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The Impact of Free Lens Anterior Capsular Disc on Corneal Endothelial Cells in Femtosecond Laser-Assisted Cataract Surgery

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Abstract: *Objective*: To investigate whether attaching a free lens anterior capsular disc to the corneal endothelial surface during femtosecond laser-assisted cataract surgery (FLACS) can effectively reduce postoperative corneal endothelial cell loss. *Methods*: This prospective study included 97 cataract patients. Among them, 33 patients served as the experimental group, where a free lens anterior capsular disc was applied for corneal endothelial protection during FLACS. The remaining 64 patients formed the control group and underwent conventional FLACS. Changes in corneal endothelial cell density were compared between the two groups before surgery and one month postoperatively. *Results*: One month after surgery, corneal endothelial cell counts in both groups were lower than preoperative levels. However, the experimental group exhibited higher corneal endothelial cell counts than the control group, with a smaller reduction in cell counts ($p < 0.05$). The corneal endothelial cell loss rate in the experimental group was lower than that in the control group one month postoperatively ($p < 0.05$). At the one-month follow-up, there were no significant differences in LogMAR visual acuity or non-contact intraocular pressure between the two groups compared to preoperative values ($p > 0.05$). Additionally, no significant differences were observed between the experimental and control groups in terms of LogMAR visual acuity, non-contact intraocular pressure, improvements in LogMAR visual acuity, or changes in non-contact intraocular pressure ($p > 0.05$). *Conclusion*: Attaching a free lens anterior capsular disc to the corneal endothelial surface during FLACS can effectively reduce intraoperative corneal endothelial cell loss.

Keywords: Femtosecond laser; Cataract; Corneal endothelial cells; Free lens anterior capsular disc

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1. Introduction

Cataract is currently a prevalent cause of blindness worldwide. In cataract treatment, phacoemulsification combined with intraocular lens implantation has become the standard surgical approach. With the widespread application of phacoemulsification, concerns have arisen regarding its associated surgical risks, particularly the mechanical and energy-induced damage that can lead to corneal endothelial cell loss during the procedure. This

may result in corneal edema and, in severe cases, endothelial decompensation [1]. In cases of hard cataract nuclei, prolonged phacoemulsification time and increased ultrasonic energy usage are associated with a higher rate of corneal endothelial cell loss. Consequently, reducing corneal endothelial cell damage during cataract surgery has become a focal point of current research.

Currently, femtosecond laser-assisted cataract surgery (FLACS) is widely applied in clinical practice. By enabling precise anterior capsulotomy and lens nucleus pre-fragmentation, FLACS effectively reduces ultrasonic energy and phacoemulsification time, particularly in cases of hard cataract nuclei, thereby minimizing intraoperative corneal endothelial cell damage to a certain extent. However, some studies have indicated no significant difference in corneal endothelial cell damage between FLACS and traditional phacoemulsification. Therefore, exploring more effective strategies for protecting corneal endothelial cells during cataract surgery is of paramount importance. During FLACS, the femtosecond laser can create a regular and intact free lens anterior capsular disc. This study proposed by attaching this free disc to the corneal endothelial surface to mitigate damage caused by ultrasonic energy and fluid turbulence during phacoemulsification. Animal experiments have confirmed that the lens anterior capsule, as a biocompatible material, can adhere well to the corneal endothelial surface [2]. Clinical reports suggest that using the lens anterior capsular disc technique in FLACS may reduce corneal endothelial cell loss, possibly due to the disc acting as a mechanical barrier that reduces turbulent impact during phacoemulsification [3]. These findings offer new directions for protecting corneal endothelial cells during cataract surgery. However, existing research is limited to animal experiments or small-scale clinical observations, with a lack of high-quality studies in human cataract surgery. Therefore, we aim to conduct a prospective clinical study to evaluate the impact of attaching a free lens anterior capsular disc to the corneal endothelial surface during FLACS on corneal endothelial cells during cataract surgery, providing new insights for further reducing corneal endothelial cell damage during the procedure.

