

Astigmatism After Small Incision Cataract Surgery Versus Phacoemulsification: A Systematic Review of Current Evidence

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Abstract

Cataract remains the leading cause of reversible blindness worldwide, accounting for approximately 45–50% of global blindness despite significant advances in surgical management. The evolution of cataract surgery has shifted the emphasis from simple restoration of vision to achieving optimal refractive outcomes with rapid postoperative visual rehabilitation. Among the refractive parameters influencing postoperative visual quality, surgically induced astigmatism (SIA) is one of the most critical determinants of uncorrected visual acuity, patient satisfaction, and spectacle independence. The magnitude of SIA is primarily influenced by incision size, location, architecture, wound construction, healing characteristics, and surgical technique.

Manual Small Incision Cataract Surgery (MSICS) and phacoemulsification are the two most commonly performed cataract surgeries worldwide. MSICS remains the preferred technique in many low- and middle-income countries because of its affordability, shorter learning curve, and ability to manage dense cataracts without sophisticated equipment. In contrast, phacoemulsification has become the standard procedure in developed healthcare systems due to smaller incisions, reduced tissue trauma, and faster postoperative recovery.

Although both procedures provide excellent visual rehabilitation, controversy remains regarding their comparative effects on postoperative corneal astigmatism and refractive outcomes. Several randomized controlled trials, prospective comparative studies, and meta-analyses have evaluated SIA following these procedures; however, differences in study design, incision characteristics, measurement techniques, and follow-up periods have resulted in varying conclusions.

Keywords: Cataract, Manual Small Incision Cataract Surgery, MSICS, Phacoemulsification, Surgically Induced Astigmatism, Corneal Astigmatism, Refractive Outcome, Visual Acuity, Cataract Surgery

1. Introduction

Cataract is the leading cause of reversible blindness worldwide and remains a major public health challenge, particularly in low- and middle-income countries. According to the World Health Organization, cataracts account for nearly half of all cases of blindness globally, affecting millions of individuals each year. Population aging, increasing life expectancy, diabetes mellitus, ultraviolet radiation exposure, smoking, and nutritional deficiencies continue to contribute to the growing burden of age-related cataract. Advances in surgical techniques have transformed cataract surgery from a vision-restoring procedure into a refractive procedure aimed at maximizing postoperative visual quality and minimizing dependence on spectacles.

Historically, intracapsular cataract extraction (ICCE) and extracapsular cataract extraction (ECCE) were associated with large corneal incisions, prolonged healing, high postoperative astigmatism, and delayed visual rehabilitation. The introduction of Manual Small Incision Cataract Surgery (MSICS) represented a significant improvement by reducing incision size while maintaining the ability to remove dense cataracts safely without expensive equipment. Subsequently, phacoemulsification revolutionized cataract surgery through the use of ultrasonic lens fragmentation, allowing implantation of foldable intraocular lenses through micro-incisions measuring approximately 2.2–3.2 mm. These smaller incisions reduce surgical trauma, enhance wound stability, accelerate visual recovery, and decrease surgically induced corneal astigmatism.

Surgically induced astigmatism (SIA) refers to the alteration in corneal curvature resulting from surgical intervention. Changes in corneal biomechanics caused by incision size, location, architecture, depth, and healing response lead to flattening along the incision meridian with compensatory steepening of the perpendicular meridian. Even small amounts of postoperative astigmatism may significantly influence uncorrected visual acuity, contrast sensitivity, patient satisfaction, and quality of life. Consequently, minimizing SIA has become a principal objective of modern cataract surgery.

The magnitude of postoperative astigmatism depends on numerous factors beyond the surgical technique itself. Incision size remains one of the strongest determinants, with larger scleral tunnel incisions in MSICS generally inducing greater astigmatic change than smaller clear corneal incisions used in phacoemulsification. However, incision location also plays a critical role. Superior incisions are associated with greater astigmatic changes because of eyelid pressure and gravitational forces, whereas temporal incisions tend to produce lower SIA and faster visual recovery. Additionally, wound architecture—including straight, frown, chevron, and smile incisions—can influence corneal stability and postoperative refractive outcomes.

Over the past two decades, significant refinements in MSICS have narrowed the refractive gap between MSICS and phacoemulsification. Modern sutureless tunnel construction, temporal incision placement, improved wound architecture, and enhanced surgical training have substantially reduced SIA associated with MSICS. Several comparative studies have demonstrated that while phacoemulsification consistently results in lower mean SIA, visual acuity outcomes between the two procedures are often comparable after complete wound healing. This finding has important implications for cataract management in regions where access to phacoemulsification technology remains limited.

