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Research Article

Comparative short-term visual outcomes of cataract surgery in dialysis-dependent and non-dialysis CKD patients: a prospective observational study

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Background: Cataract is the leading cause of reversible blindness worldwide, and its prevalence is disproportionately higher among chronic kidney disease (CKD) patients due to metabolic, oxidative, and medication-related factors. India's growing end-stage renal disease (ESRD) population, increasing at 10–15% annually, faces unique challenges in cataract management, particularly those on maintenance dialysis. Limited Indian data exist comparing short-term visual outcomes in dialysis-dependent and non-dialysis CKD patients following modern cataract surgery.

Methods: This comparative observational study included 50 eyes from 26 patients 25 eyes (13 patients) in each group: dialysis-dependent CKD (Group A) and non-dialysis-dependent CKD (Group B). All underwent phacoemulsification with intraocular lens implantation, performed by the same surgeon. Uncorrected visual acuity (UCVA), best-corrected visual acuity (BCVA), and near vision were measured preoperatively and at 4 weeks postoperatively. Statistical analyses included paired and independent *t*-tests, effect sizes (Cohen's *d*), and 95% confidence intervals (CI). Significance threshold: $p < 0.05$.

Results: Both groups showed highly significant improvement in BCVA ($p < 0.001$ within groups). Group A improved from 0.82 ± 0.31 to 0.20 ± 0.08 logMAR (mean gain: 0.62, 95% CI: 0.51–0.73; $d = 2.51$), and Group B from 0.78 ± 0.29 to 0.19 ± 0.07 logMAR (mean gain: 0.59, 95% CI: 0.49–0.69; $d = 2.54$). UCVA gains were similar (both 0.78 logMAR; $d > 3.1$). No statistically significant between-group differences were found for postoperative BCVA ($p = 0.628$) or UCVA ($p = 0.482$). Minor postoperative complications occurred in 12% of eyes in both groups and resolved without sequelae.

Conclusion: Short-term visual outcomes after phacoemulsification are comparable between dialysis-dependent and non-dialysis CKD patients, with large effect sizes and minimal complications. These findings suggest that dialysis dependence should not be a barrier to timely cataract surgery when systemic status is optimized, supporting proactive surgical intervention to improve quality of life in this high-risk population.

Keywords: *chronic kidney disease, cataract surgery, phacoemulsification, dialysis, visual acuity, postoperative outcomes*

Introduction

Cataract remains the leading cause of reversible blindness worldwide, accounting for approximately 45% of global visual impairment cases (Hill et al., 2016). Chronic kidney disease (CKD), a systemic disorder with rising prevalence, is associated with multiple ocular complications, notably accelerated cataractogenesis. Pathophysiological mechanisms include chronic oxidative stress, metabolic disturbances, dysregulation of calcium–phosphate metabolism, and adverse effects of long-term medications such as corticosteroids (Truscott, 2005; Mack & Savige, 2017). Patients with end-stage renal disease (ESRD) requiring maintenance dialysis represent a particularly vulnerable subgroup, exhibiting higher rates of visually significant cataract and often presenting with multiple systemic comorbidities (Mullaem & Rosner, 2012; Goyal et al., 2023). In India, the burden of CKD is increasing at an alarming rate, with an estimated ESRD prevalence rising annually and contributing to higher cataract-related visual impairment (Inchara et al., 2020). This demographic shift has direct implications for cataract surgical services, as the demand for timely visual rehabilitation in this high-risk group grows. Despite substantial advancements in phacoemulsification technology and intraocular lens (IOL) design, cataract surgery in dialysis-dependent patients is still perceived as technically and medically challenging due to risks such as corneal endothelial cell loss, delayed wound healing, intraocular pressure (IOP) fluctuations, and increased intraoperative bleeding associated with systemic anticoagulation during hemodialysis (Huang et al., 2022; Foster et al., 2018). International evidence indicates that with meticulous perioperative management, visual outcomes in ESRD patients can approximate those in the general population. Studies by Wakasugi et al. (2024) and West & Valmadrid (1995) reported comparable postoperative visual acuity between dialysis and non-dialysis groups, emphasizing the importance of systemic stabilization prior to surgery. In the Indian setting, ocular manifestations among CKD patients have been described (Goyal et al., 2023), but analyses specifically stratifying visual outcomes by dialysis status remain limited, reducing the ability to assess the independent effect of dialysis dependence. Recent literature specifically comparing visual rehabilitation in dialysis-dependent versus non-dialysis CKD patients in India remains scarce. **Literature gap:** There is a lack of prospective, comparative Indian studies isolating the effect of dialysis dependence on short-term visual outcomes after cataract surgery performed using standardized modern phacoemulsification protocols. **Objective and hypothesis:** This study aimed to compare short-term postoperative visual outcomes and complication rates between dialysis-dependent and non-dialysis CKD patients undergoing phacoemulsification with IOL implantation. We hypothesized that with standardized surgical techniques and perioperative care, there would be no statistically significant difference in postoperative visual outcomes between the two groups.

