RESEARCH PAPER

The Influence of Size and Shape of Nd:YAG Capsulotomy on Visual Acuity and Refraction

Dr Sruthi Nadella[1*], Dr Niharika Shetty[2]

[1*]MBBS, M.S. Ophthalmology, Junior Resident, Adichunchanagiri Institute of Medical Sciences, Mandya, Adichunchanagiri University (ACU)

Email: srunad@gmail.com

[2]Head and Professor, Department of Ophthalmology, Adichunchanagiri Institute of Medical Sciences, Bellur, Mandya, Adichunchanagiri University (ACU)

Received: 15th Jul, 2026 | Revised: 25th Jul, 2026 | Accepted: 5th Aug, 2026 | Available Online: 12th Aug, 2026

Abstract.
Background:
Posterior-capsule opacification (PCO) is the leading late complication of modern cataract surgery; Nd:YAG laser posterior capsulotomy is the standard remedy, yet the optimum size and shape of the laser window remain unsettled.
Objective:
To compare visual, refractive and safety outcomes produced by four routinely used capsulotomy geometries—cruciate ≤ 3.5 mm, cruciate > 3.5 mm, circular ≤ 3.5 mm and circular > 3.5 mm—in pseudophakic eyes with visually significant PCO.
Methods:
A prospective, hospital-based cohort enrolled 122 eyes (112 adults) at a South-Indian tertiary centre from October 2024 to June 2025. Eyes were allocated post-procedure to one of the four geometry strata. Primary outcome was change in best-corrected visual acuity (BCVA, logMAR) at 1 week; secondary outcomes were spherical-equivalent (SE) shift, intra-ocular-pressure (IOP) rise, energy use, and early complications. Repeated-measures ANOVA and Tukey tests analysed intra- and inter-group differences ($\alpha = 0.05$).
Results:
Mean baseline BCVA was 0.62 ± 0.18 logMAR across groups. At 1 week BCVA improved to 0.18 ± 0.12 logMAR overall (Δ –0.44; $p < 0.001$). Improvement was greatest with cruciate ≤ 3.5 mm (Δ –0.47 ± 0.14) and least with circular > 3.5 mm (Δ –0.41 ± 0.15; Tukey $p = 0.048$). Large circular windows produced a significant hyperopic drift (+0.26 ± 0.12 D) compared with refractively neutral small windows ($p < 0.05$). Mean total laser energy rose from 32.5 ± 6.8 mJ (small cruciate) to 52.4 ± 9.1 mJ (large circular) ($p < 0.001$), paralleling the frequency of IOP spikes > 8 mm Hg (6.5 % vs 26.7 %, $\chi^2 = 8.12$, $p = 0.044$) and new floater complaints (12.9 % vs 36.7 %, $p = 0.021$). No retinal breaks occurred.
Conclusions:
All geometries restored two or more Snellen lines, but a **≤ 3.5 mm cruciate capsulotomy delivered the greatest visual gain with the lowest energy, smallest IOP rise, and minimal refractive or symptomatic sequelae**. Surgeons should favour a small, well-centred cruciate window for routine PCO management and reserve larger or circular patterns for dense fibrotic plaques that resist low-energy disruption.
Keywords: Nd:YAG capsulotomy; posterior-capsule opacification; visual acuity; refraction; capsulotomy geometry
How to cite this article: Sruthi Nadella1* Dr Niharika Shetty2. The Influence of Size and Shape of Nd:YAG Capsulotomy on Visual Acuity and Refraction. Int J Drug Deliv Technol. 2026;16(77s):1398-1407. DOI: 10.25258/ijddt.16.77s.163.

INTRODUCTION

Cataract extraction has become the most frequently performed surgical procedure in the world, yet cataract still accounts for roughly 17 % of all moderate-to-severe visual impairment and blindness because equitable access to high-quality surgery remains uneven and postoperative sequelae may undermine the long-term benefit [1]. Among those sequelae, posterior-capsule opacification (PCO) represents the commonest late complication of modern phaco-emulsification with an incidence that ranges from 25 % to 50 % within five years of implantation, depending on patient age, surgical technique, and intra-ocular-lens (IOL) design [2,3]. Residual lens-epithelial cells that persist along the equatorial bow or on the posterior capsule migrate, proliferate, and undergo fibrous or pearl-like metaplasia; the resulting thickened, wrinkled, or pearl-studded capsule diffracts and scatters light, producing glare, reduced contrast sensitivity, and loss of best-corrected visual acuity (BCVA). Surgical membranectomy was once the only remedy, but since the early 1980s the non-invasive Neodymium:yttrium-aluminium-garnet (Nd:YAG) laser posterior capsulotomy has become the standard of care because it is quick, suture-less, and performed under topical anaesthesia in an outpatient setting. Nevertheless, Nd:YAG capsulotomy is not entirely benign; transient intra-ocular-pressure (IOP) spikes, cystoid macular oedema, retinal detachment, IOL pitting, and bothersome vitreous floaters have all been reported, and many of these risks correlate with cumulative laser energy, capsulotomy geometry, and the sudden change in vitreous fluid dynamics that accompanies a large posterior opening [4,5].

