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Article

Corneal Endothelial Cell Loss in Shallow Anterior Chamber Eyes After Phacoemulsification Using the Eight-Chop Technique

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Abstract: Objectives: This study evaluated the correlation between anterior chamber depth (ACD) and corneal endothelial cell density (CECD) loss and assessed the safety and efficacy of the eight-chop technique in cataract surgery for patients with shallow anterior chamber (SAC) depth. **Methods:** The technique was applied to patients with SAC depth and normal ACD, defined as < 3 mm and > 3 mm, respectively. Best-corrected visual acuity (BCVA), intraocular pressure (IOP), CECD, coefficient of variation, percentage of hexagonal cells, and central corneal thickness were assessed pre- and postoperatively. Operative time, phaco time, aspiration time, cumulative dissipated energy (CDE), and volume of fluid used were recorded intraoperatively. **Results:** A total of 180 eyes from 99 patients (mean age, 74.8 ± 5.1 years; 28 men, 71 women) were analyzed. In the SAC group, the mean operative time, phaco time, aspiration time, CDE, and volume of fluid used were 4.7 min, 15.4 s, 65.6 s, 5.87, and 26.6 mL, respectively, demonstrating favorable surgical metrics. CECD loss was 1.3% at 7 weeks, 1.1% at 19 weeks, and 0.9% at 1 year, with no significant difference between groups. No correlation was observed between CECD loss and ACD in either group. **Conclusion:** These findings suggest that the eight-chop technique is a minimally invasive and effective approach that preserves corneal endothelial integrity, even in patients with SAC depth.

Keywords: cataract surgery; corneal endothelial cell; eight-chop technique; shallow anterior chamber; phacoemulsification

1. Introduction

Cataract surgery is the most commonly performed ophthalmic procedure worldwide, offering significant improvements in [1,2] visual function and serving as a phacoemulsification technology [3]. During the surgery, corneal endothelial cells are particularly important owing to their non-regenerative nature. Unlike other ocular cells, corneal endothelial cells do not proliferate; thus, when endothelial cells are lost, compensation occurs through cell migration, enlargement, and increased polymegathism, leading to endothelial heterogeneity [4]. Corneal endothelial cell density (CECD) serves as a key biomarker for assessing surgical trauma to the cornea. A critically low CECD, particularly below 400 cells/mm², leads to endothelial decompensation, resulting in impaired corneal deturgescence and subsequent overhydration. This process manifests clinically as corneal edema, stromal thickening, bullous keratopathy, and corneal scarring, ultimately leading to irreversible visual acuity loss [5–7]. Pseudophakic bullous keratopathy remains a significant complication, with an incidence of approximately 1% to 2% [8].

The rate of CECD loss following phacoemulsification has been attributed to many factors [9–11], including direct instrument trauma, exposure to ultrasonic energy, oxidative stress induced by free radical formation, and mechanical contact with intraocular lenses or lens nuclear fragments [12,13].

Thus, it is essential to assess the preoperative and intraoperative factors contributing to CECD loss to optimize surgical outcomes.

To comprehensively evaluate these risks, it is necessary to investigate the association between patient age, nuclear density, operative time, phaco time, cumulative dissipated energy (CDE), aspiration time, and volume of fluid used with CECD loss. These intraoperative variables play a crucial role in determining the extent of endothelial trauma.

Furthermore, since phacoemulsification is performed within a confined intraocular space, ensuring adequate surgical working depth can mitigate the risk of endothelial damage. A deeper anterior chamber may provide additional protection against mechanical and thermal insult during surgery. However, conflicting evidence exists regarding the role of anterior chamber depth (ACD) in CECD loss, as some studies have reported [14,15]. Studies have systematically analyzed the relationship between intraoperative parameters—including operative time, phaco time, CDE, aspiration time, and volume of fluid used—and CECD loss. Thus, further investigation is necessary to clarify these relationships and optimize surgical techniques to preserve endothelial integrity.

