



Original Article

## Comparison of Endothelial Cell Density Post-Phacoemulsification Between Diabetic and Non-Diabetic Patients: A Prospective Study at A Tertiary Care Centre in Udaipur

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### ABSTRACT

**Background:** Cataract is the leading cause of reversible blindness worldwide, and phacoemulsification is currently the most widely performed surgical technique for cataract extraction. However, the procedure may cause damage to the corneal endothelium due to ultrasound energy and intraocular manipulation. Diabetes mellitus is known to cause structural and functional alterations in the corneal endothelium, potentially increasing the susceptibility of diabetic patients to endothelial damage during cataract surgery. Evaluating endothelial cell density changes following phacoemulsification in diabetic and non-diabetic patients is therefore important for understanding postoperative corneal outcomes.

**Aim:** To compare endothelial cell density changes following phacoemulsification between diabetic and non-diabetic patients.

**Materials and Methods:** This prospective comparative observational study was conducted at the Department of Ophthalmology of a tertiary care centre in Udaipur, Rajasthan, from June 2025 to November 2025. A total of 96 patients with age-related cataract undergoing phacoemulsification with posterior chamber intraocular lens implantation were included. Patients were divided into two groups: 48 diabetic patients and 48 non-diabetic patients. Preoperative and postoperative corneal endothelial parameters were evaluated using specular microscopy, including endothelial cell density, coefficient of variation, and percentage of hexagonal cells. Data were analyzed using SPSS software. Continuous variables were expressed as mean  $\pm$  standard deviation and compared using independent and paired t-tests, while categorical variables were analyzed using the chi-square test. A p-value of  $<0.05$  was considered statistically significant.

**Results:** The mean preoperative endothelial cell density was slightly lower in diabetic patients ( $2384.6 \pm 152.3$  cells/mm<sup>2</sup>) compared with non-diabetic patients ( $2441.2 \pm 147.8$  cells/mm<sup>2</sup>), although the difference was not statistically significant ( $p = 0.07$ ). Postoperatively, endothelial cell density decreased significantly in both groups; however, the reduction was greater in diabetic patients ( $2145.8 \pm 165.4$  cells/mm<sup>2</sup>) than in non-diabetic patients ( $2268.4 \pm 158.9$  cells/mm<sup>2</sup>;  $p = 0.0003$ ). The mean endothelial cell loss was significantly higher in diabetic patients ( $238.8 \pm 58.6$  cells/mm<sup>2</sup>) compared with non-diabetic patients ( $172.8 \pm 52.4$  cells/mm<sup>2</sup>;  $p < 0.001$ ). Similarly, the percentage endothelial cell loss was greater in the diabetic group ( $10.0 \pm 2.6\%$ ) than in the non-diabetic group ( $7.1 \pm 2.2\%$ ;  $p < 0.001$ ). Morphological endothelial changes, including increased coefficient of variation and decreased hexagonality, were also more pronounced in diabetic patients.

**Conclusion:** Diabetic patients experience significantly greater endothelial cell loss and morphological changes following phacoemulsification compared with non-diabetic patients. Careful preoperative evaluation and endothelial protective surgical techniques are essential to optimize surgical outcomes in diabetic individuals undergoing cataract surgery.

## INTRODUCTION

Cataract remains the leading cause of reversible blindness worldwide and contributes significantly to visual impairment, particularly in developing countries such as India. With increasing life expectancy and an aging population, the burden of cataract continues to rise. Surgical removal of the cataractous lens followed by intraocular lens implantation is the only effective treatment for restoring vision. Among the various surgical techniques available, phacoemulsification has become the preferred method because of its smaller incision size, minimal surgical trauma, rapid visual rehabilitation, and reduced postoperative complications when compared with conventional extracapsular cataract extraction [1]. Despite these advantages, phacoemulsification can still cause damage to the corneal endothelium due to ultrasound energy, mechanical manipulation of intraocular structures, and turbulence within the anterior chamber during surgery [2].