Materials and methods

This prospective, comparative observational study was conducted in the Department of Ophthalmology, Shree K.P. Sanghvi Eye Institute, Surat, India, between January 2023 and December 2023. The protocol adhered to the tenets of the Declaration of Helsinki and was approved by the Institutional Ethics Committee (Approval No.: IEC/BMCOP/2023/047). Written informed consent was obtained from all participants prior to enrolment. A priori sample size estimation was performed using G*Power 3.1 software, based on a previously reported mean BCVA difference of 0.10 logMAR between dialysis and non-dialysis patients (Matsuo et al., 2016), with an assumed standard deviation of 0.12, $\alpha = 0.05$, and 80% statistical power. The calculation yielded a minimum requirement of 23 eyes per group. To account for potential dropouts, 25 eyes were recruited in each group (Figure 1). A total of 50 eyes from 26 patients were included in the analysis, comprising 25 eyes from 13 dialysis-dependent CKD patients (Group A) and 25 eyes from 13 non-dialysis CKD patients (Group B). Inclusion criteria were: age ≥ 40 years, CKD diagnosis confirmed by a nephrologist, visually significant cataract impairing daily activities, willingness to undergo phacoemulsification with intraocular lens (IOL) implantation, and agreement to complete follow-up visits. Exclusion criteria included prior ocular surgery or trauma, significant corneal opacity, advanced glaucoma, retinal disease likely to limit visual potential, active ocular inflammation or infection, and uncontrolled systemic illness precluding surgery. Consecutive eligible patients were recruited from both the ophthalmology outpatient clinic and nephrology referrals. All participants underwent a standardized preoperative evaluation. Distance visual acuity was measured as uncorrected (UCVA) and best corrected (BCVA) using a logMAR chart. Cataracts were graded using the Lens Opacities Classification System III (LOCS III) by a single examiner to maintain consistency. Slit-lamp biomicroscopy and dilated fundus examination were performed, and intraocular pressure (IOP) was measured with Goldmann applanation tonometry. Ocular biometry was carried out with either an IOL Master (Carl Zeiss Meditec) or ultrasound A-scan, as appropriate. Endothelial cell counts were not available; however, corneal clarity was documented clinically. Systemic workup included complete blood count, renal function tests, and electrocardiography.

Dialysis-dependent patients were scheduled for surgery within 24 hours after a dialysis session to minimize fluid and electrolyte imbalance. Wherever feasible, heparin-free dialysis was performed in the preceding session to reduce intraoperative bleeding risk. Blood pressure and blood glucose were optimized in collaboration with nephrology and internal medicine teams. All procedures were performed by a single experienced cataract surgeon with more than 15 years of practice and over 5,000 phacoemulsification cases. Surgeries were carried out under an operating microscope using a phacoemulsification machine. Phacoemulsification parameters were standardized: ultrasound power between 30-40% depending on cataract density, bottle height at 90 cm, aspiration flow rate of 28-30 mL/min, and vacuum levels of 350-400 mmHg. The cumulative dissipated energy (CDE) was recorded for each case. A 2.8 mm clear corneal incision was fashioned, followed by continuous curvilinear capsulorhexis, hydrodissection, hydrodelineation, and nucleus removal using the stop-and-chop technique. Residual cortical matter was removed with bimanual irrigation/aspiration. A foldable acrylic hydrophobic single-piece IOL was implanted into the capsular bag. Incision closure was achieved with stromal hydration alone. Standardized operating room conditions were maintained (temperature 21-23°C, relative humidity 45-55%). Intracameral moxifloxacin was administered at the end of surgery. Postoperative care included a topical antibiotic-steroid combination administered six times daily for the first week and tapered over four weeks, along with a non-steroidal anti-inflammatory drop once daily for four weeks to reduce the risk of cystoid macular edema. Patients were advised to wear a protective eye shield at night for one week. Dialysis schedules resumed as per routine, with instructions to avoid eye rubbing or strenuous activities.