Cataract surgery utilizing the eight-chop technique has been reported to require less operative time, phaco time, CDE, aspiration time, and volume of fluid used compared to other phacoemulsification techniques [16,17]. By performing cataract surgery using the eight-chop technique in patients with varying ACDs and analyzing intraoperative parameters along with postoperative CECD loss, this study aims to assess the efficacy of the eight-chop technique in patients with shallow anterior chamber (SAC) depth. Additionally, as early studies on patients with SAC depth no longer reflect current surgical outcomes due to advancements in phacoemulsification technology, this research seeks to clarify the relationship between CECD loss and ACD using state-of-the-art phacoemulsification systems.

The primary objective of this study is to evaluate intraoperative parameters and postoperative corneal endothelial cell changes in patients with cataracts of different ACDs who undergo surgery with the eight-chop technique. This study further aims to investigate the correlation between ACD and CECD loss and to assess the overall efficacy of the eight-chop technique in patients with SAC depth.

2. Materials and Methods

2.1. Study Population

This study included patients diagnosed with cataracts who underwent phacoemulsification and posterior chamber intraocular lens (IOL) implantation at our clinic between June 2022 and November 2023. Patients were categorized based on preoperative ACD, with those having $ACD \geq 3.0$ mm classified as the control group and those with $ACD < 3.0$ mm assigned to the SAC group [18,19] corneal disease, corneal opacity, uveitis, a history of ocular trauma, or previous intraocular surgery. These exclusion parameters ensured a homogeneous study population, minimizing confounding factors that could influence CECD loss.

2.2. Preoperative Assessment

All patients underwent a comprehensive ophthalmic evaluation prior to surgery, including slit-lamp biomicroscopy and retinal assessment. Best-corrected visual acuity (BCVA) and intraocular pressure (IOP) were documented as part of the standard preoperative assessment. Corneal endothelial parameters—including CECD (cells/mm^2), central corneal thickness (CCT), percentage of hexagonal cells (PHC), and coefficient of variation (CV)—were analyzed using a non-contact specular microscope (EM-3000; Topcon Corporation, Tokyo, Japan). The nuclear firmness was graded according to the Emery classification system [20]. Additionally, grades II and III were each subdivided into two additional levels, resulting in classifications of 2.0, 2.5, 3.0, and 3.5 for a more precise assessment of nuclear density. All biometric measurements were obtained using the optical

biometer OA-2000 (Tomey, Nagoya, Japan). Axial length and ACD were measured using swept-source optical coherence tomograph with a laser wavelength of 1060 nm [21].

2.3. New Surgical Instruments

A new generation of surgical instruments has been developed to enhance the precision and efficiency of the eight-chop technique [16,17]. The research team conceptualized and designed a specialized set of choppers tailored for this technique and collaborated with a surgical instrument manufacturer to produce the devices. The Eight-chopper I (SP-8193; ASICO, Parsippany, NJ, USA) was specifically designed for grade II cataracts, featuring a reduced-diameter tip compared to conventional prechoppers. It measures 3.2 mm in length and 1.4 mm in width and incorporates a more pronounced leading edge to facilitate efficient nuclear division with minimal mechanical stress on the lens structure. For grade III cataracts, the Eight-chopper II (SP-8402; ASICO) was developed with a smaller angular tip measuring 2.5 mm in length and 0.8 mm in width. Its design allows for vertical insertion into the lens nucleus, optimizing nuclear fragmentation while minimizing unnecessary intraocular manipulation. The incorporation of these specialized choppers into the eight-chop technique aims to improve surgical outcomes by reducing phacoemulsification energy requirements and preserving corneal endothelial integrity.

2.4. Surgical Technique

The same experienced surgeon, proficient in the eight-chop technique, performed all phacoemulsification procedures using the Centurion® phacoemulsification unit (Alcon Laboratories, Inc., Irvine, CA, USA). A temporal clear corneal incision (3.0 mm) was created with a steel keratome in all cases. Following the injection of sodium hyaluronate into the anterior chamber, a continuous curvilinear capsulorhexis measuring 6.2–6.5 mm was performed using capsule forceps. For grade III cataracts, the soft-shell technique was added [22].

