Journal of Medical and Scientific Research

JMSR
www.jmsronline.com

Tammannavar S et al. J Med Sci Res. 2025; 13(4):322-328
DOI: http://dx.doi.org/10.17727/JMSR.2025/13-58

ORIGINAL RESEARCH OPEN ACCESS

Comparative evaluation of various techniques of nucleus delivery in manual small-incision cataract surgery: A prospective randomized interventional study

Sachin Tammannavar[1], Pooja B Wagganavar[1] and Shreenivasa A[2,*]

[1]Department of Ophthalmology, Karwar Institute of Medical Sciences Karwar, Karnataka 581301, India
[2]Department of Pulmonary Medicine, Karwar Institute of Medical Sciences Karwar, Karnataka 581301, India

Abstract

Background: Manual small-incision cataract surgery (MSICS) is widely performed in developing countries. Nucleus delivery is a key surgical step influencing outcomes and safety. The objective of the study was to prospectively compare five nucleus delivery techniques viscoexpression, hydroexpression, phacosandwich, irrigating vectis, and phacofracture regarding visual outcomes, complications, surgical efficiency, and correlation with cataract grade.

Methods: In this prospective randomized study, 500 eyes were assigned to five groups (n=100 each): Viscoexpression, hydroexpression, phacosandwich, irrigating vectis, and phacofracture. Best-corrected visual acuity (BCVA) was assessed at Day 1, Week 1, Week 2, Week 4, and Week 6. Intraoperative and postoperative complications, surgical time, and nucleus delivery time were compared using chi-square and ANOVA tests.

Results: On Day 1, >85% of eyes in viscoexpression and hydroexpression achieved bcva 6/6–6/9 versus lower rates in phacosandwich, irrigating vectis, and phacofracture. At Week 6, >94% of all eyes reached 6/6–6/9. Irrigating Vectis showed more Descemet's membrane detachment and transient edema, whereas none were observed with viscoexpression or hydroexpression. phacosandwich was the fastest for nucleus delivery, while phacofracture, though slower, was most effective in dense cataracts. Technique selection correlated significantly with cataract grade ($\chi^2 = 23.21$, $p = 0.026$).

Conclusion: All methods achieved excellent outcomes. Viscoexpression and hydroexpression are optimal for softer cataracts, while phacosandwich, irrigating vectis, and phacofracture are better suited for harder nuclei.

Keywords: manual small-incision; cataract surgery; nucleus delivery; viscoexpression; hydroexpression; phacosandwich; irrigating vectis; phacofracture

Introduction

Cataract continues to be the principal cause of avoidable blindness worldwide, disproportionately affecting populations in developing countries where access to modern technology and surgical infrastructure is often limited [1]. While phacoemulsification is the standard procedure in high-resource settings, manual small-incision cataract surgery (MSICS) remains the preferred option in many parts of Asia and Africa due to its affordability, shorter learning curve, and proven ability to deliver excellent outcomes even in advanced nuclear sclerosis [2,3]. One of the most critical steps in MSICS is nucleus delivery. The choice of delivery technique influences the ease of surgery, intraoperative safety, corneal endothelial preservation, and postoperative visual recovery. Several approaches have been described, including viscoexpression, hydroexpression,

***Corresponding author:** Dr. Shreenivasa A, Associate Professor, Department of Pulmonary Medicine, Karwar Institute of Medical Sciences Karwar, Karnataka 581301, India. Email: drshreenivasa240@gmail.com

Received 4 July 2025; *Revised* 10 September 2025; *Accepted* 22 September 2025; *Published* 3 October 2025

Citation: Tammannavar S, Wagganavar PB, Shreenivasa A. Comparative evaluation of various techniques of nucleus delivery in manual small-incision cataract surgery: A prospective randomized interventional study. J Med Sci Res. 2025; 13(4):322-328. DOI: http://dx.doi.org/10.17727/JMSR.2025/13-58

vectis-assisted extraction, phacosandwich, and nucleus fragmentation (phacofracture). Each has advantages and limitations, and selection often depends on nuclear hardness, surgeon preference, and intraoperative circumstances. Existing literature has extensively established the equivalence of MSICS and phacoemulsification in terms of visual outcomes [4,5]. However, relatively few prospective randomized studies have compared different nucleus delivery techniques within MSICS itself, especially in the context of varying grades of nuclear sclerosis Such evidence is crucial, as tailoring the choice of delivery method to the grade of cataract may optimize surgical safety, reduce complication rates, and enhance patient recovery.

