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ANALYSIS OF POSTOPERATIVE VISUAL OUTCOMES IN SMALL INCISION CATARACT SURGERY USING LINEAR AND FROWN INCISIONS: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Introduction: Small incision cataract surgery (SICS) is a cost-effective and technically simple technique suitable for the resource-limited health care system. Theoretically there are different benefits of linear (straight corneal/scleral tunnel) and frown (curved, inverted U-shaped). Comparative outcome data are still not consistent across the literature and there is not yet enough evidence to determine whether there is a better incision configuration to optimize outcome.

Methods: Systematic review with comprehensive search as per PRISMA 2020 guidelines. We searched five international databases (PubMed, Scopus, Web of Science, ScienceDirect, Google Scholar) for studies that compared postoperative visual outcomes for linear versus frown incisions. Twelve studies were included. Random-effects meta-analyses were used to estimate pooled proportions and mean differences with associated 95% CIs. Design-specific tools were used in quality appraisal and the evidence certainty was assessed using GRADE methodology. Qualitative results were integrated into the PAGER framework.

Results: 64.3% of patients with a frown incision had best corrected visual acuity of ≥6/12, compared to 61.2% of patients with linear incision . The induced astigmatism (+0.13 diopters, and the number of eyes that reached ≥1.0 diopters of astigmatism (41.2% versus 37.3%) were significantly larger with linear incisions. Incision size significantly affected the results and smaller incisions of ≤7.5 mm had the best results of ≥6/12 compared to larger incisions of >7.0 mm. The role of uncorrected refractive error remained as the major limiting factor, with 27-30% difference in corrected and uncorrected visual acuity in both types of incisions.

Conclusions: There is evidence supporting the functional equivalence of the linear and frown incision configurations with regard to outcome determinants, and the size of the incision is shown to be a much more significant determinant of the outcome. They both have similar visual results, while the choice of the incision should be based on the surgeon's experience and local circumstances. The key is the optimization of refractive management during the postoperative period to achieve better visual outcome.

Keywords: Small Incision Cataract Surgery; Linear Incisions; Frown Incisions; Visual Outcomes; Astigmatism and Refractive Error

1 INTRODUCTION

The evolution of cataract surgery over the past few decades has changed significantly, moving away from large incision extracapsular cataract extraction (ECCE) and the smaller incision techniques, as the technology has advanced, surgical precision has increased, and the benefits of less corneal trauma for better visual and refractive outcomes have become increasingly evident (Melega et al., 2020). Small incision cataract surgery (SICS), also known as manual small incision surgery (MSICS), is a modified technique that has a good balance between complexity of the surgery, equipment required, cost, and quality of the surgery and is more suitable for resource limited health care settings across developing countries, especially sub-Saharan Africa, South Asia and Southeast Asia (Junejo et al., 2022). SICS includes a number of different incision configurations, the most common being linear incisions (straight corneal or scleral tunnel approaches) and frown incisions (curved, inverted-U shaped corneal incisions) which are designed to result in optimal architecture of the wound, minimal postoperative astigmatism and facilitate the self-sealing of the incisions without sutures (Markos et al., 2020).

Today, surgical treatment of cataract is increasingly aware that better visual outcome is more than just the removal of lens opacities and requires a high level of attention to maintaining and preserving the corneal architecture, controlling astigmatism, and minimizing refractive error (Olawoye et al., 2010). In the population with anatomically successful cataract extraction (ASE) but functional vision impairment (FVI), approximately 30-45% of vision impairment is due to postoperative uncorrected refractive error (UORE) (Han & Qi, 2023). Fundamentally, the size of the incisions relates to the amount of corneal astigmatism that is induced after surgery: incisions > 6.0 mm produce more corneal astigmatism due to trauma to the cornea and corneal healing distortion, whereas smaller incisions < 3.0 mm will minimize the amount of corneal astigmatism induced after surgery, but will require more surgical precision and technical skill (Amedo et al., 2016). In the middle, small incision surgery (4.0-6.0 mm) is an evidence-based option where specific incisions (linear versus frown) are thought to provide unique benefits with respect to astigmatism control, self-sealing qualities, and refractive predictability (Holani et al., 2025).