The corneal endothelium is a single layer of hexagonal cells lining the posterior surface of the cornea. These cells play a crucial role in maintaining corneal transparency by regulating fluid transport across the cornea through barrier and pump mechanisms. Unlike many other tissues in the body, corneal endothelial cells have a very limited capacity for regeneration in vivo. Therefore, when endothelial cells are lost due to aging, disease, or surgical trauma, the remaining cells enlarge and spread to maintain endothelial integrity. Excessive loss of endothelial cells may lead to corneal edema, loss of corneal clarity, and ultimately corneal decompensation [3]. Consequently, preservation of endothelial cell density during cataract surgery is an important determinant of successful surgical outcomes.

Cataract surgery itself is known to cause varying degrees of endothelial cell loss. The magnitude of this loss depends on multiple factors including the hardness of the cataract, duration of ultrasound energy used during phacoemulsification, intraoperative complications, and the surgeon's technique. Studies have reported endothelial cell loss ranging from approximately 4% to 25% after uncomplicated phacoemulsification surgery [4]. Excessive endothelial damage may result in postoperative corneal edema, delayed visual recovery, and in severe cases, bullous keratopathy. Therefore, careful evaluation of endothelial cell density before and after cataract surgery is essential to assess surgical safety and postoperative outcomes.

Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia and associated systemic complications. In addition to well-known ocular complications such as diabetic retinopathy, diabetes also affects the cornea, producing a spectrum of changes collectively termed diabetic keratopathy. Several studies have demonstrated that diabetic patients often exhibit alterations in corneal endothelial morphology, including decreased endothelial cell density, increased polymegathism (variation in cell size), and reduced hexagonality (variation in cell shape) [5]. These structural changes indicate impaired endothelial stability and reduced functional reserve in diabetic corneas.

The mechanisms responsible for endothelial alterations in diabetes are complex and multifactorial. Chronic hyperglycemia leads to accumulation of advanced glycation end products and increased oxidative stress within endothelial cells, which can impair cellular metabolism and structural integrity. Additionally, dysfunction of the Na<sup>+</sup>/K<sup>+</sup>-ATPase pump in diabetic endothelial cells affects corneal hydration control and contributes to increased corneal thickness. These metabolic disturbances may weaken the ability of the corneal endothelium to tolerate surgical stress, making diabetic patients more susceptible to endothelial damage during cataract surgery [6].

Several clinical studies have evaluated endothelial cell changes following phacoemulsification in diabetic and non-diabetic patients. Evidence suggests that diabetic individuals may experience greater endothelial cell loss and slower recovery of corneal morphology after cataract surgery compared with non-diabetic patients [7]. However, the extent of endothelial cell damage reported in the literature varies, and some studies have found no significant difference between the two groups [8]. These inconsistent findings highlight the need for further research to better understand the impact of diabetes on corneal endothelial health during cataract surgery.

With the increasing prevalence of diabetes worldwide and the large number of cataract surgeries performed each year, understanding the effect of diabetes on postoperative corneal endothelial changes is clinically important. Evaluating endothelial cell density in diabetic and non-diabetic patients undergoing phacoemulsification can help identify patients at higher risk of postoperative complications and guide surgeons in adopting protective surgical strategies. Therefore, the present study was undertaken to compare endothelial cell density changes following phacoemulsification between diabetic and non-diabetic patients at a tertiary care centre in Udaipur, Rajasthan.

## MATERIALS AND METHODS

**Study Design:** This was a prospective comparative observational study designed to evaluate the changes in corneal endothelial cell density following phacoemulsification cataract surgery in diabetic and non-diabetic patients.

**Study Setting:** The study was conducted in the Department of Ophthalmology at a tertiary care centre in Udaipur, Rajasthan.

**Study Duration:** The study was carried out over a period of six months from June 2025 to November 2025.

**Study Population:** The study population included patients diagnosed with age-related cataract who were scheduled to undergo phacoemulsification with intraocular lens implantation at the study centre during the study period.

### Sample Size

A total of 96 patients were included in the study. The participants were divided into two groups:

- **Group I:** 48 patients with diabetes mellitus
- **Group II:** 48 patients without diabetes mellitus (non-diabetic group)

Patients fulfilling the inclusion criteria and consenting to participate were recruited consecutively until the required sample size was achieved.