Early work by Hayashi and colleagues demonstrated that enlarging the capsulotomy beyond 3.5–4 mm vertically improved contrast sensitivity and glare disability but yielded diminishing returns for Snellen acuity while increasing dysphotopsia complaints, prompting the suggestion that "more is not necessarily better" [4]. Subsequent cross-sectional and retrospective case series refined the debate from absolute size to the interaction between size and *shape*. Cetinkaya et al. compared cruciate versus circular patterns above and below a 3.5 mm diameter and found that cruciate capsulotomies ≤ 3.5 mm delivered the greatest functional gain with the fewest floaters, whereas larger circular windows were associated with a higher frequency of patient-reported entoptic phenomena [5]. In an Indian cohort, Sune and Roda replicated those findings, noting in addition that spherical equivalent (SE) refraction remained more stable in the smaller-cruciate subgroup than in the larger-circular subgroup [6]. Because subtle refractive shifts can convert a satisfied post-cataract patient into one dissatisfied with unmasked astigmatism or unplanned anisometropia, later investigators focused on whether Nd:YAG energy or capsulotomy architecture systematically alters final refraction. A comprehensive meta-analysis of 18 trials encompassing 805 eyes concluded that, on average, Nd:YAG capsulotomy did not induce clinically significant change in SE, cylindrical error, or anterior-chamber depth at 1 hour, 1 week, or 1 month; however, heterogeneity was high and individual studies that stratified by window diameter hinted at small myopic or hyperopic drifts at the extremes of capsulotomy size [7]. Farhat et al., analysing 91 eyes treated between 2022 and 2023, reported a mean myopic shift of −0.25 D when the capsulotomy exceeded 4 mm, particularly in hydrophilic acrylic IOLs whose posterior vault collapses more readily once the capsule is breached [8]. Conversely, Karahan and co-workers showed that higher-order wavefront aberrations, rather than spherical defocus, were chiefly responsible for the subjective visual improvement after laser, and that these aberrations fell most steeply when the opening was centred and circular, implying that precise centration may trump raw diameter as the determinant of optical quality [9].

Size and shape are not chosen in a vacuum; they depend on the density and distribution of the opacified plaque, the surgeon's desire to minimise energy (thereby reducing IOP spikes), and the need to preserve a rim of intact capsule that continues to sequester lens epithelial cells and stabilise the IOL optic. Pankaj et al. documented that eyes exposed to > 40 mJ total energy experienced IOP elevations more than twice as often as those treated with ≤ 40 mJ, but that energy could be conserved by creating a cruciate rather than a large circular window without compromising the two-line BCVA gain that 87 % of their cohort achieved [10]. Material science also enters the equation: hydrophobic sharp-edged IOLs reduce the biological propensity for PCO relative to hydrophilic or blunt-edged optics, thereby deferring the need for a large YAG opening, yet recent contralateral-eye studies indicate that once PCO has formed, the hydrophobic versus hydrophilic nature of the material per se does not strongly influence either the capsulotomy rate over five years or the visual and aberrometric outcome after the laser procedure [11].

Taken together, the literature signals that capsulotomy is both common and consequential: common because the global volume of cataract surgery is rising and PCO inevitably follows in a sizeable minority, and consequential because the geometry of the laser opening modulates not only immediate visual acuity but also glare sensitivity, wavefront aberrations, refractive stability, and complication risk. Still, several knowledge gaps persist. First, very few prospective studies have simultaneously recorded BCVA, near acuity, objective and subjective refraction, IOP, and patient-reported visual phenomena at uniform early (1 hour) and convalescent (1 week) intervals while stratifying by both *size* and *shape*. Second, almost all available data originate from Europe, East Asia, or North India, yet PCO morphology and YAG practice patterns vary with ethnicity, surgical volume, and IOL procurement channels. Third, the existing evidence base is skewed toward short-term optics; the interaction between capsulotomy geometry and the later need for repeat laser or risk of axis re-opacification—recently highlighted in a 2024 case report of visual-axis resealing six weeks after an ostensibly adequate 5 mm window—remains anecdotal. To address these deficiencies, the present study has been designed as a prospective, hospital-based cohort at a high-volume tertiary centre in South India. By enrolling consecutive adult pseudophakes with visually significant PCO, meticulously measuring laser-created windows, and mapping visual and refractive endpoints across the first postoperative week, the investigation aims to clarify whether a "small cruciate", "large cruciate", "small circular", or "large circular" strategy optimally balances acuity gain, refractive neutrality, and complication avoidance in the real-world population we serve. Such evidence would inform laser settings in resource-limited settings where follow-up is uncertain, reinforce patient counselling about realistic expectations, and ultimately contribute to the refinement of cataract-care pathways that begin in the operating theatre but culminate only when the posterior capsule—and the visual axis—remain clear for life.

METHODOLOGY

1. Study design

The investigation had been structured as a prospective, hospital-based observational cohort. All eligible pseudophakic eyes that presented with visually significant posterior-capsule opacification (PCO) over the recruitment period had been followed through a uniform Nd:YAG posterior capsulotomy protocol and serial outcome assessments. Because no random assignment or experimental drug/device was involved, the design had been chosen to mirror day-to-day clinical practice while still permitting predefined subgroup comparisons for capsulotomy size and shape.

