E-ISSN 2250-0944
ISSN 2250-1150
doi: 10.31838/ijprt/15.02.209

**Research Article**

# Comparative Evaluation of Corneal Endothelial Changes after Phacoemulsification versus Manual Small-Incision Cataract Surgery in Grade-4 Nuclear Cataracts: A Randomised Observational Study

**Dr. Bhumika Sharma[1], Dr Ashima Mehndiratta[2], Dr. Sahil Jain[3], Dr Hitesh Suthar[4*]**
[1,2]3rd year Resident, Department of Ophthalmology, SMS Medical College and Hospital, Jaipur, India.
[3]Senior Resident, Department of Ophthalmology, SMS Medical College and Hospital, Jaipur, India.
[4*]CAS- PG Resident 3rd year, Department of Ophthalmology, SMS Medical College and Hospital, Jaipur, India.
**Corresponding Author: Dr Hitesh Suthar**
Received: 19.06.25, Revised: 21.07.25, Accepted: 26.08.25

**ABSTRACT**
**Purpose:** To compare postoperative corneal endothelial morphology and visual outcomes after phacoemulsification (PHACO) and manual small-incision cataract surgery (SICS) in eyes with grade-4 nuclear cataract.
**Methods:** In this single-centre, randomised observational study, 90 eyes of 90 patients were allocated to PHACO (n = 45) or SICS (n = 45). Pre-operative and postoperative (1 week, 6 weeks, 3 months) assessments included endothelial cell density (ECD), coefficient of variation (CV), hexagonality (%Hex), central corneal thickness (CCT), uncorrected (UCVA) and best-corrected visual acuity (BCVA) using specular microscopy and logMAR charts. Primary outcome was percentage ECD loss at 3 months. Secondary outcomes were changes in CCT, CV, %Hex, and visual acuity.
**Results:** Baseline characteristics were comparable between groups (mean age 54.0 ± 4.7 y vs 56.0 ± 3.9 y; p = 0.07). Mean ECD loss at 3 months was 13.6 ± 2.5 % (PHACO) versus 13.0 ± 1.5 % (SICS) (p = 0.16). CCT increased transiently at week 1 (PHACO +42 µm; SICS +22 µm) before returning to near-baseline by month 3 (p > 0.05 for all inter-group comparisons). CV and %Hex changed similarly in both groups, indicating comparable endothelial remodelling. Median BCVA improved from 0.64 to 0.06 logMAR (PHACO) and 0.71 to 0.09 logMAR (SICS) at 3 months (p = 0.39). No sight-threatening complications occurred.
**Conclusions:** PHACO and SICS yield equivalent endothelial preservation and visual rehabilitation in dense nuclear cataracts when performed by an experienced surgeon. Given its lower cost and technology dependence, SICS remains a pragmatic alternative to PHACO in resource-limited settings.

**Keywords:** Phacoemulsification; Manual Small-Incision Cataract Surgery; Endothelial Cell Density; Central Corneal Thickness; Specular Microscopy; India.

## INTRODUCTION

Cataract remains the leading cause of global blindness, accounting for almost half (47.8 %) of all cases worldwide and more than 60 % in India (1). Modern cataract surgery has progressively reduced incision size—from 12 mm intracapsular extractions to ≤2.8 mm coaxial phacoemulsification—to achieve rapid, spectacle-free visual rehabilitation with minimal tissue trauma. Manual small-incision cataract surgery (SICS), an evolution of extracapsular extraction that employs a self-sealing 6–6.5 mm scleral tunnel, provides visual outcomes comparable with phacoemulsification (PHACO) while markedly lowering equipment costs, a critical advantage for high-volume programmes in low-resource settings (2, 3).

The corneal endothelium is essential for stromal deturgescence yet possesses negligible proliferative capacity; excessive postsurgical cell loss therefore risks irreversible decompensation and bullous keratopathy (4). Published series report endothelial cell loss (ECL) after modern PHACO ranging from 4 % to 20 %, influenced by nuclear hardness, cumulative ultrasound energy, and anterior-chamber turbulence (5-7). SICS eliminates ultrasound energy but entails manual nucleus delivery through the tunnel, potentially abrading the endothelium if viscoelastic protection is sub-optimal (8). Evidence directly comparing endothelial outcomes of PHACO and SICS in dense (LOCS-III grade-4) nuclei is limited and conflicting (5, 9).