### Inclusion Criteria

- Patients aged 40 years and above
- Patients diagnosed with senile cataract planned for phacoemulsification
- Patients with type 2 diabetes mellitus for the diabetic group
- Patients without diabetes mellitus for the control group
- Patients willing to participate and provide written informed consent

### Exclusion Criteria

- Pre-existing corneal diseases (corneal dystrophy, degeneration, or scars)
- History of previous ocular surgery
- Presence of glaucoma or uveitis
- Traumatic cataract
- Pseudoexfoliation syndrome
- Contact lens users
- Patients with intraoperative complications such as posterior capsular rupture or zonular dialysis

### Preoperative Evaluation

All patients underwent a detailed ophthalmic examination prior to surgery which included:

- Measurement of best corrected visual acuity (BCVA)
- Slit lamp biomicroscopy
- Intraocular pressure measurement using tonometry
- Fundus examination whenever media clarity permitted
- Measurement of blood glucose levels to determine diabetic status

Corneal endothelial parameters were assessed preoperatively using specular microscopy, which recorded:

- Endothelial cell density (cells/mm<sup>2</sup>)
- Coefficient of variation (polymegathism)
- Percentage of hexagonal cells (pleomorphism)

**Surgical Procedure:** All patients underwent standard phacoemulsification cataract surgery with posterior chamber intraocular lens implantation under aseptic conditions. The surgeries were performed by experienced ophthalmic surgeons using a uniform surgical technique. A clear corneal incision was made followed by capsulorhexis, hydrodissection, and nucleus emulsification using phacoemulsification. Cortical aspiration was performed and a foldable intraocular lens was implanted in the capsular bag. Balanced salt solution and viscoelastic substances were used during the procedure to minimize endothelial trauma.

**Postoperative Evaluation:** Postoperative follow-up examinations were conducted to assess corneal endothelial parameters. Specular microscopy was performed postoperatively to measure endothelial cell density and evaluate endothelial cell loss after surgery.

The primary outcome variable was the change in endothelial cell density (cells/mm<sup>2</sup>) after phacoemulsification. The secondary outcome variable was the percentage of endothelial cell loss and comparison between diabetic and non-diabetic groups.

**Statistical Analysis:** All collected data were entered into Microsoft Excel and analyzed using the Statistical Package for the Social Sciences (SPSS) software. Continuous variables were expressed as mean  $\pm$  standard deviation, while categorical variables were expressed as frequency and percentage. Comparison of continuous variables between the two groups was performed using the independent sample t-test. Paired t-test was used to compare preoperative and postoperative endothelial cell density within each group. Categorical variables were analyzed using the chi-square test. A p-value of less than 0.05 was considered statistically significant.

**Ethical Considerations:** The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Written informed consent was obtained from all participants after explaining the purpose and procedures of the study. Confidentiality of patient information was maintained throughout the study, and participation was voluntary without affecting the standard clinical care provided to the patients.

## RESULTS

A total of 96 patients undergoing phacoemulsification cataract surgery were included in the study. The participants were divided equally into two groups: 48 diabetic patients and 48 non-diabetic patients. The results were analyzed to compare demographic characteristics and corneal endothelial parameters between the two groups.

The mean age of participants in the diabetic and non-diabetic groups was **61.3  $\pm$  8.4 years** and **60.5  $\pm$  7.9 years**, respectively. The majority of patients belonged to the **60–69 year age group** in both groups. Males constituted **56.3% of diabetic patients** and **52.1% of non-diabetic patients**. There were **no statistically significant differences** between the groups with respect to age, gender distribution, laterality of surgery, preoperative visual acuity, or cataract grade ( $p > 0.05$ ), indicating that the two groups were comparable at baseline. (Table 1)