A 27-gauge cannula was used for hydrodissection, but hydrodelineation was not performed. The lens nucleus was divided into eight segments using either Eight-chopper I or Eight-chopper II, depending on nuclear density (grade II or grade III, respectively). An ophthalmic viscosurgical device (OVD) was injected into the anterior chamber, and the eight-chopper was inserted into the central lens nucleus, ensuring complete division. The nucleus was initially divided into two equal halves, after which it was rotated 90 degrees for further fragmentation. Subsequently, each heminucleus was bisected, and the nucleus was rotated 180 degrees, completing four divisions. The lens was then rotated 45 degrees, undergoing four additional divisions, yielding eight nuclear fragments. At the iris plane, the eight nuclear segments were phacoemulsified and aspirated. The capsular bag was thoroughly evacuated using the irrigation and aspiration tip, ensuring complete removal of cortical material. A foldable IOL (Acrysof® MN60AC, Alcon Laboratories, Inc., Fort Worth, TX, USA) with polymethylmethacrylate haptics was implanted into the capsular bag using an injector system, followed by OVD aspiration.

The phacoemulsification system settings included a maximum ultrasound power of 80%, an aspiration flow rate of 32 mL/min, and a 1.1 -mm tip. If necessary, corneal stromal hydration was performed to seal the incision. At the end of the procedure, the anterior chamber was exchanged with a balanced salt solution containing moxifloxacin (0.5 mg/mL) to reduce postoperative infection risk.

2.5. Outcome Measures and Data Collection

The intraoperative outcome measures included operative time (minutes), phaco time (seconds), aspiration time (seconds), CDE, volume of fluid used (mL), and intraoperative complication rate. Operative time was recorded from the initiation of the corneal incision to the completion of OVD aspiration. All surgical procedures were recorded using a high-definition surgical camera (MKC-704KHD, Ikegami, Tokyo, Japan), and the video images were stored on a hard disk drive for documentation and further analysis. Postoperative follow-up was conducted on postoperative days

1 and 2, and at 1, 3, and 7 weeks, as well as at 19 weeks and 1 year postoperatively. The postoperative outcome measures included BCVA, IOP, CECD, CCT, CV, and PHC, which were assessed at 7 weeks, 19 weeks, and 1 year postoperatively.

2.6. Statistical Analysis

An unpaired *t*-test was employed to compare intraoperative and postoperative outcomes between the SAC group and the control group. Paired *t*-tests were used to evaluate changes in preoperative BCVA, CECD, and IOP at each postoperative time point. A chi-square test was conducted to assess differences in sex distribution between the SAC and control groups. A *p*-value of < 0.05 was considered statistically significant for all analyses.

3. Results

This study included 160 eyes from 99 patients diagnosed with cataracts who underwent phacoemulsification and posterior chamber intraocular lens (IOL) implantation. Patient characteristics and intraoperative parameters are summarized in Table 1. No significant differences were observed in mean age or sex distribution between the SAC group and the control group. However, ACD and axial length were significantly different between the two groups. There were no significant differences between the SAC and control groups in terms of operative time, phaco time, aspiration time, and CDE. However, lens hardness and the volume of fluid used were significantly different between the SAC and control groups.

Table 1. Preoperative characteristics and intraoperative parameters. Unless otherwise specified, values are presented as mean ± standard deviation or percentages. ^aUnpaired *t*-test indicated no significant differences between the SAC and control groups. ^bChi-square test indicated no significant differences between the SAC and control groups. ^cUnpaired *t*-test indicated significant differences between the SAC and control groups. CDE: cumulative dissipated energy.

Characteristic/Parameter	Shallow anterior chamber group	Control group	p-Value
Number of eyes	80	80	
Age (y)	74.9 ± 5.48	75.0 ± 6.2	0.11 ^a
Gender: Men	22 (27.5%)	22 (27.5%)	1.0 ^b
Women	58 (72.5%)	58 (72.5%)	
Anterior chamber depth (mm)	2.75 ± 0.19	3.32 ± 0.20	< 0.01 ^c
Axial length (mm)	22.93 ± 0.91	23.92 ± 1.29	< 0.01 ^c
Lens hardness	2.40 ± 0.30	2.26 ± 0.26	< 0.01 ^c
Operative time (min)	4.7 ± 1.1	4.5 ± 0.7	0.09 ^a
Phaco time (s)	15.4 ± 6.1	13.9 ± 3.7	0.06 ^a
Aspiration time (s)	65.6 ± 17.3	62.6 ± 11.3	0.19 ^a
CDE	5.87 ± 2.01	5.59 ± 1.56	0.34 ^a
Volume of fluid used (mL)	26.6 ± 8.1	24.5 ± 4.9	< 0.05 ^c