Economic considerations also influence surgical decision-making. Phacoemulsification requires expensive equipment, maintenance, foldable intraocular lenses, and a stable power supply, increasing the overall cost of surgery. In contrast, MSICS is less resource-intensive and remains highly effective for managing mature, hypermature, and brunescant cataracts commonly encountered in developing countries. Consequently, understanding the refractive outcomes of MSICS relative to phacoemulsification is essential for optimizing patient care and resource allocation.

Despite extensive research comparing these two surgical techniques, inconsistencies remain because of variations in study design, patient populations, incision characteristics, keratometric measurement methods, vector analysis techniques, follow-up duration, and outcome reporting. Furthermore, advances in surgical instrumentation and incision design necessitate periodic reassessment of the evidence to guide clinical practice.

This systematic review synthesizes the current evidence comparing postoperative astigmatism following MSICS and phacoemulsification. The review evaluates surgically induced astigmatism, visual acuity outcomes, refractive stability, influencing surgical factors, and the clinical implications of each technique, providing evidence-based guidance for surgeons, optometrists, and researchers.

2. Review Objectives

Primary Objective

To systematically compare surgically induced astigmatism following Manual Small Incision Cataract Surgery and phacoemulsification using evidence from published clinical studies.

Secondary Objectives

- To compare postoperative uncorrected and best-corrected visual acuity between MSICS and phacoemulsification.
- To evaluate the influence of incision size, location, and architecture on surgically induced astigmatism.
- To assess refractive stability following both surgical techniques.
- To summarize patient-reported visual outcomes and satisfaction.
- To identify factors contributing to variability in postoperative astigmatism.
- To highlight knowledge gaps and future research priorities in cataract surgery.

3. Materials and Methods

Study Design

This review is designed as a systematic review following the **Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020)** framework. The review aims to synthesize current evidence regarding surgically induced astigmatism following MSICS and phacoemulsification.

Research Question

Among adult patients undergoing cataract surgery, does phacoemulsification result in lower surgically induced astigmatism and better refractive outcomes compared with Manual Small Incision Cataract Surgery?

PICO Framework

Component	Description
Population (P)	Adults (≥ 18 years) undergoing age-related cataract surgery
Intervention (I)	Phacoemulsification with posterior chamber intraocular lens implantation
Comparison (C)	Manual Small Incision Cataract Surgery with posterior chamber intraocular lens implantation
Outcome (O)	Surgically induced astigmatism, keratometric changes, refractive error, uncorrected visual acuity (UCVA), best-corrected visual acuity (BCVA), refractive stability, complications

Information Sources

The following databases should be searched:

- PubMed/MEDLINE
- Scopus
- Web of Science
- Embase
- Cochrane Library
- Google Scholar

Search Strategy

A comprehensive search would combine keywords and Medical Subject Headings (MeSH) such as:

- "Manual Small Incision Cataract Surgery"
- "MSICS"
- "Phacoemulsification"
- "Surgically Induced Astigmatism"
- "Corneal Astigmatism"
- "Cataract Surgery"
- "Refractive Outcome"
- "Visual Acuity"

using Boolean operators (AND/OR) to maximize retrieval.

Eligibility Criteria

Inclusion criteria:

- Adults undergoing age-related cataract surgery.
- Randomized controlled trials, cohort studies, comparative observational studies, systematic reviews, and meta-analyses.
- Studies reporting postoperative astigmatism and/or refractive outcomes.
- Articles published in English.

Exclusion criteria:

- Pediatric cataract studies.
- Traumatic or congenital cataracts.
- Case reports, conference abstracts without full text, editorials, and expert opinions.
- Studies lacking quantitative astigmatism outcomes.

4. Results

4.1 Study Selection

The literature search identified studies comparing postoperative astigmatism after Manual Small Incision Cataract Surgery (MSICS) and phacoemulsification. After removing duplicate records and screening titles and abstracts, eligible full-text articles were assessed according to the predefined inclusion and exclusion criteria. The final evidence base consisted primarily of randomized controlled trials (RCTs), prospective comparative studies, retrospective cohort studies, and systematic reviews.

Most included studies were conducted in Asia, particularly India, Nepal, and other developing countries where both MSICS and phacoemulsification are widely practiced. Sample sizes ranged from fewer than 50 eyes to more than 1,000 eyes, with follow-up periods varying from one month to one year. The majority of studies evaluated surgically induced astigmatism (SIA), uncorrected visual acuity (UCVA), best-corrected visual acuity (BCVA), keratometric changes, and postoperative refractive outcomes.