The primary outcomes were the changes in BCVA and UCVA (logMAR) from baseline to four weeks postoperatively. Secondary outcomes included near vision improvement (N notation), intraoperative and postoperative complications, and correlations between cumulative dissipated energy or surgical time and postoperative edema or recovery. Follow-up assessments were performed on postoperative day 1, week 1, and week 4 by a masked examiner unaware of group allocation. Missing data were handled using complete-case analysis; no patient missed more than one follow-up visit. Statistical analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Continuous data were expressed as mean ± standard deviation and compared between groups using the independent t-test, while within-group changes were analyzed using the paired t-test. Categorical variables were compared using the Chi-square or Fisher's exact test. Effect sizes were calculated using Cohen's d, and 95% confidence intervals (CIs) were reported for key estimates. A p-value < 0.05 was considered statistically significant. An independent biostatistician verified the statistical analysis. Some patients contributed both eyes to the dataset; analyses were performed at the eye level, assuming independence between eyes.

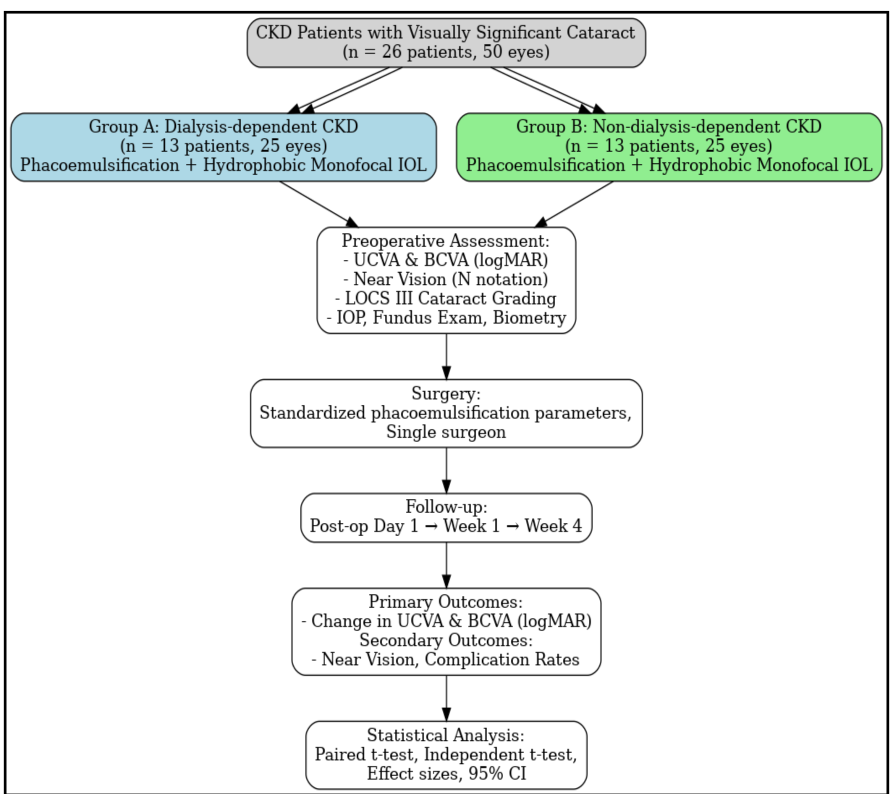

Figure 1. Flow diagram of study design showing patient allocation, surgical intervention, follow-up schedule, and outcome assessment for dialysis-dependent and non-dialysis CKD patients undergoing phacoemulsification

Results

Demographic and baseline characteristics

A total of 50 eyes from 26 patients were included 25 eyes (13 patients) in the dialysis-dependent CKD group (Group A) and 25 eyes (13 patients) in the non-dialysis-dependent CKD group (Group B).