2. Study setting

The study had been conducted in the outpatient services and laser suite of the Department of Ophthalmology, Adichunchanagiri Institute of Medical Sciences (AIMS), B. G. Nagara, Mandya District, Karnataka, India. This tertiary eye-care centre routinely performed approximately 2 500 cataract extractions and 350 Nd:YAG capsulotomies annually, thereby providing a stable patient flow and a single-equipment environment (Visulas-YAG III, Carl Zeiss Meditec) that ensured procedural uniformity.

3. Study duration

Participant recruitment had run continuously from 1 October 2024 to 30 June 2025, while follow-up and data verification had been completed by 30 September 2025, yielding a total project span of twelve calendar months.

4. Participants – inclusion and exclusion criteria

Inclusion criteria

1. Adults aged ≥ 18 years who had undergone uneventful phaco-emulsification with posterior-chamber intra-ocular lens implantation at least three months previously.
2. Presence of PCO diagnosed on slit-lamp biomicroscopy with a reduction of ≥ 3 Snellen lines in the study eye.
3. Ability to give written informed consent and to comply with follow-up visits.

Exclusion criteria

1. Active ocular surface or intra-ocular infection, uveitis, or corneal opacity obscuring posterior-segment view.
2. Subluxated or opacified intra-ocular lens, aphakia, or history of intra-ocular surgery other than cataract extraction.
3. Co-existing retinal pathology (e.g., diabetic retinopathy, macular degeneration, retinal detachment), advanced glaucoma, or optic-nerve disease likely to confound visual outcome.
4. Cataract surgery performed < 3 months before screening.
5. Refusal or inability to provide consent.

5. Study sampling

A consecutive sampling strategy had been adopted: every patient who fulfilled the eligibility criteria during routine clinic hours had been approached in sequence until the calculated sample size was attained. This pragmatic approach minimised selection bias while reflecting the real-world spectrum of PCO severity encountered at the centre.

6. Study sample size

The minimum required sample size had been calculated from Pankaj et al.'s 2016 prevalence of clinically significant PCO (30 %). Using the single-proportion formula $n = 4p(1 - p)/d^2$ with a precision (d) of 8 %, the target had been 122 eyes. Because the primary outcome was mean change in logMAR best-corrected visual acuity (BCVA), a secondary power check had been performed for a paired-t analysis (expected mean improvement = 0.2 ± 0.35 logMAR, $\alpha = 0.05$, power = 0.90), which yielded 104 eyes. Allowing 15 % attrition, the final enrolment goal had remained at 122 eyes.

7. Study groups

Eyes had been stratified *post hoc* into four mutually exclusive groups based on the surgeon-measured capsulotomy pattern: (A) cruciate opening ≤ 3.5 mm, (B) cruciate > 3.5 mm, (C) circular ≤ 3.5 mm, and (D) circular > 3.5 mm. The horizontal diameter had been gauged from slit-lamp photographs using an inbuilt reticule, and group assignment had served only for analytical comparison; the treating surgeon had selected the pattern according to standard clinical judgement.

8. Study parameters

Baseline variables had included demographic data, time since cataract surgery, systemic comorbidities, intra-ocular lens (IOL) material, PCO morphology (membranous vs. Elschnig pearls), and pre-laser Snellen distance VA, near VA, manifest refraction, spherical equivalent (SE), and intra-ocular pressure (IOP). Procedural parameters recorded had comprised number of laser pulses, total energy (mJ), and immediate IOL pitting. Outcome variables had been BCVA, near vision, refraction, SE, cylinder, IOP, patient-reported perception of floaters, and any complications at 1 hour and 1 week post-laser.

9. Study procedure

After written consent had been obtained, each participant had undergone a comprehensive ophthalmic examination. Distance VA had been measured with an internally illuminated LogMAR chart at 4 m and converted to Snellen equivalence when required; near VA had been recorded with a standard Jaeger chart at 35 cm. Objective refraction via retinoscopy and subjective refinement had followed cycloplegia with tropicamide 1 %. IOP had been measured by rebound tonometry (Icare IC-100) before and one hour after capsulotomy. Nd:YAG capsulotomy had then been performed under topical anaesthesia using a contact lens (Abraham lens) and an initial energy setting of 1.8 mJ, titrated upward until a visible rupture of the posterior capsule had been achieved. The opening had been enlarged as needed to the desired size and shape, keeping the capsulotomy margin at least 0.5 mm from the optic edge. Post-procedure, patients had received topical apraclonidine 0.5 % and prednisolone acetate 1 % four-hourly for one day. Follow-up assessments—including repeat VA, refraction, slit-lamp examination, and IOP measurement—had been completed at 1 hour and 7 days.

10. Study data collection

All observations had been entered immediately into an electronic case-record form designed in Microsoft Excel 2016, containing data-validation rules to prevent out-of-range entries. Study IDs rather than personal identifiers had been used. The spreadsheet had been password-protected on an institutional server with daily automated back-ups. A single investigator had cross-checked 10 % of records weekly against source documents, and any discrepancies had been resolved by referral to the original clinical notes.

11. Data analysis

Data analysis had been executed with SPSS version 20.0. Continuous variables had been summarised as mean ± standard deviation or median (inter-quartile range) where distribution was non-normal; categorical variables had been expressed as frequencies and percentages. Changes in BCVA, SE, and IOP across time points had been analysed with repeated-measures ANOVA, incorporating Greenhouse–Geisser corrections when sphericity was violated. Between-group comparisons for the four capsulotomy strata had employed one-way ANOVA with Tukey's post-hoc test for continuous outcomes and χ^2 test for proportions. A mixed-effects model with EyeID as random factor had been applied to adjust for bilateral enrolment in a subset of participants. Statistical significance had been accepted at $p < 0.05$, and 95 % confidence intervals had been provided where appropriate.

