphthalmos, nanophthalmos, relative anterior microphthalmos, or microcornea with anatomical anomalies were not examined. Future comprehensive research on cataract surgery for small eyes is needed.

Conclusions

The eight-chop technique demonstrated excellent intraoperative parameters for microcornea eyes, with low CECD loss and sufficient postoperative IOP decrease. While other reports on small eyes have documented various intraoperative complications, no complications occurred in surgeries using the eight-chop technique in this study. Microcornea eyes have reduced anterior chamber volume, making surgical manipulation difficult. Therefore, surgical techniques other than the eight-chop technique are likely to result in high CECD loss postoperatively , as well as a higher incidence of intraoperative complications. However, the eight-chop technique is considered effective for microcornea eyes. Research on the eight-chop technique for microcornea eyes may contribute to establishing individualized treatment strategies and improving cataract management and treatment.

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

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

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

VFU	Volume of fluid used
NR	Not reported
FLACS	Femtosecond laser-assisted cataract surgery

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