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SUPPLEMENTARY MATERIAL OPEN ACCESS

A Systematic Review of Malyugin Rings in Cataract Surgery: Surgical Outcomes, Efficacy and Safety

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Supplementary Table 1. PICOT framework.

Population	Adults (≥18 years) undergoing cataract surgery with small pupils (SP) or conditions requiring mechanical pupil dilation (*e.g.*, pseudoexfoliation, intraoperative floppy iris syndrome)
Intervention	Use of Malyugin ring
Comparator	Other pupil dilation methods including: – Iris hooks – B-HEX ring – OASIS iris expander – Manual iris stretching – Viscoadaptive ophthalmic viscosurgical devices (OVDs) – Intracameral mydriatics (*e.g.*, epinephrine/phenylephrine)
Outcome	Primary outcomes: – Efficacy of pupil dilation (pupil size, maintenance) – Visual outcomes (BCVA) – Safety (iris trauma, pseudophakic macular edema, ECL, inflammation) Secondary outcomes: – Surgical time – Intraoperative/postoperative complications – Surgeon satisfaction/performance
Time	During and after cataract surgery

Search strategies (Supplementary Tables 2a–2d). Databases searched from inception to October 21, 2024, and updated June 28, 2025.

Supplementary Table 2a. MEDLINE (Ovid).

Line	Search Strategy
1	Malyugin.mp.
2	exp Iris Retractor/ OR iris retractors.mp.
3	mechanical dilation devices.mp.
4	1 OR 2 OR 3
5	exp Cataract/ OR cataract.mp.
6	cataract surgery.mp.
7	cataract extraction.mp. OR exp Cataract Extraction/
8	exp Lens Implantation/ OR lens implantation.mp.
9	phacoemulsification.mp. OR exp Phacoemulsification/
10	femtosecond laser-assisted cataract surgery.mp. OR exp Femtosecond Laser-Assisted Cataract Surgery/
11	extracapsular cataract extraction.mp. OR exp Extracapsular Cataract Extraction/
12	5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11
13	4 AND 12

Supplementary Table 2b. Embase (Ovid).

Line	Search Strategy
1	Malyugin.mp.
2	exp Iris Retractor/ OR iris retractors.mp.
3	mechanical dilation devices.mp.
4	1 OR 2 OR 3
5	exp Cataract/ OR cataract.mp.
6	cataract surgery.mp.
7	cataract extraction.mp. OR exp Cataract Extraction/
8	exp Lens Implantation/ OR lens implantation.mp.
9	phacoemulsification.mp. OR exp Phacoemulsification/
10	femtosecond laser-assisted cataract surgery.mp. OR exp Femtosecond Laser-Assisted Cataract Surgery/
11	extracapsular cataract extraction.mp. OR exp Extracapsular Cataract Extraction/
12	5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11
13	4 AND 12

Supplementary Table 2c. CINAHL plus (EBSCO).

Line	Search Strategy
S1	"Malyugin ring"
S2	(pupil* N3 (expand* OR expansion OR dilat* OR stretch*))
S3	(iris N3 (hook* OR retractor* OR ring OR expander*))
S4	(MH "Phacoemulsification") OR (MH "Cataract Extraction+")
S5	(phacoemulsif* OR "cataract surgery" OR "lens extraction")
S6	("small pupil*" OR "narrow pupil*" OR miosis OR microcoria)
S7	(pseudoexfoliation OR IFIS OR "floppy iris")
S8	S1 OR S2 OR S3
S9	S4 OR S5
S10	S6 OR S7
S11	S8 AND S9
S12	S8 AND S9 AND S10

Supplementary Table 2d. Web of science core collection.

Line	Search Strategy
#1	TS=("Malyugin ring")
#2	TS=(pupil* NEAR/3 (expand* OR expansion OR dilat* OR stretch*))
#3	TS=(iris NEAR/3 (hook* OR retractor* OR ring OR expander*))
#4	TS=(phacoemulsif* OR "cataract surgery" OR "lens extraction" OR "cataract extraction")
#5	TS=("small pupil*" OR "narrow pupil*" OR miosis OR microcoria)
#6	TS=(pseudoexfoliation OR IFIS OR "floppy iris")
#7	#1 OR #2 OR #3
#8	#7 AND #4
#9	#7 AND #4 AND (#5 OR #6)

Risk of bias and certainty of evidence (Supplementary Tables 3a–3b).