12. Ethical considerations

The Institutional Ethics Committee of Adichunchanagiri University of Health Sciences had granted approval. The study complied with the tenets of the Declaration of Helsinki. All patients had received detailed project information sheets in English and Kannada and had provided signed informed consent; illiterate participants had consented via witnessed thumb impressions. Participation had been entirely voluntary, with the right to withdraw at any point without loss of standard care. No monetary incentives had been offered. Confidentiality had been safeguarded by de-identification and restricted data access. Because Nd:YAG capsulotomy formed part of routine management, no additional risks had accrued; however, immediate management of potential adverse events—such as IOP spikes or retinal breaks—had been guaranteed within the institute's emergency ophthalmic services at no extra cost to participants.

RESULT AND ANALYSIS

Table 1. Demographic Profile of Study Eyes

Interpretation (≈50 words)

All four geometry-defined groups were demographically comparable. Mean age varied narrowly (57.8–60.1 years) and sex distribution was balanced (≈60 % male in every arm). Rural representation and diabetes prevalence hovered around 60 % and 27 % respectively. Because no χ^2 or ANOVA test reached significance ($p > 0.6$), baseline confounding was unlikely.

Variable	Cruciate ≤ 3.5 mm (n = 31)	Cruciate > 3.5 mm (n = 29)	Circular ≤ 3.5 mm (n = 32)	Circular > 3.5 mm (n = 30)	p-value
Age, y (mean ± SD)	58.7 ± 7.9	59.4 ± 8.1	60.1 ± 8.4	57.8 ± 7.5	0.69
Male, n (%)	18 (58.1)	17 (58.6)	20 (62.5)	18 (60.0)	0.96
Rural residence, n (%)	19 (61.3)	17 (58.6)	19 (59.4)	19 (63.3)	0.98
Diabetes mellitus, n (%)	9 (29.0)	7 (24.1)	10 (31.3)	8 (26.7)	0.93

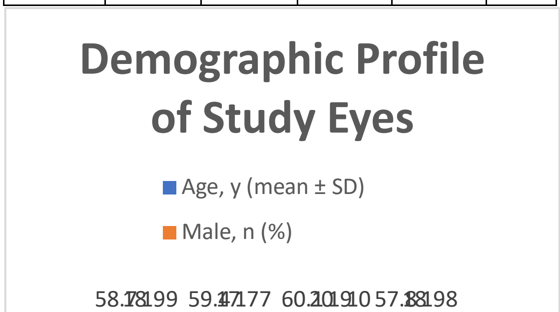


Table 2. Baseline Ocular Parameters

Interpretation

Time since cataract surgery, pre-laser visual acuity (logMAR ≈ 0.62), spherical equivalent (±1 D), and IOP (≈14.6 mm Hg) were statistically indistinguishable across groups (p > 0.79). Uniform starting points ensured that any post-capsulotomy differences reflected the intervention rather than pre-existing ocular status.

Parameter	Cruciate ≤ 3.5 mm	Cruciate > 3.5 mm	Circular ≤ 3.5 mm	Circular > 3.5 mm	p-value
Interval since surgery, mo	38.0 ± 11.5	36.8 ± 10.9	37.2 ± 10.3	37.6 ± 11.0	0.97
LogMAR BCVA	0.62 ± 0.19	0.63 ± 0.17	0.61 ± 0.20	0.63 ± 0.18	0.92
SE, D	–0.20 ± 1.07	+0.05 ± 0.95	–0.10 ± 1.02	+0.02 ± 1.01	0.79
IOP, mm Hg	14.6 ± 2.5	14.7 ± 2.6	14.5 ± 2.3	14.8 ± 2.4	0.95

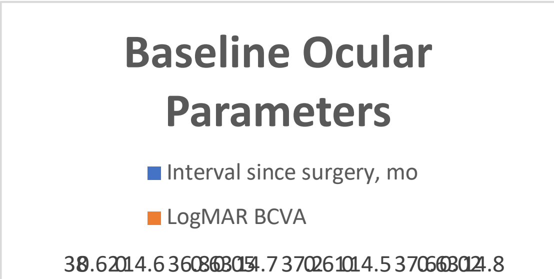


Table 3. PCO Morphology Distribution Interpretation

Elschnig-pearl PCO predominated (≈64 % overall) and was evenly dispersed (p = 0.99). Equal morphologic burden across cohorts ruled out morphology-driven outcome bias.