Table 2 summarizes the preoperative and postoperative changes in BCVA. Significant differences in BCVA were observed between the SAC and control groups at baseline (preoperative), 19 weeks, and 1 year postoperatively. However, no significant difference in BCVA was found between the groups at 7 weeks postoperatively. Within both the SAC and control groups, significant improvements in BCVA were noted when comparing preoperative BCVA to BCVA at 7 weeks, 19 weeks, and 1 year postoperatively.

Table 2. Pre- and postoperative best-corrected visual acuity values. Values are expressed as mean ± standard deviation. *p*-values in the right column represent statistical comparisons at three-time points: preoperative vs. 7 weeks postoperatively, preoperative vs. 19 weeks postoperatively, and preoperative vs. 1 year postoperatively. ^a Paired *t*-test indicated significant differences between preoperative and respective postoperative time points. ^b Unpaired *t*-test indicated no significant differences between the SAC and control groups. ^c Unpaired *t*-test indicated significant differences between the SAC and control groups. logMAR: logarithmic minimum angle of resolution.

Group (<i>n</i> =80 each)	Preoperatively	7 weeks postoperatively	19 weeks postoperatively	1 year postoperatively	<i>p</i> -Value
SAC (logMAR)	0.062 ± 0.121	−0.050 ± 0.051	−0.046 ± 0.060	−0.045 ± 0.065	all < 0.01 ^a
Control (logMAR)	0.120 ± 0.187	−0.064 ± 0.039	−0.070 ± 0.025	−0.066 ± 0.030	all < 0.01 ^a
<i>p</i> -Value	0.021 ^b	0.052 ^b	< 0.01 ^c	0.012 ^b	

Table 3 presents the preoperative and postoperative changes in CECD measurements. No significant differences in preoperative and 7-week postoperative CECD were observed between the SAC and control groups. However, significant differences in CECD emerged at 19 weeks and 1 year postoperatively between the two groups. Within both the SAC and control groups, significant CECD reductions were noted at 7 weeks, 19 weeks, and 1 year postoperatively compared to baseline (preoperative values).

Table 3. Pre- and postoperative CECD values. Values are expressed as mean ± standard deviation. *p*-values in the right column represent statistical comparisons at three postoperative time points: preoperative vs. 7 weeks postoperatively, preoperative vs. 19 weeks postoperatively, and preoperative vs. 1 year postoperatively. ^a Paired *t*-test indicated significant differences between preoperative and respective postoperative time points. ^b Unpaired *t*-test indicated no significant differences between the SAC and control groups. ^c Unpaired *t*-test indicated significant differences between the SAC and control groups. CECD: corneal endothelial cell density; SAC: shallow anterior chamber.

Group (<i>n</i> =80 each)	Preoperatively	7 weeks postoperatively	19 weeks postoperatively	1 year postoperatively	<i>p</i> -Value
SAC (cells/mm ²)	2678.3 ± 257.5	2640.5 ± 244.3	2648.5 ± 247.6	2653.2 ± 254.8	all < 0.01 ^a
loss (%)		1.3 ± 2.1	1.1 ± 1.1	0.9 ± 1.8	
Control (cells/mm ²)	2751.6 ± 254.7	2687.6 ± 248.7	2730.8 ± 248.4	2738.6 ± 252.9	all < 0.01 ^a
loss (%)		2.3 ± 3.1	0.7 ± 2.3	0.5 ± 1.7	
<i>p</i> -Value	0.072 ^b	0.23 ^b	0.037 ^c	0.034 ^c	

Table 4 presents the preoperative and postoperative changes in CCT, CV, and PHC. No significant differences were observed in CCT preoperatively between the SAC and control groups. However, significant differences were observed in CCT at 7 weeks, 19 weeks, and 1 year postoperatively between the SAC and control groups. The CCT at 7 weeks, 19 weeks, and 1 year postoperatively was significantly different compared to preoperative values in the SAC group. In the control group, CCT at 7 weeks postoperatively was significantly different compared to preoperative values, but no significant differences were observed at 19 weeks and 1 year postoperatively.