**Table 1: Baseline Demographic and Clinical Characteristics of Study Participants (n = 96)**

Variable	Diabetic (n = 48)	Non-Diabetic (n = 48)	Total	p value
Age (years, Mean $\pm$ SD)	61.3 $\pm$ 8.4	60.5 $\pm$ 7.9	60.9 $\pm$ 8.1	0.62
Age Group				0.88
40–49	6 (12.5%)	7 (14.6%)	13	
50–59	14 (29.2%)	15 (31.3%)	29	
60–69	18 (37.5%)	17 (35.4%)	35	
$\geq 70$	10 (20.8%)	9 (18.7%)	19	
Gender				0.67
Male	27 (56.3%)	25 (52.1%)	52	
Female	21 (43.7%)	23 (47.9%)	44	
Laterality of Eye Operated				0.54
Right eye	26 (54.2%)	23 (47.9%)	49	
Left eye	22 (45.8%)	25 (52.1%)	47	
Preoperative BCVA				0.71
$\leq 6/60$	28 (58.3%)	26 (54.2%)	54	
6/36 – 6/18	20 (41.7%)	22 (45.8%)	42	

<b>Grade of Cataract (Nuclear Sclerosis)</b>				0.64
Grade II	19 (39.6%)	21 (43.8%)	40	
Grade III	23 (47.9%)	22 (45.8%)	45	
Grade IV	6 (12.5%)	5 (10.4%)	11	

*Chi-square test used for categorical variables; independent t-test used for continuous variables.*

Preoperative endothelial cell density was slightly lower in diabetic patients ( $2384.6 \pm 152.3$  cells/mm<sup>2</sup>) compared with non-diabetic patients ( $2441.2 \pm 147.8$  cells/mm<sup>2</sup>), although the difference was not statistically significant ( $p = 0.07$ ). Following phacoemulsification, a significant reduction in endothelial cell density was observed in both groups; however, the decrease was significantly greater in diabetic patients ( $2145.8 \pm 165.4$  cells/mm<sup>2</sup>) compared with non-diabetic patients ( $2268.4 \pm 158.9$  cells/mm<sup>2</sup>,  $p = 0.0003$ ).

The mean endothelial cell loss was  $238.8 \pm 58.6$  cells/mm<sup>2</sup> in diabetic patients, compared with  $172.8 \pm 52.4$  cells/mm<sup>2</sup> in non-diabetic patients, which was statistically significant ( $p < 0.001$ ). Similarly, the percentage endothelial cell loss was significantly higher in the diabetic group ( $10.0 \pm 2.6\%$ ) than in the non-diabetic group ( $7.1 \pm 2.2\%$ ,  $p < 0.001$ ).

Morphological endothelial changes were also noted following surgery. The coefficient of variation, indicating polymegathism, increased significantly in diabetic patients compared to non-diabetic patients ( $p = 0.04$ ). Additionally, hexagonality percentage, reflecting pleomorphism of endothelial cells, decreased more markedly in diabetic patients ( $p = 0.03$ ).

Paired comparison of preoperative and postoperative endothelial cell density within each group showed a statistically significant reduction in endothelial cell density after surgery ( $p < 0.001$ ) for both diabetic and non-diabetic groups.

During the postoperative follow-up period, transient corneal edema was observed in 6 diabetic patients (12.5%) and 3 non-diabetic patients (6.3%), which resolved with conservative management. No cases of persistent corneal decompensation or bullous keratopathy were reported in either group. (Table 2)

**Table 2: Comparison of Corneal Endothelial Parameters in Diabetic and Non-Diabetic Patients Before and After Phacoemulsification (n = 96)**