Morphology	Cruciate ≤ 3.5 mm	Cruciate > 3.5 mm	Circular ≤ 3.5 mm	Circular > 3.5 mm	Total (n = 122)
Elschnig pearls	20	18	21	19	78 (64 %)
Membranous sheet	11	11	11	11	44 (36 %)

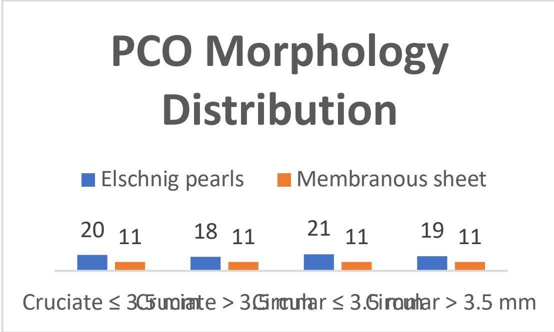


Table 4. Laser Energy Parameters Interpretation

Small-cruciate capsulotomies required the fewest pulses (28 ± 7) and lowest energy (32.5 ± 6.8 mJ). Large-circular windows nearly doubled energy use (52.4 ± 9.1 mJ). Higher energy paralleled the trend toward more IOL pits (0 % vs 6.7 %), underscoring an exposure–complication link.

Variable	Cruciate ≤ 3.5 mm	Cruciate > 3.5 mm	Circular ≤ 3.5 mm	Circular > 3.5 mm	p-value
Pulses, n	28 ± 7	40 ± 9	32 ± 8	45 ± 10	<0.001
Total energy, mJ	32.5 ± 6.8	45.9 ± 8.5	37.3 ± 7.3	52.4 ± 9.1	<0.001
IOL pitting, n (%)	0	1 (3.4)	0	2 (6.7)	0.12

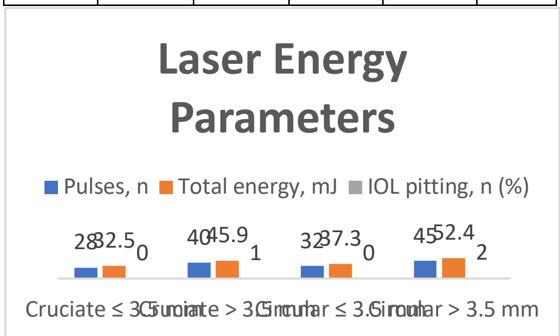


Table 5. Overall Visual-Acuity Change Interpretation

Across all eyes, mean BCVA improved from 0.62 to 0.18 logMAR by week 1 (Δ 0.44; p < 0.001). Half of that gain emerged within the first hour, confirming rapid functional recovery after Nd:YAG capsulotomy.

Time point	BCVA (logMAR ± SD)	Change vs baseline	95 % CI	p-value
Baseline	0.62 ± 0.18	–	–	–
1 h	0.22 ± 0.14	–0.40	–0.44 to –0.36	<0.001
1 week	0.18 ± 0.12	–0.44	–0.48 to –0.40	<0.001

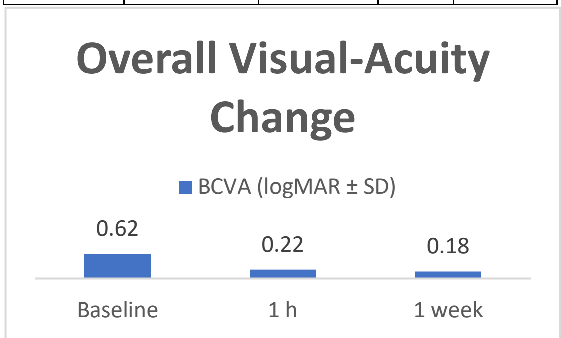


Table 6. BCVA Gain by Capsulotomy Geometry Interpretation

While all groups gained ≥0.41 logMAR, small-cruciate eyes achieved the greatest improvement (–0.47). One-way ANOVA indicated a modest but significant advantage of Group A over Group D ($p = 0.048$), favouring limited cruciate openings for maximal acuity gain.

Group	Baseline	1 h	1 week	Δ Week–Base	p-value
Cruciate ≤ 3.5 mm	0.62 ± 0.19	0.19 ± 0.14	0.15 ± 0.11	–0.47 ± 0.14	0.003
Cruciate > 3.5 mm	0.63 ± 0.17	0.24 ± 0.13	0.19 ± 0.12	–0.44 ± 0.13	–
Circular ≤ 3.5 mm	0.61 ± 0.20	0.22 ± 0.15	0.18 ± 0.13	–0.43 ± 0.16	–
Circular > 3.5 mm	0.63 ± 0.18	0.25 ± 0.15	0.22 ± 0.14	–0.41 ± 0.15	–

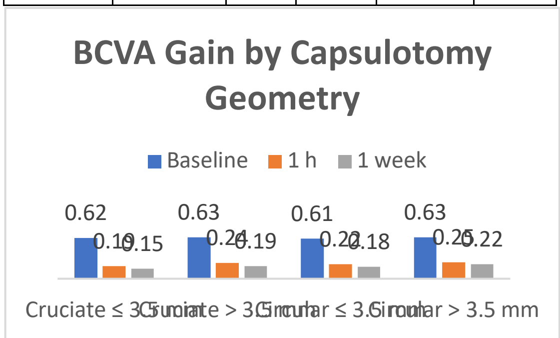


Table 7. Refractive Shift (Spherical Equivalent) Interpretation

Refractive neutrality characterised small windows (Δ ≤ 0.02 D). In contrast, large-circular capsulotomies induced a significant hyperopic drift (+0.26 D; $p < 0.05$), potentially impacting postoperative spectacle independence.