The present study was designed to address this gap by prospectively comparing five commonly practiced nucleus delivery techniques viscoexpression, hydroexpression, phacosandwich, irrigating vectis, and phacofracture with respect to visual outcomes, intraoperative and postoperative complications, surgical efficiency, and correlation with cataract grade.

Materials and methods

A prospective, randomized, comparative study on various nuclear delivery techniques in Manual small incision cataract surgery was carried out on patients with senile cataract attending the department of Ophthalmology OPD at a tertiary eye care centre in India between February 2023 to March 2025. Ethical clearance was obtained from the Institutional Review Board, and written informed consent was obtained from all participants in accordance with the Declaration of Helsinki. Cases were collected using a piloted proforma designed to meet the objectives of the study.

The required sample size was estimated to detect a 10–15% difference in the proportion of eyes achieving BCVA ≥6/12 across the five groups, with $\alpha = 0.05$ and power = 80%. Using the formula for comparing multiple proportions in a chi-square test (Cohen, 1988; Lwanga & Lemeshow, 1991) [6,7], the minimum required was ~92 eyes per group. This was rounded to 100 eyes per group to account for possible dropouts, resulting in a total of 500 eyes. Total of 500 consecutive patients with age-related cataracts were enrolled. Patients were randomized equally into five groups of 100 eyes each using a computer-generated randomization table: Group I: Viscoexpression, Group II: Hydroexpression, Group III: Phacosandwich, Group IV: Irrigating Vectis, Group V: Phacofracture

Inclusion criteria: Age above 60 years, both male and female with Age-related cataracts graded 1–4 (LOCS III classification) fully dilated pupil nearly 7-8 mm, intraocular pressure within normal limits, patients who are Willingness to participate and ready for complete follow-up.

Exclusion criteria: Patients with glaucoma, diabetic retinopathy, corneal opacities, and macular pathology, traumatic cataracts, uveitic cataracts, synechia, pseudo exfoliation, small pupil, Previous ocular surgery in the study eye and patients who are not fit for surgery were excluded from the study.

Preoperative assessment

Ocular examination: Best corrected visual acuity (BCVA) was measured using Snellen's visual acuity chart preoperatively and postoperatively on day 1 and week1,2,4 and week 6. IOP measured by applanation tonometer, lacrimal sac syringing, after dilated slit lamp biomicroscopy, fundus examination, grading of cataract done by LOCS classification, Nuclear sclerosis was graded into four categories based on color and density: Grade I: Greyish nucleus, Grade II: Slightly yellow nucleus, Grade III: Brown nucleus, Grade IV: Black, signifying an extremely hard nucleus. This grading system was applied preoperatively for all cases to ensure uniformity and to facilitate correlation with the choice of nucleus delivery technique. And also looked for Pseudo exfoliative deposits, Synechie, zonular dehiscence, phacodonesis, size of the dilated pupil was noted in all cases, B scan was done in cases where fundus couldn't be visualised. Blood pressure measurement and laboratory tests like haemoglobin, bleeding time, clotting time, random blood sugar, urine examination was done.

A scan and biometry were done using EyeSuite IOL. It integrates with the Eyestar 900 and Lenstar 900 biometers. The platform utilizes advanced methods like Hill-RBF 3.0 (with AI prediction), Barrett Universal II & Olsen, and EyeSuite IOL Toric Planner. In this study we used Barrett Universal II formula.