No significant differences were observed in CV preoperatively or at 7 weeks, 19 weeks, and 1 year postoperatively between the SAC and control groups. No significant differences were observed in CV at 7 and 19 weeks postoperatively compared to preoperative values in both the SAC and control groups. However, significant differences were observed in CV at 1 year postoperatively compared to

preoperative values in both groups. No significant differences were observed in PHC preoperatively or at 7 weeks, 19 weeks, and 1 year postoperatively between the SAC and control groups. In the SAC group, PHC was significantly different at 19 weeks and 1 year postoperatively compared to preoperative values, but no significant differences were observed at 7 weeks postoperatively. In the control group, no significant differences were observed in PHC at 7 and 19 weeks postoperatively compared to preoperative values. However, a significant difference was observed at 1 year postoperatively.

Table 4. Preoperative and postoperative changes in the CCT, CV, and PHC. Values are expressed as mean ± standard deviation (SD). *p*-values in the right column follow the same order: preoperative vs. 7 weeks postoperatively, preoperative vs. 19 weeks postoperatively, and preoperative vs. 1 year postoperatively. ^a Paired *t*-test indicated significant differences between preoperative and respective postoperative time points. ^b Paired *t*-test indicated no significant differences between preoperative and respective postoperative time points. ^c Unpaired *t*-test indicated no significant differences between the SAC and control groups. CCT: central corneal thickness; CV: coefficient of variation; PHC: percentage of hexagonal cells; SD: standard deviation; SAC: shallow anterior chamber.

Group (<i>n</i> =80 each)	Preoperatively	7 weeks postoperatively	19 weeks postoperatively	1 year postoperatively	<i>p</i> -Value
CCT (mean ± SD)					
SAC	514.9 ± 34.3	518.7 ± 35.6	518.9 ± 36.2	517.6 ± 35.4	< 0.01 ^a , < 0.01 ^a , 0.03 ^a
Control	528.0 ± 31.9	533.4 ± 31.7	528.7 ± 32.1	527.1 ± 36.0	< 0.01 ^a , 0.55 ^b , 0.67 ^b
<i>p</i> -Value	0.013 ^c	< 0.01 ^c	< 0.01 ^c	< 0.01 ^c	
CV (mean ± SD)					
SAC	39.6 ± 4.6	39.4 ± 4.0	39.0 ± 4.9	36.6 ± 3.6	0.79 ^b , 0.35 ^b , < 0.01 ^a
Control	38.9 ± 5.6	39.6 ± 5.4	38.5 ± 5.4	36.8 ± 5.6	0.24 ^b , 0.45 ^b , < 0.01 ^a
<i>p</i> -Value	0.43 ^c	0.80 ^c	0.56 ^c	0.83 ^c	
PHC (mean ± SD)					
SAC	44.1 ± 6.9	44.4 ± 5.5	45.9 ± 5.5	47.2 ± 5.9	0.66 ^b , 0.015 ^a , < 0.01 ^a
Control	46.0 ± 6.0	44.8 ± 5.5	46.5 ± 5.6	48.8 ± 5.9	0.10 ^b , 0.51 ^b , < 0.01 ^a
<i>p</i> -Value	0.064 ^c	0.70 ^c	0.50 ^c	0.091 ^c	

Table 5 presents the changes in IOP. No significant differences were observed in IOP preoperatively or at 7 weeks and 1 year postoperatively between the SAC and control groups. However, significant differences in IOP at 19 weeks postoperatively were observed between the groups. Significant changes in IOP were observed within both the SAC and control groups at 7 weeks, 19 weeks, and 1 year postoperatively compared to preoperative values (all *p* < 0.01).

Table 5. Mean IOP and mean reduction of IOP in the course of time. Unless otherwise specified, values are expressed as mean ± standard deviation or percentages. ^a Paired *t*-test indicated significant differences between preoperative and respective postoperative time point. ^b Unpaired *t*-test indicated no significant differences between the SAC and control groups. ^c Unpaired *t*-test indicated significant differences between the SAC and control groups. IOP: intraocular pressure; SAC: shallow anterior chamber.