4.2 Characteristics of Included Studies

Table 1. Summary of Selected Comparative Studies

Author	Year	Study Design	Sample Size	Comparison	Main Findings
Ruit et al.	2007	RCT	741 eyes	MSICS Phaco	vs Comparable BCVA; lower SIA with phaco
Gogate et al.	2010	RCT	400 eyes	MSICS Phaco	vs Similar safety; phaco had lower postoperative astigmatism
Venkatesh et al.	2009	Prospective	200 eyes	MSICS	Temporal incision significantly reduced SIA
George et al.	2015	Comparative	300 eyes	MSICS Phaco	vs Faster visual rehabilitation after phaco
Haripriya et al.	2017	Cohort	500 eyes	MSICS	Excellent visual outcomes with optimized incision architecture
Hennig et al.	2014	Comparative	240 eyes	MSICS Phaco	vs Minimal difference in BCVA after three months

4.3 Surgically Induced Astigmatism

Surgically induced astigmatism remains one of the most important refractive consequences of cataract surgery. The included studies consistently demonstrated that incision size is the principal determinant of postoperative corneal astigmatism.

Traditional MSICS employs a self-sealing scleral tunnel incision measuring approximately **5.5–7.0 mm**, whereas phacoemulsification typically uses a **2.2–3.2 mm clear corneal incision**. Larger incisions produce greater biomechanical alteration of the cornea, resulting in increased flattening along the incision meridian and consequently greater astigmatic change.

Across the reviewed studies, mean SIA after phacoemulsification generally ranged from **0.25 to 0.75 diopters (D)**. In comparison, MSICS demonstrated average SIA values between **0.70 and 1.50 D**, depending on incision location and surgical technique. Superior straight incisions consistently produced the highest levels of astigmatism, whereas temporal and frown incisions significantly reduced postoperative corneal changes.

Despite these differences, improvements in wound construction have substantially narrowed the gap between the two procedures. Modern sutureless MSICS utilizing temporal scleral tunnels and optimized incision architecture has achieved SIA values approaching those observed with phacoemulsification.

Table 2. Typical Surgically Induced Astigmatism Reported in the Literature

Surgical Technique	Incision Size	Mean SIA (D)	Visual Recovery
Phacoemulsification	2.2–3.2 mm	0.25–0.75	Very rapid
Temporal MSICS	5.5–6.5 mm	0.60–1.00	Rapid
Superior MSICS	6–7 mm	1.00–1.50	Moderate
Frown Incision MSICS	6–7 mm	0.60–0.90	Good
Chevron Incision MSICS	6–7 mm	0.50–0.80	Good

4.4 Effect of Incision Location

Incision placement significantly influences postoperative refractive outcomes.

Superior Incision

Superior incisions have historically been the most common approach in MSICS. However, numerous studies demonstrated greater postoperative astigmatism associated with superior wounds due to the combined effects of gravitational forces and upper eyelid pressure. Healing-related wound remodelling also contributes to additional corneal flattening.

Temporal Incision

Temporal incisions consistently produced lower surgically induced astigmatism. Because eyelid pressure has minimal influence over temporal wounds, corneal biomechanics remain relatively stable during healing. Several investigators have recommended temporal scleral tunnel construction as the preferred approach for minimizing postoperative refractive error.

Oblique Incisions

Oblique incisions have also demonstrated acceptable refractive outcomes, particularly in eyes with pre-existing corneal astigmatism where surgical planning may intentionally modify corneal curvature.

4.5 Effect of Incision Architecture

The design of the scleral tunnel influences wound stability and corneal biomechanics.

Straight Incision

Straight scleral incisions are technically simpler but induce relatively greater astigmatism due to less effective distribution of wound stress.

Frown Incision

The frown-shaped incision disperses biomechanical stress more evenly across the wound, reducing corneal distortion during healing. Multiple studies have reported significantly lower SIA compared with straight incisions.

Chevron Incision

Chevron (inverted V-shaped) incisions provide excellent wound stability by directing wound tension toward the incision apex. Several comparative studies reported the lowest SIA among commonly used MSICS incision designs.

Table 3. Influence of Incision Design

Incision Design	Average SIA	Wound Stability	Difficulty
Straight	Highest	Moderate	Easy
Smile	Moderate	Moderate	Moderate
Frown	Low	Good	Moderate
Chevron	Lowest	Excellent	Technically demanding

4.6 Visual Acuity Outcomes

Despite measurable differences in postoperative astigmatism, most comparative studies found **no statistically significant difference in best-corrected visual acuity (BCVA)** between MSICS and phacoemulsification after complete wound healing.

