Research Article

A Prospective Study on the Impact of Phacoemulsification on Corneal Endothelial Cell Count and Morphology in Different Grades of Nucleus

Mukesh Prakash, Rohit Gupta*, Ankita Singh, Namrata Patel, Aditi Saroj, Shalini Mohan

Department of Ophthalmology, GSVM Medical College, Kanpur, Uttar Pradesh, India.

Abstract

Background: Phacoemulsification, a widely used surgical technique for cataract removal, can impact the corneal structure, particularly the corneal endothelium. During cataract surgery, significant changes in endothelial cell density, corneal thickness, and endothelial cell morphology often occur. In some cases, patients with senile cataracts may develop corneal edema after phacoemulsification, which can progress to corneal opacity, resulting in irreversible visual impairment.

Method: This longitudinal observational study evaluated 524 patients who underwent phacoemulsification surgery in one eye from October 2024 to February 2025. A comprehensive eye examination was performed, including best-corrected visual acuity (BCVA, decimal notation), slit-lamp, corneal endothelial profiles, encompassing endothelial cell density (ECD), hexagonality (Hex.), cell number (CN), coefficient of variance of cell size (CV), and central corneal thickness (CCT), were assessed using a Nidek non-contact specular microscope.

Results: Grade 4 had 19% cell loss, while grade 1 had only 06%. Grades 2 and 3 (10–15% loss) suggest moderate endothelial vulnerability. Recovery was better in mild cataracts (Grade 1) compared to grade 4.

Conclusion: Phacoemulsification causes significant but mostly transient corneal endothelial changes. Higher-grade cataracts (Grades 3 and 4) have more pronounced and prolonged damage. Surgical strategies (lower energy, optimized fluidics) should be prioritized in dense cataracts to minimize endothelial injury.

Keywords: Phacoemulsification, Corneal endothelium, Visual impairment.

Introduction

Visual impairment and blindness are significant public health challenges, particularly in developing countries where access to healthcare services is limited.[1] Among the various causes of visual impairment, senile cataract stands out as a leading contributor.[2] This condition occurs when the crystalline lens loses its natural transparency, leading to blurred vision and, eventually, gradual vision loss. Age-related cataracts (Figure 1 and Table 1), the most common type of acquired cataracts, primarily affect individuals over the age of 50 and account for more than 47% of global blindness cases.[3]

Phacoemulsification, a widely used surgical technique for cataract removal, can impact the corneal structure, particularly the corneal endothelium, which plays a critical role in maintaining corneal transparency.[4] During cataract surgery, significant changes in endothelial cell density, corneal thickness, and endothelial cell morphology often occur, sometimes leading to prolonged corneal edema.[5] In some cases, patients with senile cataracts may develop corneal

Address for correspondence: Rohit Gupta
Department of Ophthalmology, GSVM Medical College, Kanpur, Uttar Pradesh, India.
E-mail: drrohitofficial@gmail.com

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edema after phacoemulsification, which can progress to corneal opacity, resulting in irreversible visual impairment.[6,7] Numerous studies have demonstrated a reduction in corneal endothelial cell count and an increase in central corneal thickness following phacoemulsification, highlighting the need for careful surgical techniques and post-operative monitoring to minimize these adverse effects (Figure 2 and Table 2).[8]

Objective

This study evaluates the impact of phacoemulsification on corneal endothelial parameters—central corneal thickness (CCT), endothelial cell density (ECD), coefficient of variation (CV), and hexagonality index (HI)—in patients with varying cataract severity. Measurements were taken preoperatively and postoperatively (day 1, 7 and 1 month).

Methods

Study Design

Prospective observational study.

Participants

Over 524 patients undergoing uncomplicated phacoemulsification with IOL implantation.

Cataract Grading (LOCS III)

- Grade 1 (Mild nuclear cataract): 120 patients.
- Grade 2 (Moderate nuclear cataract): 200 patients.
- Grade 3 (Severe nuclear cataract): 160 patients.
- Grade 4 (Hypermature cataract): 44 patients.

Exclusion Criteria

Pre-existing corneal disease, prior ocular surgery, trauma, or intraoperative complications.