2. Materials and methods

2.1. General information

A total of 97 cataract patients admitted for treatment between January 2023 and October 2024 were selected. This study was a prospective study conducted in accordance with the principles of the Declaration of Helsinki and approved by the Ethics Committee of Dongguan Aier Eye Hospital. All participants provided informed consent. Using a random number table, the patients were evenly divided into two groups: the experimental group (33 cases), comprising 13 males and 20 females, aged 48 to 89 years with a mean age of (66.53 ± 12.36) years, a mean anterior chamber depth of (3.06 ± 0.38) mm, and a mean effective ultrasound time of (9.15 ± 1.81) s; and the control group (64 cases), comprising 34 males and 30 females, aged 44 to 84 years with a mean age of (64.91 ± 11.64) years, a mean anterior chamber depth of (3.11 ± 0.46) mm, and a mean effective ultrasound time of (9.39 ± 1.65) s. No significant differences were observed between the two groups in terms of baseline data ($p > 0.05$).

2.1.1. Inclusion criteria

Diagnosed with cataract through ophthalmic examination; aged over 60 years; nuclear cataract classified as NO4-5 and NC4-5 according to the LOCS III grading system; corneal endothelial cell counts exceeding 2000 cells/mm^2; normal preoperative ocular alignment; meeting surgical indications; normal cognitive function; complete basic information; and highly informed about the study.

2.1.2. Exclusion criteria

Ocular diseases such as corneal scarring, keratoconus, pterygium, glaucoma, retinopathy, and optic neuropathy; previous history of ocular surgery; systemic diseases that may affect ocular health, such as diabetes, hypertension, and autoimmune diseases; hypermature cataract; concurrent systemic infection; immune system disorders; psychiatric disorders; and withdrawal from the study midway.

2.2. Methods

The control group underwent conventional FLACS treatment: All patients underwent slit-lamp examination with pupil dilation by an ophthalmologist before cataract surgery. All surgeries were performed under topical anesthesia using the LensX® femtosecond laser system from Alcon to complete anterior capsulotomy and lens nucleus pre-fragmentation, with all surgeries performed by the same surgeon. The preset capsulorhexis diameter was set at 5.0 mm for all patients, and the lens nucleus was cross-fragmented into six pieces. The main clear corneal incision (3.0 mm wide) and side incision (1.2 mm wide) were both located temporally and were three-layer self-sealing incisions.

In the experimental group, a free lens anterior capsular disc was applied for corneal endothelial protection during FLACS: A needle was first placed beneath the incised lens anterior capsule, and sodium hyaluronate was continuously injected to allow the free lens anterior capsular disc to adhere to the corneal endothelial surface. Subsequently, the anterior chamber was filled with viscoelastic agent. In the control group, after filling the anterior chamber with viscoelastic agent, the free lens anterior capsular disc was directly removed. During lens nucleus phacoemulsification, the ultrasound probe was consistently operated at the iris plane. For the experimental group, surgical manipulation was performed beneath the lens anterior capsular disc. After residual cortex aspiration, viscoelastic agent was first injected into the anterior chamber, and then the free anterior capsular disc in the experimental group was aspirated using an I/A needle (**Figure 1**). Subsequent steps, such as intraocular lens implantation, were the same as those in conventional phacoemulsification surgery.