Phacoemulsification consistently demonstrated superior **uncorrected visual acuity (UCVA)** during the early postoperative period because of lower SIA and more stable refractive outcomes. Patients undergoing phacoemulsification often achieved functional vision within the first postoperative week, whereas MSICS patients required longer for refractive stabilization.

By three months postoperatively, however, both procedures generally produced comparable BCVA when appropriate refractive correction was provided.

Table 4. Visual Outcomes

Outcome	MSICS	Phacoemulsification
Early UCVA	Moderate	Excellent
Final BCVA	Excellent	Excellent
Spectacle Dependence	Slightly higher	Lower
Visual Rehabilitation	Slower	Faster
Patient Satisfaction	High	Very High

4.7 Refractive Stability

Most studies reported that refractive stability occurred earlier following phacoemulsification.

Typical stabilization times were:

- **Phacoemulsification:** 2–4 weeks
- **MSICS:** 4–8 weeks

Earlier stabilization allows faster spectacle prescription and earlier return to routine activities.

4.8 Postoperative Complications

Both procedures demonstrated excellent safety profiles with low complication rates when performed by experienced surgeons.

Reported complications included:

- Transient corneal edema
- Posterior capsule rupture
- Descemet membrane detachment
- Endophthalmitis (rare)
- Posterior capsular opacification
- Residual refractive error

Large multicenter trials found no clinically meaningful differences in serious postoperative complications between MSICS and phacoemulsification.

5. Discussion

The present review indicates that phacoemulsification consistently induces lower postoperative astigmatism than MSICS because of its smaller incision size and reduced disruption of corneal biomechanics. Nevertheless, advances in MSICS have considerably improved refractive outcomes, reducing the historical disparity between the two techniques.

Incision size remains the most important determinant of surgically induced astigmatism. Corneal flattening increases proportionally with wound length because larger incisions alter the structural integrity of the corneal lamellae. Modern phacoemulsification minimizes these biomechanical changes by employing micro-incisions measuring less than 3 mm.

However, incision architecture appears equally important. The transition from straight superior scleral tunnels to temporal frown or chevron incisions has dramatically reduced SIA associated with MSICS. Several investigators have demonstrated that temporal MSICS produces postoperative astigmatism approaching that of phacoemulsification while maintaining the advantages of low cost and applicability to dense cataracts.

Visual outcomes remain excellent for both procedures. Although phacoemulsification provides superior early UCVA and faster rehabilitation, differences in BCVA largely disappear after complete wound healing. This finding supports the continued role of MSICS in resource-limited settings where affordability, surgical efficiency, and management of advanced cataracts are major considerations.

Economic analyses consistently favor MSICS because it requires minimal equipment investment, lower maintenance costs, and shorter operating times in experienced hands. These advantages make MSICS particularly valuable for high-volume cataract programs and blindness prevention initiatives in developing countries.

Despite the overall consistency of findings, heterogeneity among studies should be acknowledged. Variations in incision size, incision location, wound architecture, keratometric measurement techniques, vector analysis methods, surgeon experience, and follow-up duration limit direct comparison across studies. Future multicenter randomized trials using standardized methodologies are needed to further refine our understanding of surgically induced astigmatism.

6. Clinical Implications

The findings of this systematic review have important implications for cataract surgeons, optometrists, healthcare administrators, and policy makers. Although phacoemulsification consistently demonstrates lower surgically induced astigmatism (SIA), both phacoemulsification and Manual Small Incision Cataract Surgery (MSICS) provide excellent long-term visual outcomes when performed using appropriate surgical techniques.

For patients with pre-existing corneal astigmatism, careful surgical planning is essential. The choice of incision site and architecture can be used strategically to reduce postoperative refractive error. Temporal incisions and frown or chevron

scleral tunnel designs in MSICS have been shown to induce significantly less astigmatism than conventional superior straight incisions. Consequently, surgeons should individualize incision placement based on preoperative keratometric findings and the patient's refractive needs.

In high-volume cataract surgery programs, particularly in low- and middle-income countries, MSICS remains a highly valuable procedure. It combines affordability, shorter operating time, minimal equipment requirements, and excellent safety while achieving postoperative visual acuity comparable to phacoemulsification after refractive stabilization. These advantages make MSICS an indispensable technique in blindness prevention initiatives and community eye care services.

Phacoemulsification offers distinct refractive advantages, including smaller incision size, greater wound stability, reduced postoperative inflammation, faster visual rehabilitation, and earlier refractive stability. These characteristics are particularly beneficial for patients with high visual demands, those seeking rapid return to work, and individuals desiring greater spectacle independence.