This longitudinal observational study evaluated 524 patients who underwent phacoemulsification surgery in one eye during from October 2024 to February 2025 at Department of Ophthalmology, LLR hospital, Kanpur (Table 3 and Figure 3).

Inclusion Criteria

Inclusion criteria was eyes with normal corneal endothelial cells and cell density more than 1000 cells/mm^2 (Table 4 and Figure 4). The study excluded any patients with ocular or systemic diseases, history of previous intraocular surgery, refractive surgery or trauma as well as contact lenses wear. A comprehensive eye examination was performed including detailed history. Pre and one-month post-phacoemulsification. These included best-corrected visual acuity (BCVA, decimal notation), slit-lamp, and fundus examinations. B-scan ultrasonography was utilized when retinal visualization was obscured. Corneal endothelial profiles, encompassing endothelial cell density (ECD), hexagonality (Hex.), cell number (CN), coefficient of variance of cell size (CV), and central corneal thickness (CCT), were assessed using a Nidek non-contact specular microscope.[9] All phacoemulsification surgeries were performed by a single surgeon using a consistent supero-temporal small incision technique. Ultrasound energy, ranging from 30 to 60 Hertz per second, was adjusted based on cataract density. Statistical analysis, including descriptive and comparative methods, was performed using SPSS for Windows version 21.0. Data are presented as mean ± standard deviations (SD). Paired t-tests were employed to compare pre-and post-operative variables, while independent t-tests were used to compare means between study groups. A *p-value* of < 0.05 was considered statistically significant.[10]

Table 1: Age groups of study participants (n = 524)

Age range	*Number of patients*	*Percentage*
40–55 years	68	13
56–65 years	192	37
66–75 years	228	44
76 + years	36	6

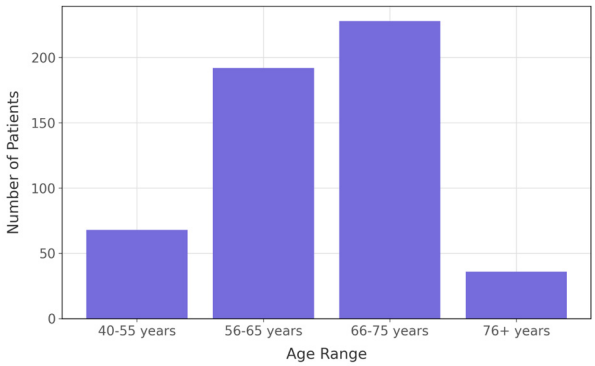

Figure 1: Age distribution of study participants

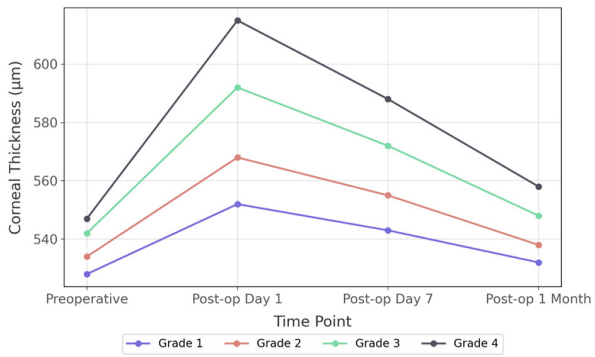

Figure 2: Corneal thickness over time by cataract grade

Key Findings

- Day 1: Maximum corneal swelling, especially in grade 4 (hypermature).
- Day 7: Thickness reduced but still elevated in grades 3 and 4.
- 1 Month: Near baseline in grades 1 and 2, but grades 3 and 4 showed residual thickening.
- 2. Endothelial cell density (ECD, cells/mm^2)*(Mean ± SD, $p < 0.05$ *vs.* preoperative)

Measurements

CCT (µm)

Ultrasonic pachymetry

ECD (cells/mm²)

Non-contact specular microscopy

CV (%)

Measure of cell size variability (polymegathism) (Table 5 and Figure 5)