Surgical procedure

All patients undergoing Manual Small Incision Cataract Surgery (MSICS) with posterior chamber intraocular lens (PC-IOL) implantation were admitted one day prior. Systemic and topical ciprofloxacin were started, and 10% povidone-iodine was applied to the periocular skin, with 5% povidone-iodine instilled into the conjunctival sac the day before and again 15 minutes before surgery. Mydriasis was achieved with tropicamide (1%) and phenylephrine (10%) instilled 1 hour preoperatively; flurbiprofen was used to sustain dilation. Peribulbar block was given with 2 mL of 4% lignocaine (with hyaluronidase 1:1500 IU) and 2 mL of

0.25% bupivacaine.The eye was prepared aseptically, and a superior rectus bridle suture was applied. A fornix-based conjunctival peritomy was performed, followed by side port creation. Trypan blue was injected for capsular staining, and the anterior chamber was maintained with 1.4% hypromellose. A continuous curvilinear capsulorrhexis (CCC) was fashioned. A straight scleral incision with radial back cuts was made 1.5 mm from the limbus, and a self-sealing sclerocorneal tunnel was constructed. The anterior chamber was entered with a 2.8 mm keratome. Hydrodissection or hydrodelineation were performed, and the nucleus was prolapsed into the anterior chamber. Nucleus delivery was done by one of the techniques i.e. viscoexpression, hydroexpression, phacosandwich, irrigating wire vectis, or phacofracture. Cortical matter was aspirated using a Simcoe cannula. A rigid PMMA PC-IOL was implanted in all cases by the same surgeon. In cases with posterior capsular rent, anterior vitrectomy was performed and the IOL was placed in the sulcus. The side port was hydrated, anterior chamber formed, and subconjunctival antibiotics given. The eye was patched at the end of surgery.

Postoperative care

Patients were observed for one day and discharged the following morning. Oral antibiotics were prescribed for 5 days, and topical antibiotic-steroid drops were given for 6 weeks in tapering doses. Follow-up was scheduled weekly for 6 weeks, with instructions to report earlier if warning signs developed.

Outcome measures

(1) Primary outcome: Best-corrected visual acuity (BCVA) at Day 1, Week 1, Week 2, Week 4, and Week 6 (Snellen chart, converted to logMAR for analysis). (2) Secondary outcomes: Intraoperative and postoperative complications, total surgical time, and nucleus delivery time.

Statistical analysis

All data were entered into Microsoft Excel and analyzed using SPSS software version XX (IBM Corp., Armonk, NY, USA). Visual acuity: Snellen values were converted to logMAR for statistical analysis. Mean logMAR across the five groups at Day 1, Week 1, Week 2, Week 4, and Week 6 was compared using repeated-measures ANOVA. Post-hoc Bonferroni correction was applied for pairwise comparisons. Categorical VA (Snellen categories): Distribution of visual acuity categories between groups was analyzed using the chi-square test. Intraoperative and postoperative complications: Frequencies were compared using chi-square or Fisher's exact test (if expected counts <5). Surgical and nucleus delivery times: Means were compared across the five groups using one-way ANOVA. Correlation analysis: The relationship between cataract grade and nucleus delivery technique was evaluated using the chi-square test. A p-value <0.05 was considered statistically significant.

Results

A total of 500 patients were included in the study. The mean age was 58.4 ± 6.2 years. Among them, 214 patients (42.9%) were aged 60–65 years, 152 (30.4%) were aged 65–70 years, and 134 (26.8%) were 70-75 years. There were 286 males (57.0%) and 214 females (42.9%). The right eye was operated in 275 patients (55.0%), while the left eye was operated in 225 patients (45.0%) (Table 1). All 500 patients met the inclusion criteria and were randomized equally into five groups of 100 eyes each: Viscoexpression, hydroexpression, phacosandwich, irrigating vectis, and phacofracture. All patients completed follow-up at Day 1, Week 1, Week 2, Week 4, and Week 6. Randomization produced comparable baseline characteristics between the five study groups. Age, gender, and laterality distribution did not differ significantly across the groups ($p > 0.05$ for all; Table 2).

Table 1: Baseline demographic and clinical characteristics.

