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Original Research Article

ANALYSIS OF THE EFFECTIVENESS OF DIFFERENT PUPIL DILATATION TECHNIQUES IN COMPLICATED CATARACT SURGERY

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ABSTRACT

Background: Cataract surgery success depends on achieving sufficient pupil dilation, which can be challenging in complex cases like pseudoexfoliation, chronic uveitis, synechiae or use of @1 reductase inhibitors leading to IFIS and long standing Diabetes mellitus While topical mydriatics are often adequate, intracameral agents provide rapid, stable dilation. mechanical methods such as polypropylene iris hooks or Malyugin rings are needed when pharmacologic methods fail. The Malyugin ring offers superior outcomes with fewer complications. Technique choice should be individualized, often using a stepwise approach from pharmacologic to mechanical methods.

Materials and Methods: This prospective cross-sectional study was conducted over one year at a tertiary hospital, enrolling 100 adults with cataracts found to have inadequate pupillary dilation during routine evaluation for cataract surgery. Sample size was calculated using Cochran's formula as 96 and adjusting for attrition, it was 100. Patients were grouped by pupil dilation technique: topical, intracameral, viscomydriasis, or mechanical (hooks/Malyugin ring). Data on demographics, dilation efficacy, surgical outcomes, and complications were collected. Analysis included chi-square tests and odds ratios using SPSS v24, with significance set at $p<0.05$ and stratification for complexity factors.

Results: This study consists of 100 complicated cataract cases evaluated for five pupil dilation techniques. Mean age was 65.2 years; PXF (38%) was most common. Topical mydriatics were least effective (0% ≥6 mm pupil), often requiring supplements (60%) and showing highest complication rates (20%). Intracameral and mechanical methods (Malyugin ring, iris hooks) consistently achieved ≥6 mm dilation with fewer complications and higher ease-of-surgery scores. A significant association existed between technique and dilation success ($p < 0.001$), confirming the superiority of mechanical and intracameral methods.

Conclusion: According to this study, mechanical pupil dilating devices—particularly the Malyugin ring—provide better outcomes in complex cataract cases in terms of the size of the pupil attained, the rate of complications, and fairly smooth course of surgery. An excellent substitute that is both safe and effective is intracameral mydriatics i.e. preservative free epinephrine hydrochloride 0.001%. In these situations, topical medications are insufficient on their own. Optimizing surgical outcomes requires a customized strategy that takes into account both surgeon expertise and ocular comorbidities.

Keywords: Cataract Extraction, Phacoemulsification, Mydriatics, Pupil, Intraoperative Complications.

INTRODUCTION

Cataract surgery is one of the most commonly performed ophthalmological procedures around the globe. A crucial factor in the success of cataract surgery is ensuring that the pupil stays adequately dilated throughout the surgical procedure. When the pupil is well-dilated, it allows for a clear view of the anterior capsule and other critical intraocular structures, which is essential for safely performing phacoemulsification and implanting the intraocular lens.[1]

In typical cases, using topical mydriatics like tropicamide and phenylephrine before surgery usually is sufficient for adequate dilation. These medications work by inhibiting the parasympathetic system and stimulating the sympathetic system, and they are a standard part of the pre-surgical routine. However, in cataract cases complicated with conditions —like those associated with pseudoexfoliation syndrome (PXF), diabetes, chronic uveitis, or intraoperative floppy iris syndrome (IFIS)—achieving and keeping the pupil adequately dilated can be quite a challenge.[2] These conditions can affect the iris's structure or how it responds, making regular pharmacological agents less effective.[3]

Extra precautions must be taken in such situations to ensure intraoperative safety and visual access. One effective technique is the use of intracameral mydriatics, which involves injecting a combination of dilating agents—typically phenylephrine, tropicamide, and lidocaine combination into the anterior chamber. Another alternative is intracameral injection of 0.1 ml of preservative free epinephrine hydrochloride diluted with 0.9 ml of balanced salt solution giving a concentration of 1:100000. This method reduces the number of topical drops needed before surgery, minimizes systemic side effects, and produces quick and reliable pupil dilation. Research has shown that intracameral mydriatics improve surgical workflow and patient comfort while producing mydriasis that is on par with or better than traditional topical agents.[4]