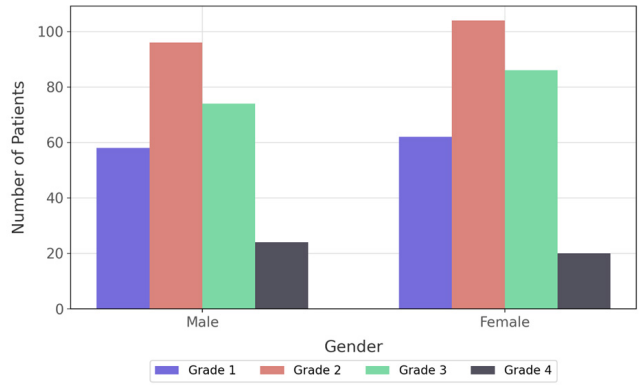

Figure 3: Gendar distribution by cataract grade

Table 2: Corneal thickness measurements by cataract grade and time point

Cataract grade	*Preoperative*	*Post-op day 1*	*Post-op day 7*	*Post-op 1 month*
Grade 1	528 ± 24	552 ± 29*	543 ± 27*	532 ± 25
Grade 2	534 ± 26	568 ± 34*	555 ± 31*	538 ± 28
Grade 3	542 ± 29	592 ± 41*	572 ± 37*	548 ± 32*
Grade 4	547 ± 33	615 ± 46*	588 ± 43*	558 ± 39*

*statistically significant difference from preoperative value ($p < 0.05$)

Table 3: Gender distribution by cataract grade

Gender	*Grade 1*	*Grade 2*	*Grade 3*	*Grade 4*	*Total*
Male	58	96	74	24	252 (48%)
Female	62	104	86	20	272 (52%)

Table 4: Endothelial cell density measurements by cataract grade and time point (Cells/mm²)

Cataract grade	*Preoperative*	*Post-op day 1*	*Post-op day 7*	*Post-op 1 month*
Grade 1	2640 ± 245	2530 ± 235*	2510 ± 230*	2480 ± 225*
Grade 2	2580 ± 260	2420 ± 250*	2370 ± 245*	2320 ± 240*
Grade 3	2520 ± 280	2250 ± 270*	2200 ± 265*	2150 ± 260*
Grade 4	2480 ± 295	2100 ± 285*	2050 ± 280*	2000 ± 275*

*statistically significant difference from preoperative value ($p < 0.05$)

HI (%)

Percentage of hexagonal cells (reflects cell regularity) (Table 6 and Figure 6).

Results

Central corneal thickness (CCT, µm)

*(Mean ± SD, $p < 0.05$ *vs.* preoperative)

Discussion

Central Corneal Thickness

Early edema peaks at day 1, resolving by 1 month in mild cataracts.

Severe cataracts (Grades 3 and 4) showed prolonged edema, likely due to higher phaco energy use.

Endothelial Cell Density Loss

Grade 4 had ~19% cell loss, while grade 1 had only ~6%.

Grades 2 and 3 (10–15% loss) suggest moderate endothelial vulnerability.

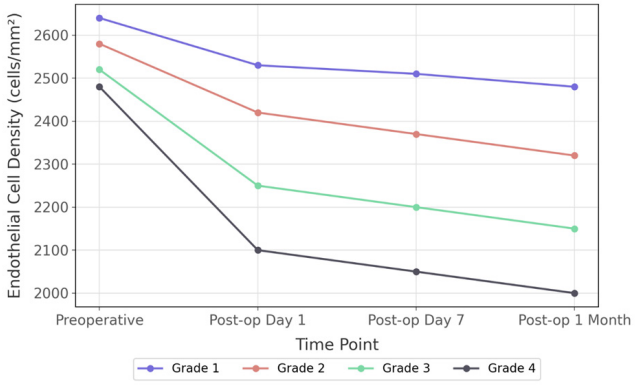

Figure 4: Endothelial cell density over time by cataract grade

Key Findings

- Cell loss was highest in Grade 4 (19.4%) *vs.* Grade 1 (6.1%) at 1 month.
- Grades 2 and 3 showed ~10–15% cell loss, indicating more endothelial stress in denser cataracts.
- Coefficient of Variation (CV, %)
- *(Reflects cell size irregularity, Mean ± SD, $p < 0.05$ *vs.* preoperative)