Accordingly, we conducted a prospective, randomised study to compare postoperative endothelial morphology and visual outcomes after PHACO versus SICS in grade-4 nuclear cataracts at a tertiary centre in North-West India.

## METHODS

### Study Design and Ethics

This single-centre, randomised observational study adhered to the tenets of the Declaration of Helsinki and was approved by the Institutional Ethics Committee of SMS Medical College, Jaipur (IEC/2023/317). Written informed consent was obtained from all participants.

### Participants

Inclusion criteria: age 40–60 y; uncomplicated senile cataract with LOCS-III nuclear grade 4; endothelial cell count > 1500 cells $mm^{-2}$. Exclusion criteria: diabetes mellitus, corneal dystrophy, glaucoma, shallow anterior chamber, ocular trauma or surgery, intra-operative complications.

### Sample Size and Randomisation

Based on a detectable mean ECD difference of 180 cells $mm^{-2}$ (SD = 300), 43 eyes per group were required ($\alpha = 0.05$, $1\text{-}\beta = 0.80$). We enrolled 90 eyes to account for attrition. Randomisation used sealed opaque envelopes generated by a statistician.

### Surgical Techniques

All procedures were performed by a single senior surgeon under peribulbar anaesthesia.

- **PHACO group:** 2.8 mm temporal clear-corneal incision; continuous curvilinear capsulorrhexis; divide-and-conquer nucleus fragmentation using Alcon Laureate (vacuum 450 mmHg, bottle height 135 cm); foldable hydrophilic IOL implantation.
- **SICS group:** 6–6.5 mm superior frown scleral tunnel 2 mm posterior to limbus; capsulorrhexis 6–8 mm; hydroprolapse and visco-expression of nucleus via wire vectis; rigid PMMA IOL implantation.

Balanced salt solution plus and dispersive viscoelastic (2 % HPMC) were used in all cases. Stromal hydration sealed incisions in PHACO; conjunctival apposition with wet-field cautery completed SICS.

### Outcome Measures

Specular microscopy (Topcon SP-3000P) measured ECD, CV, %Hex and CCT pre-operatively, and at 1 week, 6 weeks, and 3 months post-op. UCVA and BCVA were recorded in logMAR. Primary endpoint: %ECL at 3 months. Secondary endpoints: changes in CCT, CV, %Hex, UCVA, BCVA, and adverse events.

### Statistical Analysis

Data were analysed with SPSS v26.0. Normality was assessed with Shapiro–Wilk. Continuous variables are mean ± SD or median (IQR). Inter-group comparisons employed independent-t or Mann–Whitney tests; intra-group changes used paired-t or Wilcoxon tests. Repeated-measures ANOVA evaluated temporal trends. $p < 0.05$ was significant.

## RESULTS

### Baseline Characteristics

Table 1 summarises demographic data; groups were matched for age, sex, baseline ECD, CCT, CV, %Hex, and visual acuity.

Table 1. Baseline Characteristics of Study Eyes

| | PHACO (n = 45) | SICS (n = 45) | p |
|---|---|---|---|
| Age (y, mean ± SD) | 53.98 ± 4.68 | 56.04 ± 3.90 | 0.07 |
| Female:Male | 19 : 26 | 21 : 24 | 0.68 |
| ECD (cells $mm^{-2}$) | 2496 ± 246 | 2411 ± 176 | 0.16 |
| CCT (µm) | 503 ± 80 | 516 ± 25 | 0.28 |
| CV (%) | 33.8 ± 6.1 | 34.4 ± 4.6 | 0.61 |
| %Hex | 59.2 ± 5.0 | 59.9 ± 5.5 | 0.49 |
| BCVA (logMAR) | 0.64 ± 0.17 | 0.71 ± 0.20 | 0.11 |

### Endothelial Cell Density

Mean ECD declined significantly from baseline in both cohorts ($p < 0.001$ each) (Figure 1). At 3 months, ECL was 13.6 ± 2.5 % (PHACO) versus 13.0 ± 1.5 % (SICS); inter-group difference NS ($p = 0.16$).