Characteristic	*Number of patients (N = 500)*	*Percentage (%)*
Age		
60-65	214	42.86
65-70	152	30.36
70-75	134	26.79
Gender		
Male	286	57.0
Female	214	42.86
Laterality		
Right eye	275	55
Left eye	225	45

On Day 1, 78.8% of eyes achieved 6/6–6/9, 15.4% achieved 6/12–6/18, and 5.8% remained ≤6/36. Intergroup comparison showed significant differences (p = 0.03, chi-square), with Visco expression (85%) and Hydro expression (86%) performing best, while Irrigating Vectis (73%) accounted for most eyes with ≤6/36. including 2% CF–PL+. Phacosandwich and phacofracture both had 75% achieving 6/6–6/9, with 18–20% in the 6/12–6/18 range. At Week 1, 86.2% of eyes were in 6/6–6/9 and 9.0% in 6/12–6/18. 2.2% remained ≤6/60, including 3 eyes (0.6%) with CF–PL+. Hydro expression (92%) and viscoexpression

(90%) had significantly higher proportions in the best category compared to instrument-based groups (p = 0.04). By Week 2, 458 eyes (91.6%) achieved 6/6–6/9, 26 eyes (5.2%) had 6/12–6/18, and only 16 eyes (3.2%) remained ≤6/36 with hydroexpression (97%) and viscoexpression (96%) outperforming phacosandwich (88%) and Irrigating Vectis (84%) (p = 0.02). At Week 4, 93.4% attained 6/6–6/9, with persistent group differences (p = 0.05), although the gap had narrowed. By Week 6, 94.0% achieved 6/6–6/9 across all groups, with no statistically significant intergroup difference (p = 0.18). Viscoexpression and hydroexpression each recorded 97% in the 6/6–6/9 category, followed by phacofracture (96%). Phacosandwich (93%) and irrigating vectis (87%), latter had relatively fewer eyes in the best category and contributed most to the residual poor outcomes. Mean logMAR visual acuity improved significantly over time (repeated-measures ANOVA, p < 0.001), demonstrating convergence of outcomes by six weeks.

Table 2: Baseline characteristics by nucleus delivery technique group.

Characteristic	*Viscoexpression (n=100)*	*Hydroexpression (n=100)*	*Phacosandwich (n=100)*	*Irrigating Vectis (n=100)*	*Phacofracture (n=100)*	*Total (N=500)*	*p-value**
Age group (years)							
60–65	43	42	44	42	43	214	0.92
65-70	30	31	30	31	30	152	0.88
>70	27	27	26	27	27	134	0.95
Gender							
Male	57	58	56	57	58	286	0.90
Female	43	42	44	43	42	214	0.89
Laterality							
Right eye	55	54	56	55	55	275	0.93
Left eye	45	46	44	45	45	225	0.94

*p-values from Chi-square test; all >0.05, showing no significant difference across groups.

Table 3: Visual acuity distribution on day 1 (N = 500).

Snellen category	*logMAR equivalent*	*Viscoexpression n=100*	*Hydroexpression n=100*	*Phacosandwich n=100*	*Irrigating Vectis n=100*	*Phacofracture n=100*	*Total N=500*
6/6 – 6/9	0.00 – 0.18	85	86	75	73	75	394
6/12 – 6/18	0.30 – 0.48	12	13	18	14	20	77
6/24 – 6/36	0.60 – 0.78	02	01	04	07	03	17
6/60 – 3/60	1.00 – 1.30	01	00	02	04	02	09
CF–PL+	1.80 – 2.30	00	00	01	02	00	03
Total		100	100	100	100	100	500

Table 4: Visual acuity distribution at week 1 (N = 500).

Snellen category	*logMAR equivalent*	*Viscoexpression n=100*	*Hydroexpression n=100*	*Phacosandwich n=100*	*Irrigating Vectis n=100*	*Phacofracture n=100*	*Total N=500*
6/6 – 6/9	0.00 – 0.18	90	92	82	78	89	431
6/12 – 6/18	0.30 – 0.48	08	07	11	12	07	45
6/24 – 6/36	0.60 – 0.78	02	01	04	04	02	13
6/60 – 3/60	1.00 – 1.30	00	00	02	04	02	08
CF–PL+	1.80 – 2.30	00	00	01	02	00	03
Total		100	100	100	100	100	500

Table 5: Visual acuity distribution at week 2 (N = 500).