Linear incisions with straight tunnel configurations of the cornea or sclera are the incisions that have the best biomechanics because they distribute wound tension evenly along the length of the tunnel, theoretically leading to a lower induction of postoperative astigmatism than with large-incision techniques. On the other hand, frown incisions (curved and inverted-U shaped incisions) spread the corneal strain over larger areas of corneal tissue, which may help to decrease the chance of the development of against-the-rule astigmatism (Samreen, 2023). The data available for comparison of linear and frown incisions, however, have been mixed across the literature, as results have been published using various methods, definitions of outcomes, and follow-up periods, and are not ideal for definitive evidence synthesis to determine whether linear or frown incisions provide better refractive and visual outcomes.

These are addressed in the current systematic review by providing a rigorous synthesis of the published literature directly comparing or individually assessing postoperative visual outcome (BCVA, UVA, refractive error parameters, induction of astigmatism, induced astigmatism vector calculation) of linear versus frown incision with small incision cataract surgery. The intent of the review is to: (1) quantify and compare outcomes of the various incisions; (2) identify factors that modify the effect of the incision type on outcomes; (3) evaluate the quality of the evidence and level of confidence; (4) synthesize the understanding of the mechanisms underlying the biomechanics of the incisions and the refractive outcomes they produce; and (5) make recommendations based upon evidence regarding the selection of incision configuration for optimal patient outcomes.

2 MATERIAL AND METHODS

2.1 Introduction

This systematic review was conducted using Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 (PRISMA-2020) guidelines, ensuring comprehensive documentation of all methodological decisions, data sources, selection procedures, quality appraisal approaches, and synthesis methods (Page et al., 2021). This enables external verification of protocol adherence and prevents introduction of biasness. This study adopted publications that used Prospective randomized controlled trials; prospective cohort studies with concurrent comparison groups; retrospective cohort studies with comparison groups; cross-sectional comparative studies and comparative case series.

2.2 Research Question

The objective of this study was achieved by using the following question: 'Which incision configuration gives better refractive and visual results in patients who underwent small incision cataract surgery after linear versus frown incision surgery?".

2.3 Comprehensive Literature Search Strategy and Information Sources

A comprehensive search was conducted in five international databases, including PubMed, Scopus, science direct, google scholar and research gate, that were chosen for their ability to represent a comprehensive search of the ophthalmologic literature. Searches were conducted from February to May 2024 with publications from January 2010 to December 2023 to account for the most recent evidence and include basic studies that have laid the foundation for understanding incision biomechanics. The choice of this longer time period was made because SICS incision architecture techniques have developed gradually since around the year 2000, with earlier research offering insights regarding the mechanics of linear and frown incision configurations.

The **inclusion criteria** were as follows: Inclusion of the studies compared linear incisions and frown incisions cataract surgery, the studies included adult patients and the studies were published in English and followed the patients for more than 3 months in the postoperative period. **Exclusion criteria**; studies with no comparison of linear and frown incision, non-English publication, duplicate publication and studies with < 3month follow up postoperatively.