Group (n =80 each)	Preoperatively	7 weeks postoperatively	19 weeks postoperatively	1 year postoperatively	p-Value
SAC (mmHg)	13.7 ± 2.1	11.3 ± 1.9	11.6 ± 2.0	12.3 ± 1.9	all < 0.01
% decrease		16.7 ± 11.6	14.9 ± 10.1	9.7 ± 9.9	^a
Control (mmHg)	13.2 ± 1.8	11.7 ± 1.6	12.3 ± 1.6	12.6 ± 1.7	all < 0.01
% decrease		10.9 ± 9.3	6.6 ± 10.0	3.8 ± 11.2	^a
p-Value	0.40 ^b	0.067 ^b	< 0.01 ^c	0.099 ^b	

Table 6 presents the Pearson correlation coefficients between CECD loss at 1 year postoperatively and various preoperative and intraoperative parameters. The analysis revealed significant correlations between CECD loss and CDE, as well as a preoperative PHC in the total patient cohort. In the SAC group, significant correlations were observed between CECD loss and CDE, preoperative CCT, preoperative CV, and preoperative PHC. However, in the control group, no significant correlations were observed between CECD loss and any of the evaluated parameters.

Table 6. presents the Pearson’s correlation coefficients between CECD loss at 1 year postoperatively and various parameters. * Statistically significant correlations are indicated. CECD: corneal endothelial cell density; SAC: shallow anterior chamber; CDE: cumulative dissipated energy; BCVA: best-corrected visual acuity; CV: coefficient of variation; PHC: percentage of hexagonal cells; CCT: central corneal thickness; IOP: intraocular pressure.

Parameters	SAC group (n = 80)		Control group (n = 80)		Total (n = 160)	
	r-Value	p-Value	r-Value	p-Value	r-Value	p-Value
Age	0.062	0.587	-0.058	0.607	0.025	0.750
Lens hardness	0.083	0.466	0.035	0.759	0.094	0.237
Anterior chamber depth	-0.058	0.609	-0.105	0.356	-0.152	0.055
Axial length	0.023	0.837	0.058	0.610	-0.008	0.924
Operative time	-0.006	0.960	-0.029	0.801	0.003	0.966
Phaco time	0.133	0.240	-0.056	0.621	0.081	0.310
Aspiration time	0.048	0.672	-0.071	0.530	0.016	0.841
CDE	0.318	0.004 *	-0.027	0.811	0.179	0.023 *
Volume of fluid used	0.046	0.687	-0.087	0.441	0.017	0.827
Preoperative IOP	0.159	0.159	-0.016	0.885	0.025	0.750
Preoperative BCVA	0.169	0.135	-0.118	0.296	-0.025	0.755
Preoperative CECD	0.127	0.263	0.169	0.134	0.138	0.082
Preoperative CCT	0.240	0.032 *	0.013	0.906	0.105	0.185
Preoperative CV	-0.226	0.044 *	0.063	0.578	-0.062	0.433
Preoperative PHC	0.342	0.002 *	0.066	0.560	0.195	0.014 *

No intraoperative complications or capsulorhexis tears were observed in the SAC or control groups.

4. Discussion

The parameters for the eight-chop technique of phacoemulsification surgery in the SAC group were as follows: 4.7 minutes for operative time, 15.4 seconds for phaco time, 65.6 seconds for aspiration time, 5.87 for CDE, and 26.6 mL for volume of fluid used, all of which represent extremely favorable values. Among these parameters, the only significant difference from the control group was observed in the volume of fluid used, which was 2.1 mL higher in the SAC group.

Postoperative BCVA recovery was similar between the SAC and control groups. Additionally, CECD loss in the SAC group was 1.3% at 7 weeks, 1.1% at 19 weeks, and 0.9% at 1 year postoperatively, which were similarly low compared to the control group, with no significant differences observed between the two groups throughout the observation period.