Table 5: Coefficient of variation measurements by cataract grade and time point (%)

Cataract grade	*Preoperative*	*Post-op day 1*	*Post-op day 7*	*Post-op 1 month*
Grade 1	29 ± 4	34 ± 5*	33 ± 5*	31 ± 4
Grade 2	31 ± 5	37 ± 6*	36 ± 6*	34 ± 5*
Grade 3	33 ± 6	41 ± 7*	39 ± 7*	37 ± 6*
Grade 4	35 ± 7	44 ± 8*	42 ± 8*	39 ± 7*

Table 6: Hexagonality measurements by cataract grade and time point%

Cataract grade	*Preoperative*	*Post-op day 1*	*Post-op day 7*	*Post-op 1 month*
Grade 1	61 ± 8	56 ± 7*	57 ± 7*	59 + 8
Grade 2	59 ± 9	53 ± 8*	54 ± 8*	57 ± 9
Grade 3	57 ± 10	49 ± 9*	51 + 9*	55 ± 10
Grade 4	55 ± 11	46 ± 10*	48 ± 10*	53 ± 11

*statistically significant difference from preoperative value ($p < 0.05$)

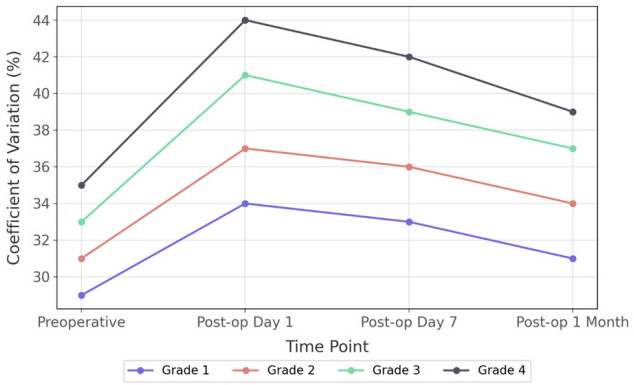

Figure 5: Coefficient of variation measurements by cataract grade

Key Findings

- Higher CV = More cell size variation (polymegathism).
- Grades 3 and 4 had persistent irregularity even at 1 month.
- Hexagonality index (HI, %)
- *(Reflects endothelial cell regularity, Mean ± SD, $p < 0.05$ *vs.* preoperative)

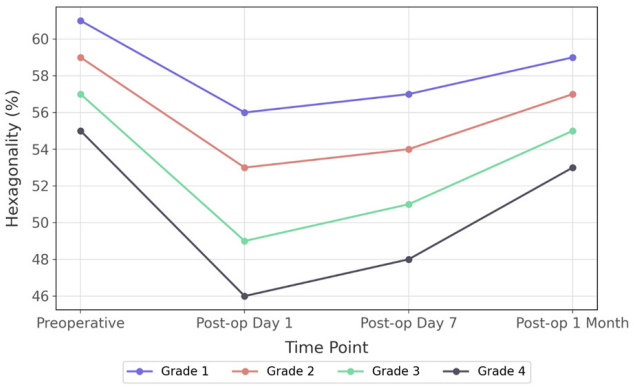

Figure 6: Hexagonality over time by cataract grade

Key Findings

- HI dropped postoperatively, indicating loss of hexagonal cell shape.
- Recovery was better in mild cataracts (Grade 1) compared to grade 4, where hexagonal cells remained reduced.

CV and HI Changes

Increased CV implies endothelial stress, worse in dense cataracts.

Reduced HI suggests cell shape disruption, with slower recovery in advanced cases.

Conclusion

Phacoemulsification causes significant but mostly transient corneal endothelial changes.

Higher-grade cataracts (Grades 3 and 4) have more pronounced and prolonged damage.

Surgical strategies (lower energy, optimized fluidics) should be prioritized in dense cataracts to minimize endothelial injury.

Clinical Takeaway

Mild cataracts (Grade 1-2)

Minimal long-term impact.

Severe cataracts (Grade 3-4)

Require closer monitoring due to higher endothelial vulnerability.

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