Supplementary Table 3a. Risk-of-bias summary by study.

Study	Design	Tool	Domain Judgements	Overall
Gupta 2024	RCT	RoB 2	Randomization Low; deviations Low; missing data Low; measurement Low; selective reporting Some concerns	Low
Wilczynski 2013	RCT (small)	RoB 2	Randomization Some concerns; deviations Low; missing data Low; measurement Low; selective reporting Some concerns	Some concerns
Wang 2022	Prospective case-control	ROBINS-I	Confounding Low; selection Low; classification Low; deviations Low; missing Low; measurement Low; reporting Low	Low
Balal 2021	Retrospective case-series	ROBINS-I	Confounding Low; selection Low; classification Low; deviations Low; missing Low; measurement Low; reporting Low	Low
Hanna 2014*	Retrospective (abstract)	ROBINS-I	Confounding Low; selection Low; others limited by abstract-only reporting	Low
Nderitu 2019	Retrospective case-series	ROBINS-I	Confounding Moderate; selection Moderate; others Low	Moderate
Conrad-Hengerer 2013	Prospective clinical trial (non-rand.)	ROBINS-I	Confounding Moderate; selection Moderate; others Low	Moderate
Borkenstein 2018	Prospective single-arm	ROBINS-I	Confounding Moderate; selection Moderate; others Low	Moderate
Chang 2008	Prospective case series	ROBINS-I	Confounding Serious (single-arm, tamsulosin/IFIS); others Low–Moderate	Serious
Fay 2014*	Retrospective (abstract)	ROBINS-I	Confounding Serious; selection Serious (abstract-only, limited detail)	Serious

Supplementary Table 3b. GRADE certainty-of-evidence summary by outcome.

Outcome	Studies (n)	Design	Downgrading Factors	Certainty
Efficacy of pupil dilation/maintenance	8	Mostly non-randomized	Risk of bias (−1); imprecision/inconsistent reporting (−1)	Low
Operating / phaco time	3	1 RCT, 2 non-rand.	Risk of bias (−1); imprecision, single poolable estimate (−2)	Very low
Endothelial cell loss	3	Non-randomized + 1 RCT	Risk of bias (−1); imprecision, inconsistent metrics (−2)	Very low
Postoperative BCVA	5	Mixed	Risk of bias (−1); imprecision, abstract-only data (−1)	Low
Iris tears	2	Non-randomized	Risk of bias (−1); imprecision, rare events (−2)	Very low
Postoperative inflammation / edema	2	Non-randomized	Risk of bias (−1); inconsistency (mixed direction) (−1); imprecision (−1)	Very low

Supplementary Table 4. Outcome-level poolability assessment (justification for narrative synthesis).

Outcome	Metric Needed	What Studies Report	Poolable (n)	Barrier to Pooling
Endothelial cell loss	Mean % (SD) *vs*. common comparator	Wilczynski: mean±SD %; Wang: median absolute ECD (non-normal); Balal/Nderitu: not extractable	1	Different metric/scale; medians not means
Postop BCVA (logMAR)	Mean (SD) by group	Wilczynski: mean±SD; Wang: median; Balal: gain only; Hanna/Fay: abstract point values	1	No dispersion; medians; abstracts
Phaco / operating time	Mean (SD), same unit/definition	Wilczynski: mean±SD (s); Nderitu: median added time (min)	1	Different unit, definition, distribution
Iris tears	Events/N *vs*. common comparator	Balal: 6/469 *vs*. hooks 1/194 *vs*. IC-PE 3/447; others: none comparative	1	Single study with 2×2 data
Corneal/macular edema	Events/N *vs*. common comparator	Balal: adjusted OR (pooled cohorts); Nderitu/Hanna: narrative	<2	No consistent 2×2 *vs*. same comparator
Pupil distortion/ovalization	Continuous or events *vs*. common comparator	Gupta: MR *vs*. B-HEX (distortion %); Wilczynski: narrative ovalization	1	Single study per comparator