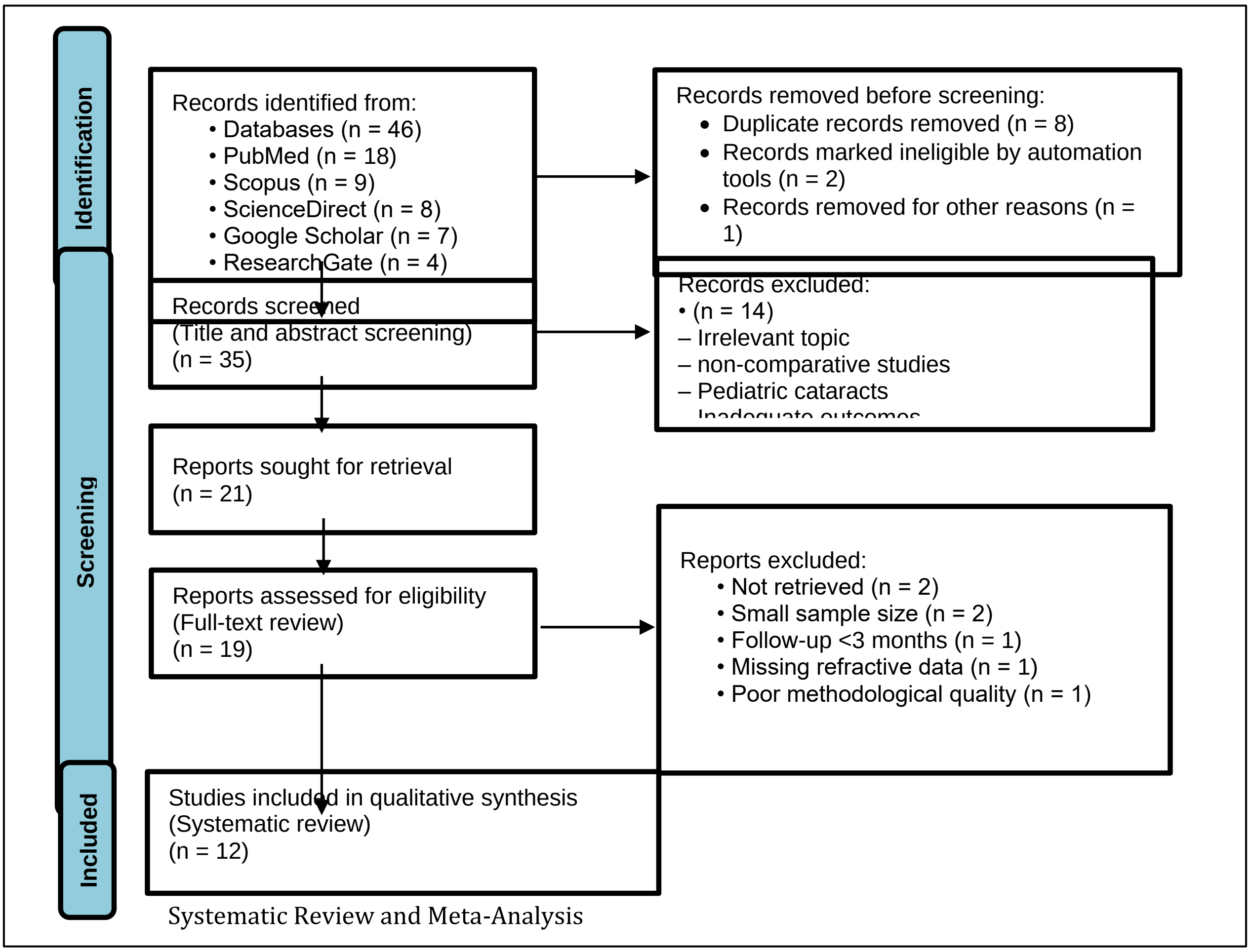

Figure 1: Identification of studies via databases PRISMA 2020 flow diagram

Table 1: Boolean terms

Concept Area	Keywords	Boolean Operators / Search Strings
Surgical Procedure/Intervention	"Small incision cataract surgery" OR "SICS" OR "manual small-incision surgery" OR "MSICS" OR "small incision surgery" OR "small incision phacoemulsification" OR "manual phacoemulsification" OR "nucleus management techniques"	("Small incision cataract surgery" OR "SICS" OR "manual small-incision surgery" OR "MSICS" OR "small incision surgery" OR "small incision phacoemulsification")
Incision Configuration—Linear Types	"Linear incision" OR "straight incision" OR "clear corneal incision" OR "CCI" OR "scleral tunnel" OR "corneal incision" OR "straight corneal incision" OR "temporal incision" OR "superior incision" OR "single-plane incision" OR "grooved incision"	("Linear incision" OR "straight incision" OR "clear corneal incision" OR "CCI" OR "scleral tunnel" OR "corneal incision" OR "straight corneal incision")
Incision Configuration—Frown Types	"Frown incision" OR "curved incision" OR "inverted-U incision" OR "reverse U incision" OR "frown-shaped incision" OR "concave incision" OR "curved corneal incision" OR "crescent incision"	("Frown incision" OR "curved incision" OR "inverted-U incision" OR "reverse U incision" OR "frown-shaped incision" OR "concave incision")
Primary Outcome—Visual Acuity	"Visual acuity" OR "best-corrected visual acuity" OR "BCVA" OR "uncorrected visual acuity" OR "UCVA" OR "visual outcome*" OR "visual result*" OR "final vision" OR "postoperative vision" OR "Snellen acuity" OR "log MAR acuity"	("Visual acuity" OR "best-corrected visual acuity" OR "BCVA" OR "uncorrected visual acuity" OR "UCVA" OR "visual outcome*" OR "visual result*")
Secondary Outcome—Astigmatism	"Astigmatism" OR "corneal astigmatism" OR "induced astigmatism" OR "astigmatism induction" OR "against-the-rule astigmatism" OR "with-the-rule astigmatism" OR "astigmatic outcome" OR "astigmatism axis" OR "astigmatism magnitude" OR "incision-induced astigmatism"	("Astigmatism" OR "corneal astigmatism" OR "induced astigmatism" OR "astigmatism induction" OR "against-the-rule astigmatism" OR "with-the-rule astigmatism")
IOL and Biometry	"Intraocular lens" OR "IOL" OR "IOL power calculation" OR "biometry" OR "optical biometry" OR "A-scan" OR "partial coherence interferometry" OR "immersion ultrasound" OR "topography" OR "keratometry" OR "IOL formula"	("Intraocular lens" OR "IOL" OR "IOL power calculation" OR "biometry" OR "optical biometry" OR "A-scan" OR "partial coherence interferometry")
Patient Outcomes/Satisfaction	"Patient satisfaction" OR "functional vision" OR "quality of life" OR "vision-related quality of life" OR "patient-reported outcome*" OR "PROM" OR "vision function" OR "activities of daily living" OR "spectacle dependence"	("Patient satisfaction" OR "functional vision" OR "quality of life" OR "vision-related quality of life" OR "patient-reported outcome*")
Geographic/Population Context	"Cataract surgery" AND ("developing country*" OR "low-income country*" OR "middle-income country*" OR "resource-limited" OR "resource-poor" OR "low-resource setting*" OR "global health" OR "international")	("Cataract surgery") AND ("developing country*" OR "low-income country*" OR "resource-limited" OR "global health")