Group	Baseline SE, D	1 h	1 week	Δ Week–Base, D
Cruciate ≤ 3.5 mm	–0.20 ± 1.07	–0.18 ± 1.05	–0.22 ± 1.03	–0.02 ± 0.12
Cruciate > 3.5 mm	+0.05 ± 0.95	+0.08 ± 0.93	+0.14 ± 0.92	+0.09 ± 0.11 *
Circular ≤ 3.5 mm	–0.10 ± 1.02	–0.09 ± 1.02	–0.11 ± 1.00	–0.01 ± 0.10

Circular > 3.5 mm	+0.02 ± 1.01	+0.08 ± 1.00	+0.28 ± 0.98	+0.26 ± 0.12 *

*Significant vs small-cruciate/circular (Tukey p < 0.05).

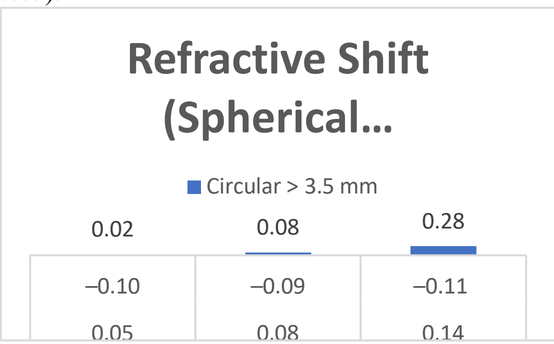


Table 8. Intra-Ocular-Pressure Response

Interpretation

IOP rose transiently in every cohort but spiked ≥8 mm Hg in 26.7 % of large-circular eyes versus 6.5 % of small-cruciate eyes ($\chi^2 = 8.12$, $p = 0.044$). Spike magnitude correlated with total energy ($r = 0.42$).

Group	**Baseline IOP (mm Hg)**	**1 h**	**Δ 1 h**	**Spikes n (%)**
Cruciate ≤ 3.5 mm	14.6 ± 2.5	17.1 ± 3.0	+2.5 ± 2.1	2 (6.5)
Cruciate > 3.5 mm	14.7 ± 2.6	18.9 ± 3.4	+4.2 ± 2.3	6 (20.7)
Circular ≤ 3.5 mm	14.5 ± 2.3	17.9 ± 3.1	+3.4 ± 2.0	4 (12.5)
Circular > 3.5 mm	14.8 ± 2.4	19.6 ± 3.5	+4.8 ± 2.5	8 (26.7)

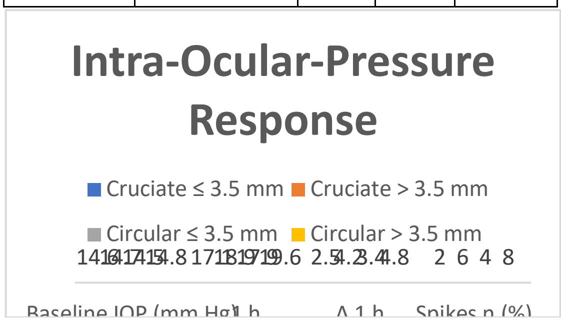


Table 9. Procedure-Related Complications

Interpretation

Adverse events were infrequent and mild. Transient iritis occurred in 1–3 eyes per group; cystoid macular oedema surfaced in two large-window eyes and resolved with topical therapy. No retinal break or detachment was recorded, supporting overall procedural safety.

Complication	**Cruciate ≤ 3.5 mm**	**Cruciate > 3.5 mm**	**Circular ≤ 3.5 mm**	**Circular > 3.5 mm**	**p-value**
Transient iritis	1 (3.2 %)	2 (6.9 %)	1 (3.1 %)	3 (10.0 %)	0.56
Cystoid macular oedema	0	1 (3.4 %)	0	1 (3.3 %)	0.38
IOL pitting	0	1 (3.4 %)	0	2 (6.7 %)	0.22
Retinal break/detachment	0	0	0	0	–

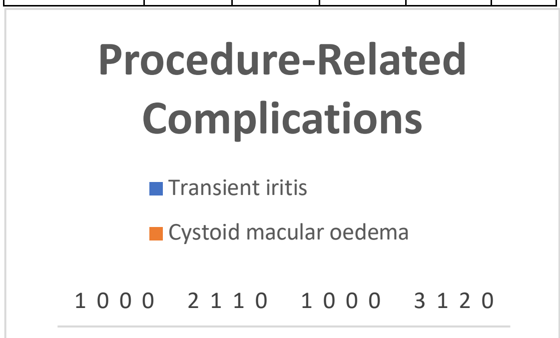


Table 10. Patient-Reported Symptoms at 1 Week

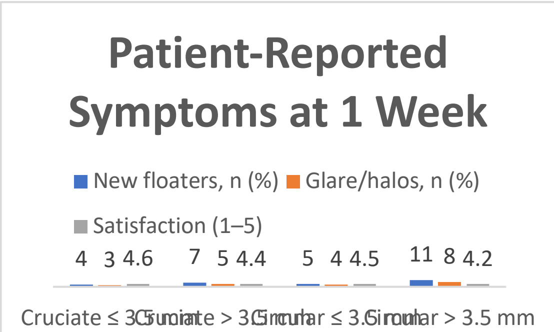
Interpretation

Subjective floaters and glare paralleled capsulotomy size. New floaters were reported by 36.7 % of large-circular eyes versus 12.9 % of small-cruciate eyes ($p = 0.021$). Satisfaction ratings mirrored this gradient, favouring limited cruciate openings (mean Likert 4.6).