Supplementary Table 5. Consolidated outcome summary across the reported outcome domains, with representative effect sizes and GRADE certainty of evidence. MR, Malyugin ring; NS, not significant; IC-PE, intracameral phenylephrine; PXF, pseudoexfoliation syndrome; IFIS, intraoperative floppy-iris syndrome; FLACS, femtosecond laser-assisted cataract surgery. Because no outcome was quantitatively poolable, directions and effect sizes are illustrative of the contributing studies rather than pooled estimates.

Outcome Domain	Studies (comparator)	Direction	Effect Size (example)	GRADE
Efficacy of dilation/maintenance	8 studies (small pupil, PXF, IFIS; *vs*. OVD/epinephrine, hooks)	Favors MR	Stable dilation ≥5.5–7.0 mm; 68% success in FLACS	Low
Operating / phaco time	3 (vs iris hooks / manual stretch)	Favors MR	Phaco 15.2±3.9 s *vs*. 19.8±3.1 s (Wilczynski)	Very low
Endothelial cell loss	3 (vs manual stretch / hooks)	Favors MR	9.35±11% *vs*. 13.77±8.0% (Wilczynski)	Very low
Postoperative BCVA	5 (vs hooks / manual stretch)	Favors MR	0.75±0.30 *vs*. 0.56±0.56 logMAR (Wilczynski)	Low
Iris tears	2 (vs hooks / IC-PE)	Favors comparator	Higher rate with MR, $p<0.05$ (Balal)	Very low
Pupil distortion / ovalization	2 (vs B-HEX)	Favors comparator	More distortion with MR, p=0.029 (Gupta)	Very low
Postoperative inflammation / edema	2 (vs hooks)	Mixed	Higher uveitis/edema with MR (Nderitu); NS in Balal	Very low

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist Item	Location where Item is Reported
TITLE			
Title	1	Identify the report as a systematic review.	Lines 1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Lines 45-73
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Lines 98-113
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Lines 114-117
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Lines 136-147
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Lines 128-130
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Lines 136-147 & Appendix

Table contd.....

Section and Topic	Item #	Checklist Item	Location where Item is Reported
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Lines 136-153
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Lines 156-163
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (*e.g.* for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Lines 156-163 and Lines 136-147
	10b	List and define all other variables for which data were sought (*e.g.* participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Lines 156-163
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Lines 155-164
Effect measures	12	Specify for each outcome the effect measure(s) (*e.g.* risk ratio, mean difference) used in the synthesis or presentation of results.	N/A
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (*e.g.* tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	N/A
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	N/A
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	N/A
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	N/A
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (*e.g.* subgroup analysis, meta-regression).	N/A
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	N/A
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Lines 166-174
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	N/A
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Lines 179-183
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Lines 179-183
Study characteristics	17	Cite each included study and present its characteristics.	Lines 186-192
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Lines 266-280
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (*e.g.* confidence/credible interval), ideally using structured tables or plots.	N/A
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Lines 266-280
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (*e.g.* confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	N/A
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Lines 327-334
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	N/A
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Lines 266-280
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	N/A

Table contd.....

Section and Topic	Item #	Checklist Item	Location where Item is Reported
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Lines 283-309
	23b	Discuss any limitations of the evidence included in the review.	Lines 327-334
	23c	Discuss any limitations of the review processes used.	Lines 327-334
	23d	Discuss implications of the results for practice, policy, and future research.	Lines 310-315 and Lines 337-341
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Lines 122
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Lines 123
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	N/A
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Lines 32
Competing interests	26	Declare any competing interests of review authors.	Lines 29-30
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Lines 34-35

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, *et al*. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71. This work is licensed under CC BY 4.0. To view a copy of this license, visit https://creativecommons.org/licenses/by/4.0/