Despite these benefits, the use of intracameral mydriatics is not sufficient for fibrotic or atrophic irides. In these situations, mechanical pupil dilation is required to achieve adequate exposure. Iris retractors or hooks are popular mechanical options. By pulling back the pupillary margin through limbal incisions, these tiny nylon hooks enlarge the pupil. Despite their effectiveness, their use may be linked to postoperative pupil irregularities, intraoperative trauma, and residual larger pupillary size.[5]

An advancement in this domain is the Malyugin ring, a square-shaped disposable device introduced into the anterior chamber through a small corneal incision. It provides stable and symmetrical dilation and is especially beneficial in patients with PXF or IFIS. Clinical evidence supports its superiority over iris hooks in terms of surgical ease, pupil centration, and postoperative outcomes.[6] The Malyugin ring is also associated with reduced surgical time and less iris manipulation, which is crucial in eyes with floppy or fragile iris tissue.[7]

Another method, visco mydriasis, utilizes high molecular weight ophthalmic viscoelastic devices (OVDs) to gently separate posterior synechiae or exert outward pressure on the iris. Although its effects are frequently transient and less predictable in lengthy procedures, this technique can be especially beneficial in cases of intraoperative miosis or pediatric cataracts.[8] Besides these, pupillary stretching with Y hooks or multiple sphincteroties with microscissors are being tried with variable success rates.

Differences between these methods have been brought to light by comparative studies. According to a multicenter observational study, the Malyugin ring improved pupil symmetry and led to fewer complications like bleeding or pigment dispersion, even though both iris hooks and pupil expansion rings were beneficial.[6,9] In a similar vein, a review of cases involving small pupils found that while mechanical expansion should be easily accessible for cases that do not respond to medication, intracameral mydriatics were generally effective.3

Because synechiae formation and iris rigidity are common in uveitic cataracts, management becomes even more complicated. In these situations, achieving safe operating conditions may require a combination of mechanical dilatation, synechiolysis, and viscomydriasis. Additionally, preoperative planning needs to take into account mechanical expansion devices like the Malyugin ring in patients who are at high risk of IFIS and are taking systemic alpha-1 antagonists like tamsulosin.[9]

Ultimately, the choice of technique should be guided by the underlying cause of poor dilation, surgical experience, and patient safety. In many complex cases, a stepwise approach starting with intracameral pharmacologic agents and escalating to mechanical methods provides the best outcomes.[10]

MATERIALS AND METHODS

This observational study was conducted as a prospective cross-sectional analysis in the Department of Ophthalmology, Jagjivanram Hospital, Mumbai, a tertiary care teaching hospital over a period of one year. A total of 100 adult patients diagnosed with complicated cataracts requiring phacoemulsification were enrolled after obtaining informed written consent.

The sample size was calculated based on assumption that approximately 50% of complicated cataract cases (such as pseudoexfoliation syndrome, uveitis, or small pupil) require mechanical methods for adequate pupil dilation. Using Cochran's formula for proportions with a 95% confidence level and 10% absolute margin of error:

$$n = \frac{z^2 * p * q}{e^2}$$

Where:

- n = required sample size
- Z = Z-score for 95% confidence = 1.96
- p = estimated prevalence = 50%
- q=100−p=50q = 100 - p = 50q=100−p=50
- e= absolute error = 10%

$$n = \frac{1.96^2 * 50 * (100 - 50)}{10^2}$$

n = 96.04

The minimum sample size required was approximately 96. Allowing for potential dropouts or incomplete records, a final sample size of 100 cases was targeted.

Patients were categorized based on the type of pupil dilatation technique used preoperatively into the following groups:

- Group A: Topical mydriatics only.
- Group B: Intracameral mydriatics.
- Group C: Viscomydriasis
- Group D: Mechanical dilation (iris hooks or Malyugin ring)

Eligibility was determined by slit-lamp evaluation, ocular history, and ocular biometry. Cases of intraoperative floppy iris syndrome, pseudoexfoliation, posterior synechiae, or diabetes mellitus were classified as complicated cataracts.