Parameter	Diabetic (Mean $\pm$ SD)	Non-Diabetic (Mean $\pm$ SD)	p value
Preoperative Endothelial Cell Density (cells/mm <sup>2</sup> )	$2384.6 \pm 152.3$	$2441.2 \pm 147.8$	0.07
Postoperative Endothelial Cell Density (cells/mm <sup>2</sup> )	$2145.8 \pm 165.4$	$2268.4 \pm 158.9$	0.0003*
Mean Endothelial Cell Loss (cells/mm <sup>2</sup> )	$238.8 \pm 58.6$	$172.8 \pm 52.4$	<0.001*
Percentage Endothelial Cell Loss (%)	$10.0 \pm 2.6$	$7.1 \pm 2.2$	<0.001*
Coefficient of Variation (Preoperative)	$33.6 \pm 4.8$	$32.9 \pm 4.5$	0.43
Coefficient of Variation (Postoperative)	$36.8 \pm 5.2$	$34.7 \pm 4.9$	0.04*
Hexagonality (%) Preoperative	$51.4 \pm 6.1$	$52.8 \pm 5.9$	0.28
Hexagonality (%) Postoperative	$47.2 \pm 6.4$	$49.9 \pm 6.0$	0.03*

\*Statistically significant ( $p < 0.05$ )

## DISCUSSION

Phacoemulsification has become the preferred surgical technique for cataract extraction because of its safety, rapid postoperative recovery, and smaller incision size. However, despite these advantages, corneal endothelial damage remains an important concern following cataract surgery. The corneal endothelium is responsible for maintaining stromal deturgescence and corneal transparency, and any significant reduction in endothelial cell density (ECD) can compromise corneal clarity. Since endothelial cells have minimal regenerative capacity, intraoperative trauma during phacoemulsification may lead to permanent cell loss and postoperative corneal complications [2,3].

In the present study, a total of 96 patients undergoing phacoemulsification were evaluated, including 48 diabetic and 48 non-diabetic patients. The baseline demographic characteristics such as age, gender distribution, laterality of the operated eye, and grade of cataract were comparable between the two groups, with no statistically significant differences. Ensuring similar baseline characteristics is important to minimize confounding factors and allows a more reliable comparison of endothelial cell changes attributable to diabetes status. Cataract is typically an age-related condition, and the majority of patients in this study were in the sixth and seventh decades of life, which is consistent with previous epidemiological studies on age-related cataract [4].

The present study demonstrated that the preoperative endothelial cell density was slightly lower in diabetic patients compared with non-diabetic patients, although the difference did not reach statistical significance. This finding is consistent with previous studies which have reported subclinical endothelial alterations in diabetic corneas even before surgical intervention. Diabetes mellitus is known to cause structural and functional changes in the corneal endothelium, including decreased cell density, increased cell size variability, and altered cellular morphology [5]. These changes are thought to be related to chronic hyperglycemia, oxidative stress, and accumulation of advanced glycation end products affecting endothelial metabolism and pump function [6].

Following phacoemulsification, both diabetic and non-diabetic groups in the present study showed a significant reduction in endothelial cell density. However, the magnitude of endothelial cell loss was significantly greater in diabetic patients. The mean endothelial cell loss in diabetic patients was  $238.8 \pm 58.6$  cells/mm<sup>2</sup>, compared with  $172.8 \pm 52.4$  cells/mm<sup>2</sup> in non-diabetic patients, and the difference was statistically significant. Similarly, the percentage endothelial cell loss was higher in the diabetic group (10.0%) compared with the non-diabetic group (7.1%). These findings suggest that diabetic corneas may have reduced resilience to surgical trauma during phacoemulsification.

These observations are supported by previous clinical studies which have reported increased endothelial cell loss after cataract surgery in diabetic patients. Salavat et al. reported significantly greater endothelial cell loss in diabetic patients compared with non-diabetic controls following phacoemulsification, indicating that diabetes may increase endothelial vulnerability to intraoperative stress [7]. Similarly, Ciorba et al. observed that diabetic patients demonstrated greater endothelial cell density reduction and delayed morphological recovery following cataract surgery [8].

The increased susceptibility of diabetic corneal endothelium to surgical trauma may be explained by several pathophysiological mechanisms. Chronic hyperglycemia leads to metabolic and structural alterations in endothelial cells, including mitochondrial dysfunction, increased oxidative stress, and impaired Na<sup>+</sup>/K<sup>+</sup>-ATPase pump activity. These changes compromise endothelial cell function and reduce the ability of the cornea to maintain stromal dehydration following surgical trauma. In addition, diabetic corneas often exhibit increased central corneal thickness and abnormal endothelial morphology, which further reduce the functional reserve of the endothelium [5,6].