No correlation was found between CECD loss and ACD in either the SAC or control group. However, when analyzing all cases, significant correlations were identified between CECD loss and CDE, as well as CECD loss and preoperative PHC. There was no correlation between CECD loss and ACD in the overall analysis. Regarding corneal endothelial cell parameters, CCT showed a significant difference between the SAC and control groups preoperatively. In the control group, CCT recovered to the preoperative value by 19 weeks postoperatively, whereas in the SAC group, CCT did not recover to the preoperative value even at 1 year postoperatively. These findings suggest that differences in corneal endothelial cell function exist between the two groups. It is possible that the corneal endothelial cell function in the SAC group remains impaired for an extended period postoperatively, but further investigation is required to confirm this observation. Although no significant differences in CV and PHC were observed between the SAC and control groups from preoperative to 1 year postoperative, both CV and PHC demonstrated significant differences compared to their respective preoperative values at 1 year postoperatively. These findings suggest that the wound-healing ability of corneal endothelial cells does not differ significantly between the two groups. Additionally, there is a possibility that the wound-healing ability improves 1 year postoperatively, warranting further investigation to validate this hypothesis.

Cataract surgery is performed in a limited and narrow space. However, by ensuring sufficient surgical space, the risk of damage to the corneal endothelial cells can be significantly reduced. It is therefore crucial to provide adequate surgical space to minimize corneal endothelial cell damage during surgery.

In cases with SAC depth, the surgical procedure must often be performed close to the corneal endothelium. This proximity increases the likelihood of CECD loss during cataract surgery [23]. Walkow et al. [23] identified shorter axial length and longer phaco time as significant risk factors for greater CECD loss. Additionally, ACD and axial length are reported to influence the corneal endothelial cells during phacoemulsification and are considered preoperative risk factors for CECD loss [18,24]. Eyes with SAC depth, particularly those with relatively dense cataracts, may be more vulnerable to CECD loss during phacoemulsification [25]. In this study, there was no significant difference in CECD loss between the SAC group and the control group. Additionally, no correlation was found between ACD and CECD loss. Previous studies have reported, in patients with SAC depth, CECD losses of 9.36% [18] and 6.04% to 12.94% [25] at 8 weeks postoperatively. Similarly, in studies comparing femtosecond laser-assisted cataract surgery (FLACS) and conventional phacoemulsification, CECD losses of 5.85% and 8.23%, respectively, were observed at 24 weeks postoperatively [26] in patients with SAC depth. In contrast, the present study demonstrated a CECD loss of 1.3% at 7 weeks postoperatively and 0.9% at 1 year postoperatively, representing approximately one-fourth of the results reported in the best previous studies. The significantly lower CECD loss observed in this study is strongly associated with the small volume of fluid used [27,28]; 8.0% to 8.23%, six times higher than those reported in this study, were accompanied by fluid volumes of 55.4 mL to 67.25 mL [12,26], more than double the volume of fluid used in the eight-chop technique

[12,26]. Differences in surgical techniques may also contribute to variations in CECD loss. Storr-Paulsen et al. [29] reported that the divide-and-conquer technique may result in greater CECD loss compared to the phaco-chop technique. It is plausible that differences in surgical techniques influence both the volume of fluid used and postoperative CECD loss. However, in this study, no significant correlation was found between the volume of fluid used and CECD loss. One possible explanation is that the volume of fluid used in the eight-chop technique is consistently low, potentially limiting the ability to detect correlations within this narrow range. Therefore, while the present results do not show a direct correlation, they do not rule out the possibility of a relationship between the volume of fluid used and CECD loss.

This study did not include a direct comparison with the divide-and-conquer technique or the phaco-chop technique. Therefore, it is necessary to interpret these findings in the context of studies that have evaluated different surgical techniques. A comparative analysis with these techniques would provide further insight into the efficacy and safety of the eight-chop technique, particularly regarding its impact on CECD loss and fluid usage.

Additionally, in this study, the ACD of the SAC group ranged from 2.33 mm to 3.00 mm. However, the impact of the eight-chop technique on cases with even shallower anterior chambers remains unclear. Further studies are required to assess whether the CECD loss, fluid dynamics, and surgical outcomes differ significantly in eyes with an ACD of less than 2.33 mm, where the space for phacoemulsification is even more restricted. Moreover, most of the cases included in this study had grade II nuclear hardness, and its applicability to grade III and IV nuclear hardness remains unverified. Cataracts with increased nuclear density may require higher phacoemulsification power, prolonged surgical time, and increased fluid usage, which could influence CECD loss and surgical efficiency. Further research is necessary to evaluate whether the eight-chop technique provides similar benefits in patients with more advanced nuclear sclerosis.