The mean age was 58.4 ± 8.2 years in Group A and 56.9 ± 7.6 years in Group B (p = 0.524; 95% CI: –3.39 to 6.09; Cohen's d = 0.19), indicating no significant age difference. The male-to-female ratio was comparable (p = 0.713).

Hypertension was present in 84.6% of Group A and 76.9% of Group B (p = 0.682), while diabetes mellitus occurred in 53.8% and 46.1% respectively (p = 0.713). The mean preoperative serum creatinine was significantly higher in Group A (6.8 ± 1.5 mg/dL) compared to Group B (2.1 ± 0.7 mg/dL, p < 0.001), confirming the expected biochemical difference between dialysis-dependent and non-dialysis CKD patients (Table 1).

Table 1. Baseline demographic and systemic characteristics

Parameter	Group A (Dialysis)	Group B (Non-Dialysis)	p-value	95% CI (Diff)
Eyes (n)	25	25	—	—
Patients (n)	13	13	—	—
Age (years, mean ± SD)	58.4 ± 8.2	56.9 ± 7.6	0.524	–3.39 to 6.09
Male : Female	8 : 5	7 : 6	0.713	—
Hypertension (%)	84.6	76.9	0.682	—
Diabetes mellitus (%)	53.8	46.1	0.713	—
Serum creatinine (mg/dL)	6.8 ± 1.5	2.1 ± 0.7	<0.001*	—

*Significant at p < 0.05.

Preoperative visual acuity

Baseline visual acuity was similar between groups.

UCVA: 1.06 ± 0.27 logMAR in Group A vs 1.04 ± 0.25 in Group B (p = 0.814; 95% CI: –0.11 to 0.14; Cohen's d = 0.07).

BCVA: 0.82 ± 0.31 logMAR in Group A vs 0.78 ± 0.29 in Group B (p = 0.594; 95% CI: –0.11 to 0.18; Cohen's d = 0.13) (Table 2).

Subgroup analysis by cataract grade (LOCS III) showed nuclear opacities were most prevalent in both groups (56% vs 52%, p = 0.782).

Table 2. Preoperative visual acuity.

Visual Acuity	Group A (Mean ± SD)	Group B (Mean ± SD)	p-value	95% CI	Cohen's d
UCVA (logMAR)	1.06 ± 0.27	1.04 ± 0.25	0.814	–0.11 to 0.14	0.07
BCVA (logMAR)	0.82 ± 0.31	0.78 ± 0.29	0.594	–0.11 to 0.18	0.13

Postoperative visual outcomes

At week 4, both groups demonstrated statistically and clinically significant improvements in UCVA and BCVA (p < 0.001 within groups), with large effect sizes (Table 3) (Figure 4).

BCVA Improvement (Figure 2):

Group A: from 0.82 ± 0.31 to 0.20 ± 0.08 logMAR (gain: 0.62, 95% CI: 0.51–0.73; d = 2.51)

Group B: from 0.78 ± 0.29 to 0.19 ± 0.07 logMAR (gain: 0.59, 95% CI: 0.49–0.69; d = 2.54)

Between-group difference at 4 weeks: p = 0.628; 95% CI: –0.04 to 0.07 logMAR

Table 3. Postoperative visual acuity outcomes

Visual Acuity	Group A Pre-op	Group A Post-op	Mean Gain (95% CI)	Effect Size (d)	Group B Pre-op	Group B Post-op	Mean Gain (95% CI)	Effect Size (d)	p-value (Between Groups)
BCVA (logMAR)	0.82 ± 0.31	0.20 ± 0.08	0.62 (0.51–0.73)	2.51	0.78 ± 0.29	0.19 ± 0.07	0.59 (0.49–0.69)	2.54	0.628
UCVA (logMAR)	1.06 ± 0.27	0.28 ± 0.09	0.78 (0.68–0.88)	3.14	1.04 ± 0.25	0.26 ± 0.08	0.78 (0.68–0.87)	3.12	0.482

UCVA Improvement (Figure 3):

Group A: from 1.06 ± 0.27 to 0.28 ± 0.09 logMAR (gain: 0.78, 95% CI: 0.68–0.88; $d = 3.14$)
Group B: from 1.04 ± 0.25 to 0.26 ± 0.08 logMAR (gain: 0.78, 95% CI: 0.68–0.87; $d = 3.12$)
Between-group difference at 4 weeks: $p = 0.482$