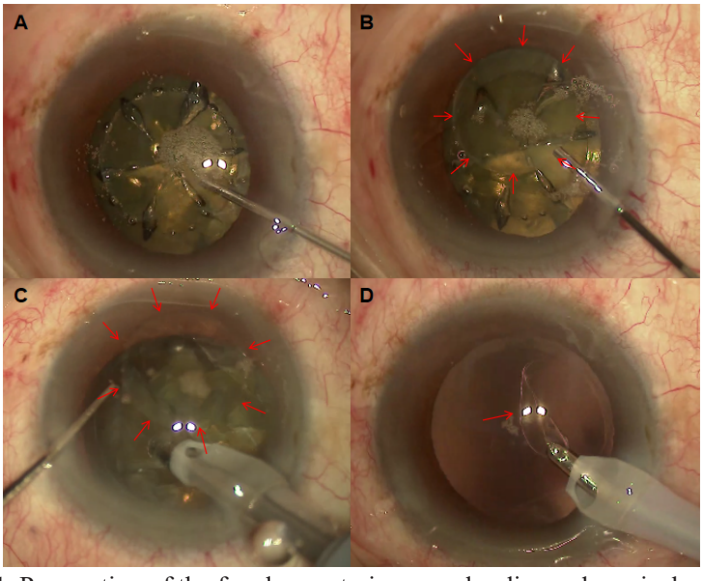

Figure 1. Preparation of the free lens anterior capsular disc and surgical procedure

Note: A shows the state after femtosecond laser-assisted anterior capsulotomy and nuclear fragmentation; B illustrates the use of viscoelastic agent to float and adhere the free lens anterior capsular disc to the posterior corneal surface; C depicts phacoemulsification performed beneath the free lens anterior capsular disc; D demonstrates the aspiration of the free lens anterior capsular disc adhered to the posterior corneal surface using an I/A needle.

2.3. Observation indicators

Corneal endothelial cell counts in the central corneal region were performed using the Nidek CEM-530 non-contact corneal endothelial microscope before surgery and one month after surgery. The corneal endothelial cell loss rate was calculated based on the number of corneal endothelial cells lost postoperatively. Biological indicators such as LogMAR visual acuity and intraocular pressure were measured before and after surgery.

2.4. Statistical analysis

Data processing was conducted using SPSS 28.0 statistical software. Categorical data were expressed as [number of cases (%)] and compared using the χ^2 test. Continuous data were tested for normal distribution using the Kolmogorov-Smirnov (K-S) test and, if normally distributed, were expressed as mean ± standard deviation ($\overline{x} \pm s$). Comparisons between groups were performed using the independent samples *t*-test, while comparisons within groups were conducted using the paired *t*-test. A *p*-value of less than 0.05 was considered statistically significant.

3. Results

3.1. Comparison of corneal endothelial cell changes between the two groups

One month after surgery, the corneal endothelial cell counts in both groups were lower than those before surgery. However, the corneal endothelial cell count in the experimental group was higher than that in the control group, and the reduction in corneal endothelial cell count was less in the experimental group compared to the control group ($p < 0.05$). One month postoperatively, the corneal endothelial cell loss rate in the experimental group was lower than that in the control group ($p < 0.05$). See **Table 1**.

Table 1. Comparison of corneal endothelial cell changes between the two groups [mean ± standard deviation ($\overline{x} \pm s$)]

Group	Number of cases	Corneal endothelial cell count (cells/mm^2)			Corneal endothelial cell loss rate (%)
		Preoperative	1 month postoperative	Reduction	
Experimental group	33	2564.54 ± 175.14	2509.46 ± 160.53	55.19 ± 9.21	2.21 ± 0.38
Control group	64	2560.90 ± 176.85	2406.26 ± 158.78	154.64 ± 18.11	6.19 ± 1.97
t	-	0.096	3.022	29.583	11.468
p	-	0.923	0.003	< 0.001	< 0.001

3.2. Comparison of visual acuity and intraocular pressure changes between the two groups

One month after surgery, there were no significant differences in LogMAR visual acuity and non-contact intraocular pressure between the two groups compared to preoperative values ($p > 0.05$). Furthermore, no significant differences were observed in LogMAR visual acuity and non-contact intraocular pressure between the experimental group and the control group. Additionally, there were no significant differences in the improvement of LogMAR visual acuity and the change in non-contact intraocular pressure between the two groups when compared to the control group ($p > 0.05$). See **Table 2**.