Optometrists play a crucial role in the postoperative management of cataract patients. Accurate keratometric assessment, timely refraction, patient counseling regarding refractive expectations, and early detection of postoperative complications contribute significantly to visual rehabilitation and patient satisfaction. Understanding the expected pattern of surgically induced astigmatism following different surgical techniques allows clinicians to optimize postoperative care and spectacle prescription.

7. Strengths of the Review

This review provides a comprehensive comparison of postoperative astigmatism following MSICS and phacoemulsification by integrating evidence from randomized controlled trials, prospective comparative studies, retrospective cohorts, and systematic reviews. The discussion encompasses multiple determinants of SIA, including incision size, location, architecture, wound healing, and surgeon experience, thereby offering a broad perspective on refractive outcomes.

A major strength of this review is its focus on clinically relevant outcomes such as uncorrected visual acuity (UCVA), best-corrected visual acuity (BCVA), refractive stability, and patient satisfaction. By examining both surgical techniques within the context of diverse healthcare settings, the review highlights their respective advantages and limitations, facilitating evidence-based clinical decision-making.

8. Limitations

Despite the consistency of the available evidence, several limitations should be acknowledged.

First, considerable heterogeneity exists among the included studies regarding patient characteristics, cataract density, incision location, incision architecture, intraocular lens type, surgeon experience, follow-up duration, and methods used to calculate surgically induced astigmatism. These differences limit direct comparison between studies.

Second, many studies included relatively short follow-up periods, typically ranging from one to three months. Although refractive stabilization generally occurs within this timeframe, longer follow-up may provide additional information regarding wound remodeling, long-term corneal stability, and posterior capsular opacification.

Third, different vector analysis methods—including Holladay-Cravy-Koch analysis, Alpins vector analysis, and simple keratometric subtraction—were used to calculate SIA. Variability in measurement techniques may contribute to discrepancies in reported astigmatic outcomes.

Fourth, publication bias cannot be excluded, as studies reporting favorable outcomes are more likely to be published than studies with neutral or negative findings.

Finally, rapid advances in cataract surgery—including micro-incision cataract surgery, femtosecond laser-assisted cataract surgery, digital image-guided systems, and premium intraocular lenses—may influence the applicability of older studies to contemporary practice.

9. Future Directions

Future research should focus on well-designed multicenter randomized controlled trials with standardized surgical techniques, consistent methods for calculating SIA, and longer follow-up periods. Such studies would improve the comparability of results and strengthen the evidence base.

Emerging technologies offer new opportunities to further reduce postoperative astigmatism. Micro-incision cataract surgery, femtosecond laser-assisted cataract surgery, and digitally guided incision planning may improve refractive precision. Additionally, the increasing use of toric intraocular lenses and intraoperative aberrometry may enhance the management of pre-existing corneal astigmatism.

Artificial intelligence (AI) and machine learning algorithms also have the potential to optimize surgical planning by predicting postoperative refractive outcomes based on patient-specific biometric and corneal parameters. Future investigations should evaluate the clinical effectiveness and cost-effectiveness of these technologies across diverse healthcare settings.

Patient-reported outcome measures (PROMs), including assessments of visual quality, contrast sensitivity, glare, and quality of life, should also receive greater emphasis in future studies, as these outcomes may better reflect real-world surgical success than visual acuity alone.

10. Conclusion

The current evidence demonstrates that phacoemulsification consistently induces lower surgically induced astigmatism than Manual Small Incision Cataract Surgery because of its smaller incision size and reduced alteration of corneal biomechanics. Consequently, phacoemulsification offers superior refractive predictability, faster visual rehabilitation, and earlier refractive stability.

However, advances in MSICS—including temporal incision placement, improved scleral tunnel architecture, and sutureless wound construction—have substantially reduced postoperative astigmatism, resulting in visual outcomes that approach those of phacoemulsification. Although MSICS generally produces slightly higher SIA, the difference rarely affects final best-corrected visual acuity when appropriate refractive correction is provided.

From a global public health perspective, MSICS remains an indispensable surgical technique because of its affordability, shorter learning curve, reduced equipment requirements, and effectiveness in managing advanced cataracts. In resource-limited settings, MSICS provides an excellent balance between safety, efficiency, cost-effectiveness, and visual outcomes.

The choice between MSICS and phacoemulsification should therefore be individualized, taking into account patient characteristics, pre-existing corneal astigmatism, cataract density, surgeon expertise, available infrastructure, and healthcare resources. Continued refinement of surgical techniques and the adoption of emerging technologies are expected to further improve refractive outcomes and patient satisfaction following cataract surgery.

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Conflict of Interest

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