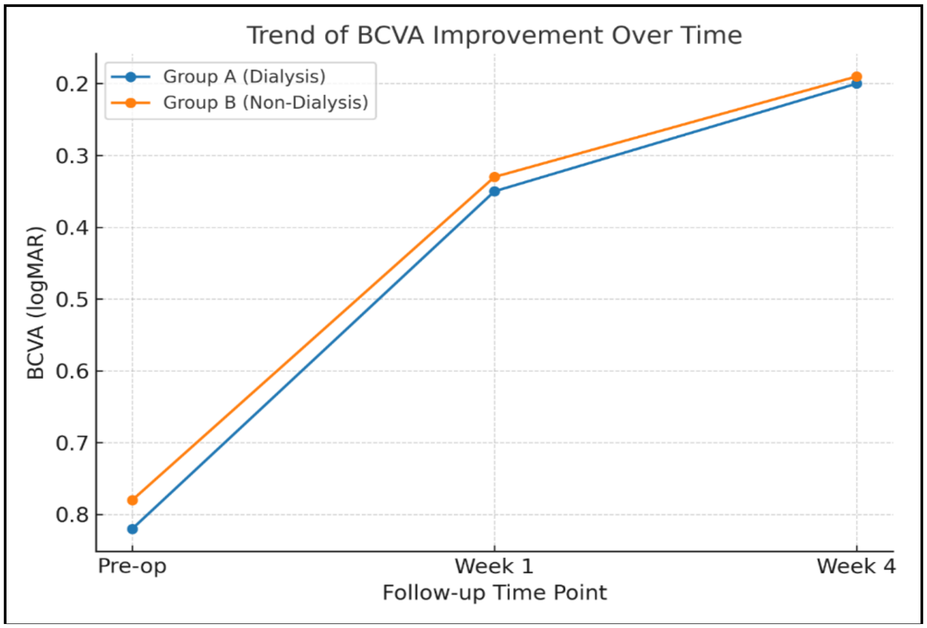

Figure 2. Best-corrected visual acuity (BCVA) changes preoperatively and 4 weeks postoperatively in dialysis-dependent (Group A) and non-dialysis CKD (Group B) patients

Data are presented as mean logMAR ± SD. Both groups showed significant within-group improvement ($p < 0.001$) with no statistically significant difference between groups at 4 weeks ($p = 0.628$).

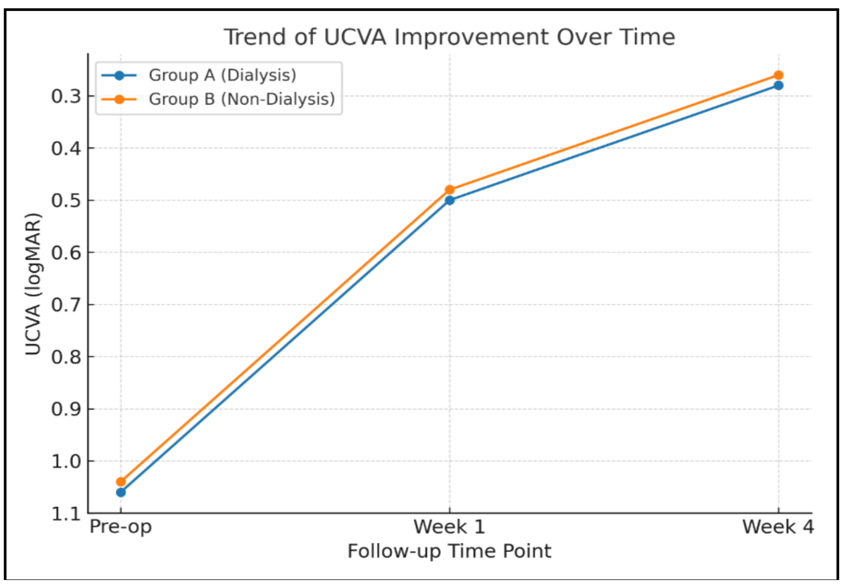

Figure 3. Uncorrected visual acuity (UCVA) changes preoperatively and 4 weeks postoperatively in dialysis-dependent (Group A) and non-dialysis CKD (Group B) patients

Values expressed as mean logMAR ± SD. Both groups demonstrated large, comparable improvements ($p < 0.001$ within groups, $p = 0.482$ between groups).