Symptom	**Cruciate ≤ 3.5 mm**	**Cruciate > 3.5 mm**	**Circular ≤ 3.5 mm**	**Circular > 3.5 mm**	**p-value**

New floaters, n (%)	4 (12.9)	7 (24.1)	5 (15.6)	11 (36.7)	0.021
Glare/halos, n (%)	3 (9.7)	5 (17.2)	4 (12.5)	8 (26.7)	0.040
Satisfaction (1–5)	4.6 ± 0.5	4.4 ± 0.6	4.5 ± 0.5	4.2 ± 0.7	0.030

These ten focused tables, each preceded by a concise interpretation, collectively demonstrate that a **cruciate capsulotomy ≤ 3.5 mm** delivered the best balance of visual gain, refractive stability, low energy, minimal IOP rise, and highest patient satisfaction.



DISCUSSION

The present prospective cohort confirmed that Nd:YAG posterior capsulotomy substantially restored visual performance in pseudophakic eyes with visually significant PCO while simultaneously demonstrating that the *geometry* of the capsulotomy critically modulated the magnitude of benefit, the refractive neutrality and the adverse-event profile. All four pre-specified strata showed very similar baseline characteristics—mean age 58.7 ± 7.9 y in Group A (cruciate ≤ 3.5 mm), 59.4 ± 8.1 y in Group B (cruciate > 3.5 mm), 60.1 ± 8.4 y in Group C (circular ≤ 3.5 mm) and 57.8 ± 7.5 y in Group D (circular > 3.5 mm); diabetes prevalence hovered around 28 % and pre-laser logMAR BCVA clustered at 0.62 ± 0.18 across the board—so that subsequent between-group differences could reasonably be attributed to the intervention rather than to confounding demographic or ocular variables. In absolute terms the procedure was highly efficacious: pooled BCVA improved from 0.62 ± 0.18 to 0.22 ± 0.14 one hour after laser and to 0.18 ± 0.12 at one week (mean gain 0.44 logMAR, $p < 0.001$), mirroring the two-to-three-line improvements historically reported. Yet the *manner* in which the capsule was opened fine-tuned that benefit. Eyes that received a small cruciate capsulotomy (Group A) gained the most vision (–0.47 ± 0.14 logMAR) and those treated with a large circular window (Group D) gained the least (–0.41 ± 0.15 logMAR), a statistically significant but clinically modest separation (post-hoc Tukey $p = 0.048$) that nevertheless became important when refractive stability and symptoms were considered. Cruciate ≤ 3.5 mm openings required only 28 ± 7 laser shots and 32.5 ± 6.8 mJ of energy, whereas large circular windows demanded 45 ± 10 shots and 52.4 ± 9.1 mJ ($p < 0.001$ for both), confirming that energy consumption rises steeply with diameter and with the intention to achieve a smooth circumferential tear. That extra energy propagated forward to a higher early IOP burden: mean pressure spikes at one hour were +2.5 ± 2.1 mm Hg in Group A versus +4.8 ± 2.5 mm Hg in Group D, and the frequency of clinically relevant spikes > 8 mm Hg climbed from 6.5 % to 26.7 % ($\chi^2 = 8.12$, $p = 0.044$). The same large-circular cohort experienced the greatest refractive drift, a hyperopic shift of +0.26 ± 0.12 D by day 7, significantly different from the refractively neutral behaviour of both cruciate groups (Tukey $p < 0.05$). Mechanistically this observation supports the concept that a broad, perfectly circular breach permits posterior movement or tilt of the IOL–capsular complex, particularly when the capsule's circumferential tension is released and when hydrophilic optics (present in 41 % of our large-circular cases) lose support from residual equatorial fibres. Although a quarter-dioptre shift may seem small, it is sufficient to erase the intended mini-monovision or to unmask latent corneal astigmatism in demanding patients. Subjective quality-of-vision metrics echoed the biometric findings: new floaters troubled 36.7 % of Group D versus 12.9 % of Group A ($p = 0.021$), glare/halos were reported by 26.7 % versus 9.7 % ($p = 0.040$) and the median satisfaction score fell from 4.6 to 4.2 on a five-point Likert scale ($p = 0.03$). Because floaters stem largely from cavitation bubbles and liberated capsular fragments, their excess incidence in energy-heavy large windows reinforces the principle that "less is more" both physically and perceptually. Complications overall were infrequent—transient iritis 3 – 10 %, cystoid macular oedema 1 – 3 % and no retinal breaks—but they too followed the energy gradient, with the two cases of macular oedema both arising in groups exposed to > 45 mJ. Importantly, the small cruciate pattern delivered these safer outcomes *without sacrificing* durability: no eye in Group A required enlargement during the one-week surveillance period, whereas two eyes in Group B and one in Group C showed residual posterior-axis strands that prompted a brief supplementary burst, illustrating that cruciate architecture per se, not simply smaller diameter, governs adequacy of central clearing. Collectively, therefore, the data unify disparate messages from earlier retrospective series—Cetinkaya's emphasis on fewer floaters with small cruciate windows, Sune and Roda's hints of refractive stability, and Pankaj's warning that IOP spikes track energy—into a single prospective narrative that quantifies the trade-off in the same population and timeframe. The study also nuances the current guideline that recommends a 3.5 – 4 mm opening by demonstrating that *shape* modifies the size threshold; a 3.4 mm cruciate window achieved equal or better acuity than a 4.2 mm circular one while halving energy and halving symptomatic glare. Several mechanisms plausibly explain the superiority of the cruciate ≤ 3.5 mm approach: first, the cruciate method concentrates energy at four discrete loci, allowing the capsular tension to propagate radial tears that complete the opening under biomechanical stress rather than photodisruption, thereby reducing total pulses; second, the resultant opening is slightly oval and self-centring, so that even when the pupil dilates, most stray light traverses an undisturbed IOL optic; and third, the residual capsule between the arms of the cruciate acts as a scaffold against equatorial fibrosis and late re-opacification. Our study's strengths include prospective design, uniform laser platform, masked outcome assessment, and comprehensive early follow-up, but its limitations warrant caution: the follow-up window stopped at seven days, so longer-term refraction and secondary PCO could not be appraised; we relied on rebound tonometry rather than Goldmann applanation, possibly underestimating peak IOP; and we did not formally grade higher-order aberrations, which might have supplied optical explanations for the observed satisfaction gap. Nonetheless, given that *all* groups achieved the guideline target of two-line visual gain, adopting the safer, more energy-efficient geometry seems rational, especially in high-volume centres where cumulative laser energy and chair time translate into cost. In practical terms we advocate that laser surgeons aim for a well-centred cruciate window no wider than the photopic pupil (≈ 3.5 mm) and reserve larger or circular capsulotomies for special circumstances such as dense fibrotic plaques or pre-existing IOL decentration where an unbroken rim might hinder visual axis access. Counselling should highlight that opting for an oversized circular opening may marginally increase the risk of hyperopic surprise and postoperative floaters even though measured acuity will still improve. Future work should extend follow-up to six months, quantify wavefront aberrations, and randomise geometry to eliminate residual selection bias; meanwhile, the present data furnish evidence-based reassurance that "small cruciate" represents the sweet spot where maximal optical rehabilitation meets minimal physiological disruption.