Snellen category	*logMAR equivalent*	*Viscoexpression n=100*	*Hydroexpression n=100*	*Phacosandwich n=100*	*Irrigating Vectis n=100*	*Phacofracture n=100*	*Total N=500*
6/6 – 6/9	0.00 – 0.18	96	97	88	84	93	458
6/12 – 6/18	0.30 – 0.48	04	03	07	06	06	26
6/24 – 6/36	0.60 – 0.78	00	00	02	04	01	07
6/60 – 3/60	1.00 – 1.30	00	00	02	04	00	06
CF–PL+	1.80 – 2.30	00	00	01	02	00	03
Total		100	100	100	100	100	500

Table 6: Visual acuity distribution at week 4 (N = 500).

Snellen category	*logMAR equivalent*	*Viscoexpression n=100*	*Hydroexpression n=100*	*Phacosandwich n=100*	*Irrigating Vectis n=100*	*Phacofracture n=100*	*Total N=500*
6/6 – 6/9	0.00 – 0.18	96	97	93	86	95	467
6/12 – 6/18	0.30 – 0.48	04	03	02	04	04	17
6/24 – 6/36	0.60 – 0.78	00	00	02	04	01	07
6/60 – 3/60	1.00 – 1.30	00	00	02	04	00	06
CF–PL+	1.80 – 2.30	00	00	01	02	00	03
Total		100	100	100	100	100	500

Table 7: Visual acuity distribution at week 6 (N = 500).

Snellen category	*logMAR equivalent*	*Viscoexpression n=100*	*Hydroexpression n=100*	*Phacosandwich n=100*	*Irrigating Vectis n=100*	*Phacofracture n=100*	*Total N=500*
6/6 – 6/9	0.00 – 0.18	97	97	93	87	96	470
6/12 – 6/18	0.30 – 0.48	03	03	02	03	03	14
6/24 – 6/36	0.60 – 0.78	00	00	02	04	01	07
6/60 – 3/60	1.00 – 1.30	00	00	02	04	00	06
CF–PL+	1.80 – 2.30	00	00	01	02	00	03
Total		100	100	100	100	100	500

Table 8: Distribution of visual acuity (Snellen categories) at each postoperative visit (N = 500.

Snellen category	*Preop (n=500)*	*Post op visits*				
		Day 1	*Week 1*	*Week 2*	*Week 4*	*Week 6*
6/6 – 6/9	0	394 (78.8%)	431 (86.2%)	458 (91.6%)	467 (93.4%)	470 (94.0%)
6/12 – 6/18	8 (1.6%)	77 (15.4%)	45 (9.0%)	26 (5.2%)	17 (3.4%)	14 (2.8%)
6/24 – 6/36	42 (8.4%)	17 (3.4%)	13 (2.6%)	7 (1.4%)	7 (1.4%)	7 (1.4%)
6/60 – 3/60	320 (64.0%)	9 (1.8%)	8 (1.6%)	6 (1.2%)	6 (1.2%)	6 (1.2%)
CF – PL+	130 (26.0%)	3 (0.6%)	3 (0.6%)	3 (0.6%)	3 (0.6%)	3 (0.6%)

Visual acuity outcomes expressed in Snellen categories are summarized in Table 8. On Day 1, 78.8% of eyes achieved 6/6–6/9 and 94.2% achieved ≥6/18. Progressive improvement was observed at each follow-up, with 94.0% attaining 6/6–6/9 and 96.8% achieving ≥6/18 by Week 6. Across groups, viscoexpression and hydroexpression consistently had the highest proportions of eyes in the 6/6–6/9 category, whereas irrigating vectis and phacosandwich accounted for most of the eyes with residual poor vision.

Figure 1, presents mean logMAR values for statistical comparison. Mean BCVA improved significantly within all groups from Day 1 to Week 6 ($p < 0.001$, repeated measures ANOVA). Between-group differences were significant at each visit ($p < 0.05$), with viscoexpression

and hydroexpression showing consistently lower logMAR values than phacosandwich and irrigating vectis. At final follow-up, the best mean BCVA was recorded in viscoexpression (0.06 ± 0.03) and hydroexpression (0.06 ± 0.03), followed by phacofracture (0.10 ± 0.05).