In the present study, morphological endothelial parameters also showed significant changes following surgery. The coefficient of variation, which reflects polymegathism or variability in endothelial cell size, increased significantly in diabetic patients after surgery. Likewise, the percentage of hexagonal cells, an indicator of normal endothelial cell morphology, decreased more prominently in diabetic patients. These findings suggest that diabetes not only affects endothelial cell density but also alters cellular morphology and stability.

Similar morphological changes have been reported in several studies evaluating the effect of cataract surgery on the diabetic cornea. Joo et al. demonstrated that diabetic patients showed increased polymegathism and decreased hexagonality after phacoemulsification, suggesting structural instability of the endothelial layer [9]. Another study by Hugod et al. reported that diabetic corneas showed delayed endothelial morphological recovery after surgery compared with non-diabetic patients [10].

The greater endothelial damage observed in diabetic patients may also be influenced by surgical factors such as increased phacoemulsification energy required for denser cataracts, prolonged surgical time, and intraocular turbulence during lens fragmentation. However, in the present study, the surgical technique was standardized and performed by experienced surgeons to minimize procedural variability. The use of viscoelastic substances and balanced salt solution also helped protect the corneal endothelium during surgery.[11]

Postoperative corneal edema was observed in a small proportion of patients in both groups; however, the incidence was slightly higher among diabetic patients. Importantly, all cases of postoperative corneal edema were transient and resolved with conservative management. No cases of persistent corneal decompensation or bullous keratopathy were observed during the follow-up period. This indicates that although endothelial cell loss was higher in diabetic patients, the overall surgical outcome remained favorable when proper surgical techniques were employed.[12]

The findings of the present study highlight the importance of careful preoperative evaluation of corneal endothelial status in diabetic patients undergoing cataract surgery. Specular microscopy plays a valuable role in assessing endothelial cell density and morphology before surgery and helps identify patients who may be at increased risk of postoperative endothelial damage. In addition, adopting protective surgical strategies such as minimizing ultrasound energy, using dispersive viscoelastic agents, and reducing surgical time may help preserve endothelial integrity in diabetic patients.[13]

The present study adds to the growing body of evidence suggesting that diabetes mellitus has a significant impact on corneal endothelial health and postoperative outcomes following cataract surgery. Given the rising prevalence of diabetes worldwide, ophthalmologists are increasingly encountering diabetic patients requiring cataract surgery. Understanding the influence of diabetes on corneal endothelial behavior is therefore essential for optimizing surgical outcomes and preventing postoperative complications.

However, certain limitations should be acknowledged. The study was conducted at a single tertiary care center with a relatively modest sample size and a limited follow-up period. Longer follow-up studies with larger sample sizes would be useful to evaluate long-term endothelial changes after cataract surgery in diabetic patients.

## CONCLUSION

The present study demonstrated that phacoemulsification cataract surgery results in a significant reduction in corneal endothelial cell density in both diabetic and non-diabetic patients. However, the magnitude of endothelial cell loss was significantly greater in diabetic individuals compared with non-diabetic controls. Diabetic patients also showed more pronounced morphological endothelial changes, including increased coefficient of variation and decreased hexagonality, indicating greater endothelial stress following surgery. These findings suggest that diabetes mellitus adversely affects corneal endothelial integrity and reduces its ability to withstand surgical trauma during phacoemulsification. Although transient postoperative corneal edema was observed in a small proportion of patients, no cases of persistent corneal decompensation occurred, indicating that phacoemulsification remains a safe and effective procedure when performed with appropriate surgical precautions. Careful preoperative assessment of corneal endothelial status and adoption of endothelial protective surgical strategies are recommended when performing cataract surgery in diabetic patients.

## DECLARATIONS

**Consent for Publication:** Written informed consent for publication of anonymized data was obtained from all participants.

**Availability of Data and Materials:** The datasets used and analyzed during the study are available from the corresponding author on reasonable request.

**Competing Interests:** The authors declare that they have no competing interests.

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