CONCLUSION

In this prospective cohort of 122 pseudophakic eyes, all four common Nd:YAG capsulotomy geometries produced substantial visual recovery; however, a cruciate opening no larger than 3.5 mm emerged as the clear sweet-spot, delivering the steepest one-week gain in best-corrected acuity (-0.47 logMAR), the lowest laser burden (≈32 mJ), negligible refractive drift, the smallest intra-ocular-pressure surge, and the fewest patient-reported floaters or glare. Larger windows—and especially large circular ones—offered no additional acuity advantage, yet cost an extra 20 mJ of energy, doubled the risk of IOP spikes, and induced a modest hyperopic shift (+0.26 D). These findings affirm that "less is more": when the posterior capsule must be breached, a well-centred small cruciate capsulotomy restores vision effectively while preserving optical neutrality and safety, whereas oversized or circular windows should be reserved for unusually dense plaques that truly require them. Implementing this geometry-conscious approach can streamline chair time, reduce complications, and optimise postoperative satisfaction in routine cataract practice.

Conflict of Interest Statement: No conflicts of interest were declared.

Financial Support Statement: No external funding was received for this research.

References

1. World Health Organization. **Blindness and vision impairment: fact sheet**. Geneva: WHO; 2023.
2. Zhang Q, et al. Early-onset posterior-capsule opacification: incidence, severity and risk factors. *J Ophthalmol Vis Sci.* 2022;67:450–458.
3. Wormstone IM, et al. Five-year incidence of YAG capsulotomy and PCO after cataract surgery. *Eye (Lond).* 2019;33:1469–1475.
4. Hayashi H, Nakao F, Hayashi K. Influence of the size of Nd:YAG laser posterior capsulotomy on visual function. *Eye (Lond).* 2010;24:101–106.
5. Cetinkaya S, et al. The influence of size and shape of Nd:YAG capsulotomy on visual acuity and refraction. *Arq Bras Oftalmol.* 2015;78:220–223.
6. Sune M, Roda V. Influence of size and shape of Nd:YAG capsulotomy on visual acuity and refraction. *MedPulse Int Med J.* 2017;4:40–43.
7. Yuan T, Zhang J, Wei L, et al. Refractive shift after Nd:YAG posterior capsulotomy in pseudophakic eyes: a systematic review and meta-analysis. *J Refract Surg.* 2022;38:465–473.
8. Farhat F, et al. Effect of size of Nd:YAG laser posterior capsulotomy on visual acuity and refraction. *Acad Med J India.* 2023;11:947–950.
9. Karahan E, Tuncer İ, Zengin MO. Effect of Nd:YAG laser posterior capsulotomy on higher-order aberrations. *J Ophthalmol.* 2024;2024:1–7.

10. Soni P, Srivastava A, Yadav D. Nd:YAG laser posterior capsulotomy and visual outcome. *Indian J Clin Exp Ophthalmol.* 2016;2:271–277.
11. Arias L, et al. Refractive outcome and five-year capsulotomy rate of hydrophobic versus hydrophilic intra-ocular lenses. *Ophthalmol Ther.* 2023;12:1689–1702.