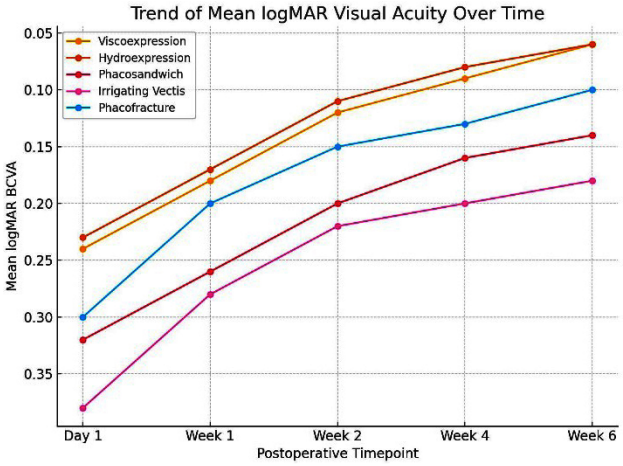

Figure 1: Trend of mean logMAR BCVA across all five groups from day 1 – Week 6.

Table 10, and figure 2 showing the percentage distribution of nucleus delivery techniques across cataract grades. Viscoexpression (48%) and hydroexpression (52%) were used exclusively in Grade 1, with declining proportions in higher grades. In contrast, phacosandwich (24–28%), Irrigating vectis (10–27%), and phacofracture (10–22%) were increasingly employed in Grades 2–4. A significant association was observed between cataract grade and the choice of technique (χ^2 = 23.21, df = 12, p = 0.026).

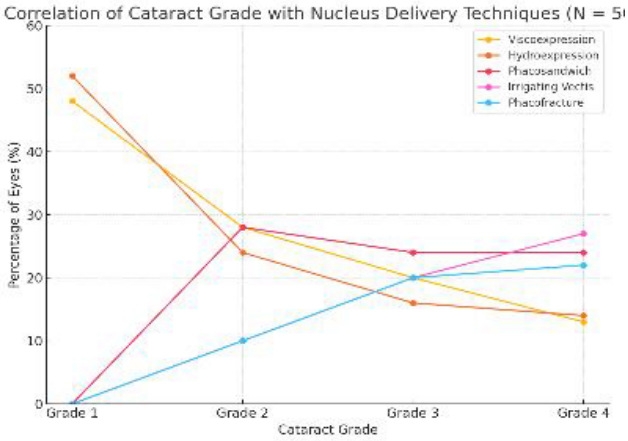

Figure 2: Correlation of cataract grade with nucleus delivery techniques (N = 500).

Table 10: Correlation of cataract grade with nucleus delivery techniques (N = 500).

Cataract Grade	*Viscoexpression*	*Hydroexpression*	*Phacosandwich*	*Irrigating vectis*	*Phacofracture*	*Total*
Grade 1 (8%)	48.0%	52.0%	0.0%	0.0%	0.0%	100%
Grade 2 (22%)	28.0%	24.0%	28.0%	10.0%	10.0%	100%
Grade 3 (33%)	20.0%	16.0%	24.0%	20.0%	20.0%	100%
Grade 4 (37%)	13.0%	14.0%	24.0%	27.0%	22.0%	100%

Statistical analysis: χ^2 = 23.21, df = 12, p = 0.026 (significant).

Discussion

Manual small-incision cataract surgery (MSICS) continues to be widely practiced in developing regions because it is economical, efficient, and delivers outcomes comparable to phacoemulsification in dense cataracts. Nucleus delivery remains the most critical step, influencing surgical ease, endothelial safety, complication profile, and visual recovery. A number of delivery methods are currently employed, including viscoelastic-assisted expression, hydroexpression, vectis-based extraction, phacosandwich, and fragmentation. In this prospective randomized study of 500 eyes, we compared viscoexpression, hydroexpression, phacosandwich, irrigating vectis, and phacofracture in terms of vision, complications, surgical time, and suitability across different grades of cataract.