Table 2. Comparison of visual acuity and intraocular pressure changes between the two groups ($\overline{x} \pm s$)

Group	Number of cases	LogMAR visual acuity			Non-contact intraocular pressure (mmHg)		
		Preoperative	1 Month Postoperative	Improvement	Preoperative	1 Month Postoperative	Change
Experimental group	33	0.98 ± 0.19	0.12 ± 0.07	-0.79 ± 0.22	13.52 ± 2.74	12.79 ± 2.71	-0.73 ± 0.35
Control group	64	1.01 ± 0.37	0.16 ± 0.11	-0.85 ± 0.34	13.98 ± 2.79	13.18 ± 2.64	-0.80 ± 0.31
t	-	0.436	1.898	0.918	0.774	0.683	1.008
p	-	0.664	0.061	0.361	0.441	0.496	0.316

4. Discussion

The results of this study indicate that, compared to traditional FLACS, the application of a free lens anterior capsular disc adhered to the corneal endothelial surface during FLACS significantly reduces the rate of corneal endothelial cell loss one month postoperatively. Additionally, there were no significant differences in postoperative visual acuity or intraocular pressure between this technique and traditional FLACS, suggesting that temporarily adhering the free lens anterior capsule to the corneal endothelial surface during FLACS can safely and effectively reduce corneal endothelial cell damage, providing a degree of protection to the corneal endothelium.

The lens anterior capsule exhibits good elasticity, a certain thickness, and excellent transparency, along with biological compatibility that allows it to adhere well to the corneal endothelial surface without obstructing observation or manipulation of the anterior chamber [4,5]. This makes it an ideal autologous mechanical barrier for corneal endothelial protection. In traditional cataract phacoemulsification surgery, obtaining an intact free lens anterior capsular disc is challenging. However, with the widespread clinical application of FLACS, the anterior capsular disc created by femtosecond laser has regular, complete edges and is easy to manipulate, resulting in a stable free anterior capsular disc that serves as a foundation for its use as a mechanical barrier [5–7]. During surgery, the prepared free lens anterior capsular disc can be easily elevated and adhered to the corneal endothelial cells using viscoelastic agents, providing a basis for further utilizing this technique for corneal endothelial protection.

In this study, conventional FLACS procedures were performed after elevating and adhering the free lens anterior capsular disc to the corneal endothelial surface using viscoelastic agents. The results showed that the reduction in endothelial cell count and the loss rate one month postoperatively were significantly lower in the experimental group than in the control group, with no difference in postoperative visual acuity recovery between the two groups. This suggests that the free lens anterior capsular disc provides effective corneal endothelial protection during FLACS without affecting postoperative visual acuity recovery [8–10]. These results differ significantly from those of Zhang Hongyan et al., who reported corneal endothelial cell densities of (2241 ± 547) cells/mm^2 and (2152 ± 580) cells/mm^2 in the DisCoVisc viscoelastic agent group and the I-Visc viscoelastic agent group, respectively, one month postoperatively [11]. This indicates that the free lens anterior capsular disc significantly enhances corneal endothelial protection, thereby ensuring surgical efficacy. The protective mechanism of the free lens anterior capsular disc may stem from its ability to block turbulent fluid flow and direct energy exposure to endothelial cells during phacoemulsification [12]. FLACS technology itself enables the creation of a regular, intact free lens anterior capsular disc and reduces ultrasound energy and time through pre-fragmentation of the nuclear mass, which complements the barrier effect of the free lens anterior capsular disc, collectively

enhancing endothelial protection [13–15].

This study has certain limitations. As a single-center study with a limited sample size and follow-up only up to one month postoperatively, the generalizability of the results may be restricted. Long-term changes in endothelial cells (e.g., at 6–12 months) require further evaluation. Additionally, the study did not include high-risk patients with low corneal endothelial cell counts, and the protective effect in complex scenarios needs further validation. Future studies should involve multi-center, large-sample long-term follow-up and incorporate histological analysis to elucidate the protective mechanism in depth.

5. Conclusion

In conclusion, this study demonstrates the effectiveness of using a free lens anterior capsular disc adhered to the corneal endothelial surface during FLACS in protecting corneal endothelial cells, providing a new approach and method for corneal endothelial protection during cataract surgery.

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Disclosure statement

The authors declare no conflict of interest.

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