Table 2. Temporal Change In ECD (Cells $Mm^{-2}$)

| Time-point | PHACO | SICS | p |
|---|---|---|---|
| Pre-op | 2496 ± 246 | 2411 ± 176 | 0.16 |
| 1 wk | 2243 ± 230 | 2188 ± 178 | 0.21 |
| 6 wk | 2180 ± 233 | 2130 ± 168 | 0.24 |
| 3 mo | 2145 ± 233 | 2097 ± 164 | 0.26 |

**Central Corneal Thickness**

CCT increased transiently at week 1 (PHACO +42 µm vs SICS +22 µm; p = 0.04), but values converged by 6 weeks and 3 months (p = 0.80 and 0.55) (Table 3).

**Morphological Indices**

CV rose modestly from 34 % to 38 % in both groups without significant inter-group differences throughout follow-up (p > 0.90). %Hex decreased similarly (≈7 %) in both groups, indicating comparable polymegathism and pleomorphism trends.

**Visual Acuity**

Median UCVA improved from 0.75→0.18 logMAR (PHACO) and 0.83→0.17 logMAR (SICS). BCVA reached ≥0.1 logMAR (6/7.5 Snellen) in 98 % (PHACO) vs 97 % (SICS) at 3 months (p = 0.39).

Table 3. Visual Acuity Outcomes (Logmar)

| Time-point | UCVA PHACO | UCVA SICS | p | BCVA PHACO | BCVA SICS | p |
|---|---|---|---|---|---|---|
| Pre-op | 0.75 ± 0.42 | 0.83 ± 0.22 | 0.27 | 0.64 ± 0.17 | 0.71 ± 0.20 | 0.11 |
| 1 wk | 0.26 ± 0.14 | 0.30 ± 0.15 | 0.21 | 0.16 ± 0.15 | 0.21 ± 0.15 | 0.16 |
| 6 wk | 0.19 ± 0.17 | 0.19 ± 0.14 | 0.98 | 0.06 ± 0.14 | 0.10 ± 0.15 | 0.24 |
| 3 mo | 0.18 ± 0.16 | 0.17 ± 0.15 | 0.82 | 0.06 ± 0.14 | 0.09 ± 0.14 | 0.39 |

**Adverse Events**

No intra-operative posterior capsular rupture, corneal decompensation, cystoid macular oedema, or endophthalmitis occurred.

## DISCUSSION

Our findings show that PHACO and SICS are equivalent in preserving the corneal endothelium, with mean 3-month cell losses of 13.6 % and 13.0 %, respectively—closely mirroring earlier randomised trials that found no clinically important difference between the two techniques (2, 5, 6, 9). The transient spike in central corneal thickness (CCT) at one week—greater after PHACO (+42 µm) than SICS (+22 µm)—echoes previous reports linking early postoperative oedema to reversible endothelial pump stress, with CCT returning to near-baseline by six weeks (7, 10-12). The slightly higher early ECL and CCT in the PHACO arm likely reflect cumulative ultrasound energy and anterior-chamber turbulence (13, 14). Nevertheless, modern torsional platforms and energy-efficient chopping strategies have substantially reduced absolute ultrasound delivery, accounting for the modest inter-group difference observed (15). By contrast, SICS avoids ultrasound but relies on mechanical nucleus expression; meticulous viscodissection and continuous endothelial coating—as advocated in earlier studies—can keep cell loss below 15 % (8, 16). Polymegathism (rise in coefficient of variation) and pleomorphism (decline in hexagonality) followed similar trajectories in both groups, indicating comparable endothelial stress and remodelling (9). Functionally, median best-corrected visual acuity improved to ≤0.1 logMAR (~6/7.5 Snellen) in >97 % of eyes irrespective of technique, corroborating large community-based trials from Nepal and India that reported near-identical visual outcomes for PHACO and SICS (2, 3). From a programme-planning perspective, SICS remains highly attractive: it requires inexpensive, reusable instruments, no phaco machine or power backup, and has a short learning curve while delivering PHACO-like safety and efficacy (3). Our results therefore support continued integration of SICS into high-volume cataract services, especially in resource-constrained environments, without exposing patients to additional endothelial risk. Limitations of this study include single-surgeon performance, a modest sample, and a 3-month follow-up; longer observation could reveal delayed endothelial attrition or late decompensation, particularly in eyes with borderline pre-operative counts (17). Future multicentre trials with extended follow-up and specular-microscopy sub-studies of subclinical endothelial dysfunction would further strengthen the evidence base.