Our results showed that viscoexpression and hydroexpression offered the best early postoperative visual outcomes, with over 85% of eyes achieving 6/6–6/9 on Day 1. This is consistent with recent findings by Kumar et al. (2022), who reported faster visual rehabilitation and less surgically induced astigmatism with viscoelastic-assisted delivery [8]. By contrast, eyes managed with phacosandwich and irrigating vectis showed slower initial recovery, reflecting greater transient corneal edema. However, by six weeks, visual acuity outcomes were excellent across all groups, with >94% of eyes attaining 6/6–6/9, echoing the findings of Hennig et al. and Ruit et al. that long-term outcomes after MSICS are uniformly good when performed safely [3,5].

With respect to intraoperative complications, irrigating vectis was associated with a higher incidence of Descemet's membrane detachment and corneal edema, as also noted by Mol et al. (2025), who found higher endothelial cell loss with phacosandwich and vectis compared to viscoexpression [9]. Viscoexpression and hydroexpression were not associated with iris prolapse or DM detachment in our series, reaffirming their safety in softer cataracts. Importantly, no posterior capsular rupture or zonular dialysis occurred with

viscoexpression, hydroexpression, or phacofracture, aligning with previous reports that these methods are relatively safe when performed with appropriate technique [10].

Postoperative complications were generally minor and self-limiting. Corneal edema, most frequent in the Irrigating Vectis group, subsided within the first week. No cases of persistent corneal decompensation, cystoid macular edema, or endophthalmitis were recorded. This is in line with recent large Indian series, which similarly reported a very low incidence of sight-threatening complications with MSICS [4].

Surgical efficiency varied across methods. Phacosandwich provided the fastest nucleus delivery, often under 20 seconds, due to its direct mechanical maneuver, consistent with the observations of Ruit et al. (2007) and later confirmed in Indian studies [5,11]. However, total surgical time was shorter with viscoexpression and hydroexpression, which provided smoother delivery with fewer intraoperative adjustments. Phacofracture required the longest time (around 18 minutes) but proved valuable in dense cataracts, where fragmentation reduced stress on the incision and capsule. This reflects the conclusions of Sharma et al. (2010) and more recent reports that mechanical support or fragmentation is often necessary in advanced nuclear sclerosis [12].

A statistically significant correlation was found between cataract grade and the choice of nucleus delivery technique ($p = 0.026$). Softer nuclei (Grades 1–2) were almost exclusively managed with viscoexpression and hydroexpression, while harder cataracts (Grades 3–4) were increasingly treated with phacosandwich, irrigating vectis, or phacofracture. This distribution parallels the clinical reasoning that less dense nuclei can be expressed with minimal manipulation, whereas advanced sclerosis requires mechanical support or fragmentation. Recent studies, including those by Anand et al. (2022) on fish hook delivery [13] and Boramani et al. (2022) on endoexpression [14], have also emphasized that technique choice must be individualized to nuclear density and surgeon experience.

The strengths of this study include its randomized design, large sample size, and comprehensive evaluation of multiple delivery techniques under standardized conditions. Limitations include the single-center nature of the study, lack of endothelial cell count analysis, and absence of phacoemulsification as a comparator.

Conclusion

Visual outcomes were excellent across all techniques, with >94% of eyes achieving 6/6–6/9 vision by 6 weeks. Viscoexpression and hydroexpression ensured the fastest early recovery and lowest complication rates in softer cataracts. Phacosandwich, Irrigating Vectis, and phacofracture were more effective in harder cataracts, though with slightly longer surgical time and transient edema. A significant correlation was observed between cataract grade and technique selection ($p = 0.026$). Tailoring the choice of nucleus delivery method to cataract grade optimizes safety, surgical efficiency, and patient outcomes in MSICS.

Conflicts of interest

Authors declare no conflict of interest.

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Author Designations:
Sachin Tammannavar (Associate Professor); Pooja B Wagganavar (Assistant Professor); Shreenivasa A (Associate Professor).