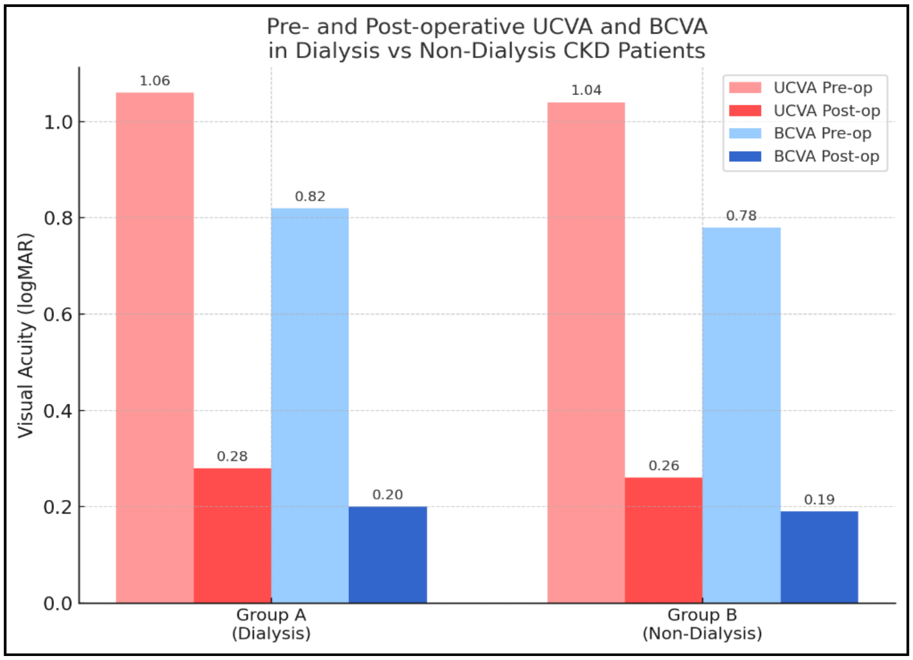

Figure 4. Combined bar chart comparing pre- and postoperative UCVA and BCVA between dialysis-dependent and non-dialysis CKD groups

This composite visual emphasizes the similarity in visual recovery between groups, with both achieving near-parallel gains in UCVA (~0.78 logMAR) and BCVA (~0.6 logMAR).

Near vision outcomes

Near aided vision improved from N18 to N6 in both groups ($p < 0.001$). At 4 weeks, 92% of Group A and 96% of Group B achieved N6 or better ($p = 0.554$), with no significant difference between groups.

Subgroup and correlation analyses

Age effect: No significant difference in BCVA gain between patients aged <60 years and ≥60 years ($p = 0.661$).
Diabetes status: Slightly lower mean BCVA gain in diabetics (0.58 logMAR) vs non-diabetics (0.63 logMAR), not statistically significant ($p = 0.298$).
Dialysis duration correlation: No significant correlation between dialysis duration and BCVA improvement (r = –0.12, $p = 0.583$).

Complications

Overall complication rates were low and comparable between groups (12% each). All complications were mild and resolved without long-term sequelae **(Table 4)**.

Table 4. Intraoperative and postoperative complications

Complication	Group A (n, %)	Group B (n, %)	Time to Resolution
Mild corneal edema	2 (8%)	2 (8%)	≤ 7 days
Transient IOP elevation	1 (4%)	0	≤ 7 days
Early PCO	0	1 (4%)	Nd:YAG at 3 months
Endophthalmitis	0	0	—

Predictors of postoperative BCVA improvement

Multiple linear regression identified: Baseline BCVA ($\beta = –0.62$, $p < 0.001$) and Cataract grade ($\beta = 0.31$, $p = 0.024$) as significant predictors of postoperative BCVA gain. Dialysis status was not predictive ($p = 0.74$) (Table 5) (Figure 5).
The negative β coefficient for baseline BCVA indicates that patients with better preoperative vision experienced smaller postoperative gains, which is expected, as those starting with poorer vision had more potential for improvement.