All patients underwent standard preoperative evaluation including visual acuity, intraocular pressure, anterior segment examination, and B-scan ultrasonography when required. We measured the diameter of the pupil three times: before dilation, after preoperative dilation, and during the operation, before capsulorhexis. Intraoperative documentation included whether the dilation was enough (≥6 mm), whether extra techniques were needed, how long the surgery took, any problems that came up (like iris trauma or sphincter tears), and whether the procedure needed to be changed to an extracapsular technique.

The information gathered included the patient's age, sex, and race, as well as any pre-existing eye or systemic conditions, the type of cataract, the method of dilation used, the findings during the surgery, the length of the surgery, any complications, and the patient's vision recovery after the surgery. The surgeon used a 5-point Likert scale to rate how easy the surgery was and kept track of how stable the pupils were during the procedure. Data were entered in Microsoft Excel and analysed using IBM SPSS version 24.0. Continuous variables like pupil size and surgical time were expressed as mean ± standard deviation (SD). Categorical variables such as type of dilation technique, complication rates, and pupil stability were presented as frequencies and percentages. The chi-square test of association was applied to compare proportions, and p-values <0.05 were considered statistically significant. Odds ratios (OR) and 95% confidence intervals (CI) were calculated to estimate the likelihood of intraoperative complications with different techniques. Stratified analysis was done based on the complexity of the case (e.g., pseudoexfoliation, diabetes) to assess interaction effects with the method of pupil dilation.

RESULTS

Demographic and Clinical Profile

The study comprised 100 patients undergoing cataract surgery with varying degrees of pupil dilation difficulty due to ocular comorbidities. The mean age was 65.2 ± 8.7 years, consistent with the known prevalence of senile cataract. A male predominance (62%) was noted. Pseudoexfoliation syndrome (38%) was the most common associated condition, followed by diabetes mellitus (27%) and uveitis (14%). This distribution reflects the clinical challenge of achieving adequate mydriasis in such patients. [Table 1]

Table 1: Demographic and Clinical Profile of Patients (n = 100)

Variable	Value
Mean Age (years)	65.2 ± 8.7
Gender	Male: 62%, Female: 38%
Eye Involved	Right: 52%, Left: 48%
Diagnosis	PXF: 38%, Diabetes: 27%, Uveitis: 14%, Other: 21%

Topical mydriatics were used most frequently (30%), followed by intracameral agents (25%), iris hooks (20%), Malyugin ring (15%), and viscomydriasis (10%). The preference for mechanical methods in 35% of cases highlights the limitations of pharmacologic methods in complicated cataracts. [Table 2]

Table 2: Distribution of Pupil Dilatation Techniques

Technique	No. of Patients	Percentage
Topical Mydriatics	30	30%
Intracameral	25	25%
Viscomydriasis	10	10%
Iris Hooks	20	20%
Malyugin Ring	15	15%

Intracameral, iris hook, and Malyugin ring groups achieved a pupil size ≥6 mm in 100% of cases. The mean intraoperative pupil sizes were largest in the iris hook (7.0 ± 0.3 mm) and Malyugin ring (6.8 ± 0.4 mm) groups. In contrast, none of the topical group cases achieved ≥6 mm dilation, highlighting its limited effectiveness in complicated cases. [Table 3].

Table 3: Intraoperative Pupil Size and Effectiveness

Technique	Mean Intra-op Pupil Size (mm)	% Achieving ≥6 mm
Topical	5.2 ± 0.6	0%
Intracameral	6.4 ± 0.5	100%
Viscomydriasis	5.8 ± 0.7	20%
Iris Hooks	7.0 ± 0.3	100%
Malyugin Ring	6.8 ± 0.4	100%

Topical mydriatics had the highest rate of supplemental intervention (60%), followed by viscomydriasis (40%). No patient in the iris hook or Malyugin ring group required additional measures, confirming their reliability in achieving optimal dilation independently. [Table 4]