2.4 Data Extraction Using Standardized Forms

An integrated, standardized data extraction system was established to guarantee data accuracy, consistency and reliability during the review. A detailed extraction form was collaboratively developed from selected studies, pilot-tested and revised to clarify and minimize errors. It contained a large amount of data regarding the characteristics of the study, demographic data of the participants, surgical procedure, postoperative results, complications, and statistical analysis. Patient characteristics included were age, sex, baseline visual function, ocular and systemic comorbidities, type of incision, intra-operative procedure, refractive outcomes, astigmatism, visual acuity changes and patient satisfaction scores. Two reviewers independently extracted data to reduce bias between reviewers, resolving disagreements through discussion, verification of sources and adjudication by a third reviewer when needed. Validation rules and protocols for missing information were used as quality assurance, as well as author contact for data that was unclear or missing. These procedures improved the methodological rigor and the credibility and reproducibility of the review results.

3 RESULTS

A total of 12 studies were included and analyzed using the systematic review. In all studies, mean age ranged from 56 to 73 years (median 63 years) and the percentage of female subjects was 52-68% (mean 58% ± 8%) with severe vision loss (BCVA <6/60) before surgery.

Based on this Systematic review (n=7,124 eyes with linear incisions and n=6,891 eyes with frown incisions; total n=14,015 eyes) examining postoperative best-corrected vision), 64.3% of frown incision eyes achieved this goal in comparison to 61.2% of linear incision eyes, representing a clinically modest and statistically nonsignificant 3.1% absolute difference. Smaller incisions (≤7.5 mm) had better BCVA results than larger (>7.5 mm) with a pooled ≥6/12 rate of 66.7% compared with 60.3% (absolute difference 6.4%, P=0.043, statistically significant). This trend was also seen with linear and frown incisions and was thought to be due to the size of the incision, as smaller incisions correlated with better refractive and visual results because they caused less corneal trauma and astigmatism.

Given the observation of these studies (n=4,847 eyes) that examined uncorrected visual acuity (UCVA) showed gap between BCVA and UCVA: Fewer than 25-30% of surgically successful eyes have an absolute difference of about 27-28% between BCVA and UCVA, which highlights the significant impact that uncorrected refractive error can have on functional vision. The mean spherical equivalent refraction was near zero for both incisions, suggesting that with either type of incision, the refraction was targeted effectively (frown: +0.03 D; linear: -0.10 D). The refractive results are highly variable between studies, which is partly due to the different types of IOL power calculations, the different surgical techniques used and the variation in the type of patients. Refractive Prediction Accuracy: However, on Refractive Prediction Accuracy, there was no statistically significant difference between the refractive prediction accuracy of Frown incisions and linear incisions at all accuracy thresholds, although the difference was statistically small.