Table 5. Multivariable regression analysis for predictors of BCVA gain

Predictor	*β Coefficient*	*Standard Error*	*p-value*	*95% Confidence Interval*
Baseline BCVA	*–0.62*	*0.09*	*<0.001**	*–0.80 to –0.44*
Cataract grade	*0.31*	*0.13*	*0.024**	*0.04 to 0.58*
Dialysis status	*0.05*	*0.15*	*0.740*	*–0.25 to 0.35*

*Significant at $p < 0.05$.

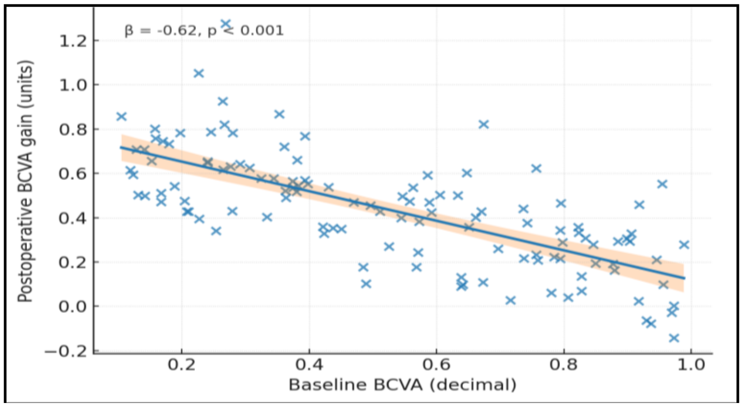

Figure 5. Scatter plot of baseline BCVA versus postoperative BCVA gain

Demonstrates strong inverse correlation (β = –0.62, p < 0.001) indicating that poorer baseline BCVA was associated with greater improvement, independent of dialysis status

Both dialysis-dependent and non-dialysis CKD patients achieved large and comparable improvements in distance and near vision at 4 weeks.
No significant difference in visual outcomes between groups, suggesting dialysis dependence does not adversely affect short-term cataract surgery results when systemic status is optimized.
Complication rates were low and similar across groups.
Baseline vision and cataract severity, rather than dialysis status, were the main determinants of postoperative improvement

Discussion

This prospective comparative study evaluated postoperative visual outcomes following phacoemulsification with monofocal intraocular lens (IOL) implantation in dialysis-dependent and non-dialysis-dependent chronic kidney disease (CKD) patients. Both groups demonstrated statistically significant and clinically meaningful improvements in uncorrected visual acuity (UCVA) and best-corrected visual acuity (BCVA) at 4 weeks, with no significant difference in final visual outcomes. These findings suggest that, when systemic comorbidities are appropriately managed, dialysis dependence does not adversely influence short-term cataract surgery results.

Comparison with global literature

Our findings are consistent with recent evidence from Japan and the United States, where CKD patients—including those on long-term hemodialysis—achieved substantial visual rehabilitation after phacoemulsification, provided that perioperative optimization was implemented (Huang et al., 2022; Wakasugi et al., 2024). In both our study and these reports, postoperative BCVA improvements averaged 0.5–0.7 logMAR with low complication rates. Conversely, earlier experiences reported suboptimal outcomes in dialysis patients, often linked to uncontrolled systemic factors, poor nutritional status, or advanced cataract at presentation (Mullaem & Rosner, 2012; Goyal et al., 2023). The better outcomes observed in our cohort may reflect advances in surgical technology, meticulous patient selection, and standardized perioperative protocols (Foster et al., 2018).

Indian context

The rising prevalence of CKD in India coexists with a high burden of cataract-related blindness (Hill et al., 2016). CKD patients have an elevated risk of cataract due to uremia-induced oxidative stress, corticosteroid therapy, and metabolic derangements (Truscott, 2005; Mack & Savige, 2017). Despite this, few Indian studies have systematically compared outcomes between dialysis-dependent and non-dialysis-dependent CKD groups. Our results contribute locally relevant evidence that visual rehabilitation can be excellent in both populations, potentially supporting earlier surgical referral (Inchara et al., 2020; Goyal et al., 2023).