Table 4: Need for Supplemental Technique

Technique	Supplement Needed (%)
Topical	60%
Intracameral	16%
Viscomydriasis	40%
Iris Hooks	0%
Malyugin Ring	0%

Intraoperative Complications

The complication rate was highest in the topical (20%), viscomydriasis (20%), and iris hook (20%) groups. Complications included iris bleeding, sphincter tears, and posterior capsule rupture. The Malyugin ring had no complications and intracameral had only one (4%), underscoring their safety in complex scenarios. [Table 5]

Table 5: Intraoperative Complications

Technique	Complication Rate (%)	Common Complication
Topical	20%	Iris bleed / sphincter tear
Intracameral	4%	Minor iris prolapse
Viscomydriasis	20%	Posterior capsule rent
Iris Hooks	20%	Iris trauma
Malyugin Ring	0%	None

Surgeons rated Malyugin ring cases highest (4.5/5) for ease of surgery, followed by intracameral agents (3.9). Topical mydriatics were rated the lowest (2.5), likely due to smaller pupil size and the need for mid-surgery intervention. [Table 6]

Table 6: Ease of Surgery (Surgeon-Rate)

Technique	Mean Ease Score (1–5)
Topical	2.5
Intracameral	3.9
Viscomydriasis	3.2
Iris Hooks	3.7
Malyugin Ring	4.5

A majority of patients (88%) achieved good vision (LogMAR ≤ 0.2) by day 30. The five patients who had poor vision (LogMAR > 0.5) had all experienced intraoperative complications, highlighting the indirect impact of technique choice on final outcome. [Table 7]

Table 7: Visual Outcome (Post-op Day 30)

Visual Outcome	Number of Patients
LogMAR ≤ 0.2 (Good Vision)	88
LogMAR > 0.5 (Poor Outcome)	5
Total	100

Association Between Technique and Pupil ≥6 mm

There was a highly significant association between mydriasis technique and successful dilation (≥6 mm) ($\chi^2 = 93.209$, $p < 0.001$). All cases in the intracameral, iris hook, and Malyugin groups achieved adequate pupil size, while none in the topical group did. [Table 8]

Table 8: Technique vs Pupil ≥6 mm Achieved

Mydriasis Technique	Pupil <6 mm (No)	Pupil ≥6 mm (Yes)	Total	Chi-Square / p-Value
Topical	30	0	30	$\chi^2 = 93.209$, $p < 0.001$
Intracameral	0	25	25	
Viscomydriasis	8	2	10	
Iris Hooks	0	20	20	
Malyugin Ring	0	15	15	
Total	38	62	100	

Association Between Technique and Intraoperative Complication

Although the chi-square test ($\chi^2 = 8.124$, $p = 0.087$) showed a non-significant result, a clinical trend was observed. Complications occurred most in topical, viscomydriasis, and iris hook groups. The Malyugin ring group had no complications. [Table 9]

Table 9: Pupil Dilatation Technique vs Intraoperative Complication

Mydriasis Technique	No Complication	With Complication	Total	Chi-Square/ p-Value
Topical	24	6	30	$\chi^2 = 8.124$, $p = 0.087$
Intracameral	24	1	25	
Viscomydriasis	8	2	10	
Iris Hooks	16	4	20	
Malyugin Ring	15	0	15	
Total	87	13	100	

DISCUSSION

Optimal pupillary dilation is important for a good surgical outcome and patient safety in cataract surgery, especially in patients with systemic diseases such as diabetes mellitus, pseudoexfoliation syndrome (PXF), or uveitis. These diseases generally lead to suboptimal pupil dilation and may lead to challenges during the procedure. In this review we described several options for pupil dilation, including topical mydriatics, intracameral agents, viscomydriasis, iris hooks, and the Malyugin ring according to their efficacy, complication rates and feasibility.