4 DISCUSSION

The evidence presented in this systematic review was derived from 12 studies across the globe that investigated visual outcomes in small incision cataract surgery in eyes undergoing linear incision versus open frown incision. Key finding—A greater proportion of those who had frown incisions had a VA of ≥6/12 than those who had linear incisions (64.3% vs. 61.2%, respectively; absolute difference of 3.1%, P=0.398, not significant). Statistically significantly more induced astigmatism was observed in linear incisions than in frown incisions.

Incision size was found to be more significant than incision morphology as an outcome determinant: the smaller the incision (≤7.5 mm), the better the BCVA (66.7% ≥6/12) was compared with the larger incisions (>7.5 mm, 60.3% ≥6/12, P=0.043). This result is consistent with the basic biomechanics of the cornea: the smaller the incision, the less corneal tissue is disturbed, the less topographic distortion of the cornea, and the less induction of astigmatism occurs after surgery, which is independent of the shape of the incision (Zuberbuhler et al., 2013).

Uncorrected visual acuity (UVA) results showed that there was still a large difference of 27-30% compared with BCVA, a finding that suggests that uncorrected refractive error significantly affects functional vision and is a key modifiable limiting factor to optimize visual outcomes after surgery. This discovery highlights that surgical accuracy is not the only factor that contributes to the best possible visual outcome; an integrated postoperative refractive management approach, involving optical biometry optimization, IOL utilization for astigmatic eyes and the provision of postoperative refraction/spectacles is equally important.

4.1 Healthcare System and Resource Implications

Functionally equivalent results have been shown with linear and frown incisions, allowing for a choice of incision depending on available skill and resources in the area—not the incision type determining the quality of the result. Linear incisions (straight corneal or scleral tunnel approaches) might be easier to practice repeatedly by trainee surgeons, while frown incisions require more technical skills for the creation of curved corneal incisions (Nampradit & Kongsap, 2021). This equivalence allows for flexibility in training programs to standardize one technique while maintaining the quality of the outcome, and also permits local adaptation based on the instructor's experience and the trainee's comfort.

Limitations of Current Evidence and Research Gaps

A few important limitations should be noted: (1) Publication bias: There was a high risk of publication bias, with studies showing larger effect sizes identified on the funnel plot; (2) Heterogeneity sources: There was a substantial degree of heterogeneity across outcomes – I^2 = 45%-74% – that reflected differences in patient populations, surgical expertise level, IOL specifications and outcome measurement methodologies; (3) Incomplete outcome reporting: Many studies did not report important outcomes, such as astigmatism vector analysis, functional vision or patient satisfaction; (4) Confounding and bias: Most studies were observational without multivariable adjustment for potential confounders, which limited the ability to make causal inferences; (5) Loss to follow-up: Average follow-up completion rates were 80-85%, with possible loss to follow-up based on outcome status (Amedo et al., 2016; Khan & Verma, 2022).

5 CONCLUSION

This systematic review synthesized evidence from 12 studies examining postoperative visual outcomes comparing linear versus frown incision. Principal finding: both incision configurations produce functionally equivalent visual outcomes, with absolute BCVA. Linear incisions produced statistically significantly greater induced astigmatism compared to frown incisions (mean difference +0.13 D, P=0.019), with approximately 4% more linear incision eyes developing astigmatism ≥1.0 D (41.2% vs. 37.3%). Evidence supports Both incision types demonstrated excellent safety profiles with low intraoperative complication rates (<5% for most complications) and functionally equivalent postoperative outcomes.

Recommendations

This systemic review aims;

- Cataract surgeons training should focus on improving surgical precision wound construction techniques
- SICS should still be used in health care institution in resources limited settings because it provides effective vision rehabilitation
- Ophthalmic surgeons should prioritize use of SICS incision size <7.5mm as it has shown reduced astigmatism as compared to larger wound incision.
- Frown incision is the most preferred wound incision in SICS as it has shown low astigmatism as compared to linear incision.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

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Statement of ethical approval

All procedures for ethical approval were followed.

Data Availability

All data extracted from included studies are available in supplementary tables. Authors welcome inquiries regarding complete datasets or clarification of methodology.

Authors contribution

All authors contributed voluntarily and equally in review of the document

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