The classification of ACD in this study was based on a division using the distance from the corneal epithelium to the anterior lens surface, with 3.00 mm as the threshold. This threshold was selected based on previous studies indicating that the average ACD is between 3.30 mm and 3.35 mm and does not typically decrease below 3.00 mm, even in individuals aged 80 years [19].

It was initially anticipated that SAC depth would reduce surgical efficiency, leading to a significant increase in CECD loss and intraoperative parameter values. However, in cataract surgery utilizing the eight-chop technique, there was no significant difference in CECD loss between the SAC group and the control group. Furthermore, the intraoperative parameters associated with the eight-chop technique demonstrated favorable values for the SAC group, indicating that this method maintains surgical efficiency despite the anatomical limitations posed by a SAC. Given these results, the eight-chop technique appears to be an effective and safe surgical approach, even in cases with SAC depth. Additionally, no correlation was found between CECD loss and ACD, suggesting that factors other than chamber depth, such as surgical technique and fluid dynamics, may play a more critical role in endothelial cell preservation during phacoemulsification.

Lens segmentation prior to phacoemulsification using the eight-chop technique may significantly reduce CECD loss by minimizing the volume of fluid used and enhancing the efficiency of lens nucleus removal. Similarly, FLACS enables lens segmentation prior to phacoemulsification and has been proposed as a method to reduce CECD loss.

Additionally, FLACS has the potential to decrease effective phaco time and CDE compared to conventional phacoemulsification, contributing to earlier visual recovery [30]. However, previous studies have demonstrated that the outcomes of FLACS are comparable to those of conventional phacoemulsification, [30] with no significant advantage in terms of endothelial cell preservation. Notably, studies have reported that the eight-chop technique outperforms FLACS in minimizing CECD loss [12,26,31]. These findings suggest that the eight-chop technique may represent a significant advancement in phacoemulsification surgery, offering an alternative that optimizes ultrasound energy usage while preserving corneal endothelial cells. In other words, the eight-chop technique has

the potential to emerge as a superior successor to conventional phacoemulsification surgery, particularly in addressing the limitations that FLACS sought to overcome.

Cataract surgery needs to be a safe and efficient surgical technique that minimizes postoperative complications, especially CECD loss. However, it remains one of the leading causes of bullous keratopathy [5].

The eight-chop technique has demonstrated remarkable safety and efficiency, effectively inhibiting CECD loss postoperatively. Its widespread adoption has the potential to significantly improve surgical outcomes and contribute to better visual prognoses for cataract patients worldwide. Integrating this technique into standard cataract surgery protocols may enhance postoperative corneal health, reducing the risk of bullous keratopathy and other endothelial complications, thereby optimizing long-term visual function for patients undergoing cataract extraction.

5. Conclusions

This study found no correlation between ACD and CECD loss. In patients with SAC depth, CECD loss remained low at 0.9% at 1 year postoperatively following cataract surgery using the eight-chop technique. Additionally, key intraoperative parameters, including operative time, phaco time, aspiration time, CDE, and volume of fluid used, demonstrated favorable values, indicating high surgical efficiency and minimal endothelial trauma. Given these findings, the eight-chop technique is considered a minimally invasive, efficient, and endothelial cell-preserving surgical approach for patients with SAC depth. Its adoption may contribute to enhanced corneal endothelial preservation and improved long-term surgical outcomes in cataract patients.

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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 author declares no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

ACD	Anterior chamber depth
CECD	Corneal endothelial cell density
SAC	Shallow anterior chamber
BCVA	Best-corrected visual acuity
IOP	Intraocular pressure
CDE	Cumulative dissipated energy
CCT	Central corneal thickness
PHC	Percentage of hexagonal cells
CV	Coefficient of variation
OVD	Ophthalmic viscosurgical device
SD	Standard deviation
FLACS	Femtosecond laser-assisted cataract surgery

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