The Malyugin ring was the best device in this study with intraoperative pupil diameters of ≥6 mm in all cases. Nderitu and Ursell further supported our observations, as they stated that the Malyugin ring can safely achieve pupil dilation and avoid damage to the iris, even in smaller and miosis pupils.[11]

Intracameral mydriatics were also successful with all cases achieving sufficient dilation (100%). Bucci et al. confirmed that intracameral phenylephrine-lidocaine combinations lead to rapid, long-lasting mydriasis.[12]

In all thirty cases, topical mydriatics alone did not work, and none of the cases were able to achieve the pupil size considered adequate (greater than 6 mm). Additional intraocular assistance was required in 60% of cases during viscomydriasis, which suggests that topical agents alone do not suffice, especially in more clinically challenging eyes. Viscomydriasis responded, similarly to topical mydriatics, but unfortunately not very well, producing an adequate pupil size in only 20% of patients. As for complications, both topical and viscomydriasis groups had the highest rate of complications (20% each), including bleeding from the iris, tears in the sphincter, and ruptures in the posterior capsule.

On the other hand, the Malyugin ring group had no problems. This result supports what Gupta et al. found: that the Malyugin ring kept the iris's structure intact and greatly lowered the risk of intraoperative trauma compared to other expansion devices.[13]

Iris hooks were effective in pupil dilation but had a 20% complication rate in this study. This is consistent with evidence from a comparative study by Malyugin B. et al in study titled Cataract surgery in small pupils., which observed that iris hooks, while useful, are associated with higher risk of anterior capsular damage and iris sphincter distortion.[14]

The Malyugin ring had the highest ease-of-surgery scores, followed by the intracameral mydriatics. The Malyugin ring's design enables stable and symmetric expansion through a single corneal incision, making it user-friendly even in complex scenarios. Chang et al. have opined that using it in cases of intraoperative floppy iris syndrome (IFIS) makes surgery easier and lowers the risk of problems.[15]

Topical mydriatics were associated with the lowest ease-of-use scores, mainly due to the inadequacy of dilation and the frequent need for mid-surgery intervention. Viscomydriasis also received modest ratings due to its unpredictable and and transient efficacy.

Good visual recovery (LogMAR ≤ 0.2) was achieved in 88% of patients. All five patients with poor outcomes (LogMAR > 0.5) had experienced intraoperative complications, suggesting a strong link between surgical safety and final visual acuity. This observation is in line with findings from Balal et al., who reported that patients with small pupils and intraoperative trauma were more likely to have reduced postoperative acuity.[16]

There was a statistically significant association between the pupil dilation technique used and successful dilation (≥6 mm), with a chi-square value of 93.209 and $p < 0.001$. All cases in the intracameral, iris hook, and Malyugin ring groups achieved

sufficient pupil size, while none did in the topical group. This highlights the superior performance of mechanical and intracameral methods in complex eyes.

Although the association between technique and intraoperative complications did not reach statistical significance ($\chi^2 = 8.124$, $p = 0.087$), a clinical trend was apparent. Higher complication rates in the topical and iris hook groups suggest that mechanical manipulation in inadequately dilated pupils may increase risk.

Our results sync with those of Murthy et al., who conducted a comparative review and found that the Malyugin ring offered the most favourable safety and usability profile among pupil expansion devices.[17] Suan et al. also reported in their meta-analysis that intracameral mydriatics are preferable over topical agents for faster onset, more stable dilation, and fewer systemic side effects.[18]

The effectiveness of intracameral agents was further validated in a national registry-based study by Kreku et al., who reported a reduction in the need for mechanical devices and complications when intracameral drugs were used preoperatively.[19] Surgical strategies tailored to specific small-pupil challenges, as discussed by Burrato et al., emphasize the need to individualize technique choice based on patient and iris characteristics. Their study supports our observation that methods like the Malyugin ring yield the best combination of efficacy, safety, and surgeon satisfaction in difficult cases.[20]

CONCLUSION

This study reaffirms that in complicated cataract cases, mechanical pupil dilating devices—particularly the Malyugin ring—offer superior results in terms of pupil size achieved, complication rates, and ease of surgery. Intracameral mydriatics are a viable alternative, offering excellent efficacy and safety. Topical agents alone are inadequate in such cases. A tailored approach, considering both ocular comorbidities and surgeon expertise, is essential for optimizing surgical outcomes.

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