## CONCLUSIONS

Both PHACO and SICS are safe and effective for grade-4 nuclear cataracts, with equivalent endothelial cell loss (~13 %) and excellent visual recovery at 3 months. In settings constrained by cost and technology, SICS provides a pragmatic, high-quality alternative to PHACO without additional endothelial risk.

## REFERENCES


1. Murthy G, Gupta SK, John N, Vashist P. Current status of cataract blindness and Vision 2020 initiative in India. Indian J Ophthalmol. 2008;56:489-94.
2. Ruit S, Tabin G, Chang D, et al. A prospective randomised clinical trial of phacoemulsification versus manual small-incision cataract surgery in Nepal. Am J Ophthalmol. 2007;143:32-38.
3. Gogate P, Ambardekar P, Kulkarni S, et al. Visual outcomes following manual small-incision cataract surgery and phacoemulsification at a rural eye hospital in India. J Cataract Refract Surg. 2010;36:246-53.
4. Hoffer KJ, Kraff MC. Endothelial damage during and after cataract extraction. Ophthalmology. 1980;87:430-40.
5. Ganekal S, Nagarajappa A. Endothelial cell loss after phacoemulsification versus manual small-incision cataract surgery. Middle East Afr J Ophthalmol. 2014;21:56-60.
6. Jagani SN, Lune AA, Magdum RM, et al. Comparative study of endothelial cell loss in phacoemulsification and manual small-incision cataract surgery. Niger J Ophthalmol. 2015;23:54-59.
7. Cheng H, Bates AK, Wood L, McPherson K. Corneal endothelial cell loss during phacoemulsification. Arch Ophthalmol. 1988;106:1208-12.
8. Wilczynski M, Drobniewski I, Synder A, Omulecki W. Early endothelial cell loss after manual small-incision cataract surgery compared with phacoemulsification. Eur J Ophthalmol. 2006;16:798-803.
9. Matsuda M, Suda T, Manabe R. Serial alterations in corneal endothelium after cataract surgery. Am J Ophthalmol. 1984;98:313-19.
10. Ventura AC, Ventura R, Walti R, Bohnke M. Corneal thickness and endothelial loss in phacoemulsification. Br J Ophthalmol. 2001;85:18-20.
11. Kongsap P. Central corneal thickness changes in white cataract after manual small-incision cataract surgery and phacoemulsification. Rom J Ophthalmol. 2019;63:61-67.
12. Deshpande S, Agarwal A, Shah P, Gala Y. Changes in central corneal thickness before and after cataract surgery: manual SICS versus phacoemulsification. Niger J Ophthalmol. 2018;26:35-39.
13. Cameron MD, Poyer JF, Aust SD. Structural and oxidative stresses during phacoemulsification. J Cataract Refract Surg. 2001;27:463-70.
14. Walkow T, Anders N, Klebe S. Endothelial cell loss and posterior capsule opacification after different phaco times. J Cataract Refract Surg. 2000;26:727-32.
15. Christakis PG, Braga-Mele RM. Phacoemulsification energy: comparison of torsional and longitudinal modes. J Cataract Refract Surg. 2012;38:234-41.
16. Thakur SK D, Dan A, Singh MI, et al. Endothelial cell loss following manual small-incision cataract surgery in Nepal. Nepal J Ophthalmol. 2011;3:177-80.
17. Olsen T. Long-term variations in corneal endothelial cell morphology after intracapsular cataract extraction. Acta Ophthalmol (Copenh). 1979; 57:1014-29.