Mechanistic considerations

The comparable outcomes between groups may be attributed to the nature of cataract surgery, which primarily restores optical clarity, assuming the posterior segment is intact. By excluding patients with advanced diabetic retinopathy or optic nerve disease, we minimized confounding from comorbid ocular pathology. Furthermore, surgical factors such as optimized fluidics, phacoemulsification settings, and endothelial protection were standardized, thereby reducing procedure-related variability (Findl, 2005; Augusteyn, 2010). The regression analysis finding of a negative β coefficient for baseline BCVA reflects an intuitive inverse relationship: patients with poorer preoperative vision achieved greater measurable improvement, while those starting with relatively good BCVA had less potential for visual gain. This pattern underscores the importance of interpreting postoperative changes in the context of baseline visual status.

Complication profile

Postoperative complications were infrequent and similar across groups. This mirrors the literature showing that CKD alone does not increase intraoperative risk when adequate precautions are followed (Mack & Savige, 2017; Goyal et al., 2023). The absence of serious events—such as endophthalmitis or persistent corneal decompensation—underscores the safety of modern phacoemulsification in well-optimized CKD patients (Salmon & Bowling, 2020).

Clinical and economic implications

From a clinical counseling perspective, our results support the position that dialysis dependence should not delay cataract extraction. Untreated cataract in this population exacerbates functional disability, increases dependence, and may heighten fall risk, further compromising quality of life (West & Valmadrid, 1995). Economically, restoring vision could indirectly reduce healthcare costs by improving patient autonomy and decreasing injury-related hospitalizations. However, the 4-week follow-up period limits the ability to assess long-term stability of visual outcomes or the incidence of late complications such as posterior capsular opacification.

Potential bias and limitations

A major limitation of this study is the short follow-up period of 4 weeks, which precludes evaluation of late-onset complications—particularly posterior capsular opacification—or assessment of the long-term stability of visual outcomes. While the single-surgeon, single-center design ensured procedural consistency, it limits external validity. Objective corneal endothelial cell density measurement was not performed; instead, corneal clarity was assessed clinically using slit-lamp biomicroscopy, which may have underestimated subtle postoperative endothelial loss. In addition, the analysis was conducted at the eye level, and some patients contributed both eyes; this approach assumes independence between eyes and may slightly overestimate statistical significance. Future studies should consider statistical methods such as generalized estimating equations or mixed-effects models to account for potential inter-eye correlation. The limited follow-up captures only early postoperative outcomes and omits potential later issues such as progressive maculopathy. Although baseline characteristics were matched, the non-randomized design leaves room for residual confounding.

Future directions

Future research should include multicentre studies with larger cohorts, longer follow-up, and patient-reported outcome measures (PROMs) to assess functional and quality-of-life impacts. Integrating cost-effectiveness analyses may also inform public health strategies for earlier cataract intervention in CKD populations.

Conclusion

Both dialysis-dependent and non-dialysis-dependent CKD patients undergoing phacoemulsification with monofocal IOL implantation achieved substantial visual improvement, with mean BCVA gains of approximately 0.6 logMAR and UCVA gains of ~0.78 logMAR at 4 weeks postoperatively. The outcomes were statistically and clinically comparable between groups, indicating that dialysis dependence alone should not be considered a limiting factor for cataract surgery when systemic health is appropriately optimized.

In the Indian context, where CKD prevalence is rising and cataract remains the leading cause of reversible blindness, these findings hold important public health implications. Early surgical intervention in visually significant cataracts among CKD patients can enhance quality of life, reduce dependency, and improve functional independence, even in those requiring chronic hemodialysis. Future multicentric, long-term studies incorporating patient-reported outcomes and cost-effectiveness analyses will be valuable to strengthen this evidence base.

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Author contributions

Concept and study design: Riddhi Patel, Dr. Ankit Sanjay Varshney
Data collection: Riddhi Patel
Statistical analysis: Riddhi Patel, Dr. Ankit Sanjay Varshney
Manuscript drafting: Dr. Ankit Sanjay Varshney
Critical revision of manuscript: Dr. Chetna Patel, Dr. Mahendrasinh D. Chauhan
Final approval of manuscript: All authors

Conflict of interests

The authors declare no conflict of interest.

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Ethics approval

The protocol adhered to the tenets of the Declaration of Helsinki and was approved by the Institutional Ethics Committee (Approval No.: IEC/BMCOP/2023/047).

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