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ASSESSING THE ROLE OF INCISION DESIGN IN SURGICALLY INDUCED ASTIGMATISM FOLLOWING MANUAL SMALL-INCISION CATARACT SURGERY

DR. PAVITHRA. V[1], DR. DIVYA N[2], DR. V. PANIMALAR. A. VEERAMANI[3], DR. ANGELIN FIONA J[4]

[1] DEPARTMENT OF OPHTHALMOLOGY, SAVEETHA MEDICAL COLLEGE AND HOSPITALS, SAVEETHA INSTITUTE OF MEDICAL AND TECHNICAL SCIENCES, SAVEETHA UNIVERSITY · CHENNAI, IND
[2] DEPARTMENT OF OPHTHALMOLOGY, SAVEETHA MEDICAL COLLEGE AND HOSPITALS, SAVEETHA INSTITUTE OF MEDICAL AND TECHNICAL SCIENCES, SAVEETHA UNIVERSITY · CHENNAI, IND
[3] DEPARTMENT OF OPHTHALMOLOGY, SAVEETHA MEDICAL COLLEGE AND HOSPITALS, SAVEETHA INSTITUTE OF MEDICAL AND TECHNICAL SCIENCES, SAVEETHA UNIVERSITY · CHENNAI, IND
[4]SENIOR LECTURER, DEPARTMENT OF PERIODONTOLOGY, SREE BALAJI DENTAL COLLEGE & HOSPITAL, CHENNAI, INDIA

CORRESPONDING AUTHOR:
DR. DIVYA. N
ASSOCIATE PROFESSOR, DEPARTMENT OF OPHTHALMOLOGY,
SAVEETHA MEDICAL COLLEGE AND HOSPITALS, SAVEETHA INSTITUTE OF MEDICAL AND TECHNICAL SCIENCES, SAVEETHA UNIVERSITY · CHENNAI, IND

Abstract

Introduction: To compare the Surgically Induced Astigmatism (SIA) following Chevron, Straight, and Frown incisions in Manual Small-Incision Cataract Surgery (MSICS) and to evaluate their impact on postoperative astigmatism correction, visual acuity, and wound healing.

Material and Methods: A prospective, hospital-based study was conducted at the Department of Ophthalmology, Saveetha Medical College, Chennai, with 45 patients (15 per group) undergoing MSICS with Chevron, Straight, or Frown incisions. Patients were assessed at Day 1, Week 1, and Week 6 for SIA (measured using the SIA Calculator v2.1), Uncorrected Visual Acuity (UCVA), Best Corrected Visual Acuity (BCVA), wound integrity, and inflammation. Repeated Measures ANOVA and One-way ANOVA were used to analyze differences in SIA over time, and correlations were assessed between incision type, astigmatic changes, and wound healing parameters.

Results: The Chevron incision demonstrated the lowest residual SIA (0.255 ± 0.090D at Week 6) and the best wound integrity (2.666 ± 0.617), while the Frown incision exhibited favorable long-term astigmatic stability (0.242 ± 0.112D at Week 6). The Straight incision induced the highest SIA (0.798 ± 0.255D at Day 1, 0.462 ± 0.16D at Week 6), delaying astigmatic stabilization. UCVA and BCVA improved significantly in all groups, with the Chevron group achieving the best final BCVA (0.35 ± 0.141 at Week 6). ANOVA results showed significant differences in SIA between incision types at all time points ($p < 0.05$), confirming that incision type significantly influences postoperative astigmatism.

Conclusion: Chevron incisions are the most effective for reducing post-operative astigmatism and ensuring superior wound stability, while Frown incisions provide good long-term stability. Straight incisions result in higher residual astigmatism and require longer stabilization periods. The choice of incision should be tailored based on patient corneal biomechanics to optimize post-operative visual outcomes. Further research with larger sample sizes and extended follow-ups is recommended.

Keywords: Surgically Induced Astigmatism, Manual Small-Incision Cataract Surgery, Chevron Incision, Frown Incision, Straight Incision, Visual Acuity, Wound Healing.

INTRODUCTION:

Cataract surgery is one of the most commonly performed ophthalmic procedures worldwide, with advancements in surgical techniques significantly improving post-operative visual outcomes(1) . Manual small-incision cataract surgery (MSICS) is widely used in developing countries due to its cost-effectiveness and ability to manage dense cataracts(2) . However, surgically induced astigmatism (SIA) remains a key concern, as it can impact post-operative visual rehabilitation (3). The type and shape of the corneal incision play a crucial role in determining SIA, as they influence wound architecture, healing, and corneal curvature changes (4) . Among the commonly used incisions in MSICS, Chevron, Straight, and Frown incisions have been explored for their impact on astigmatic outcomes. The Chevron incision, with its angled design, is believed to provide better wound stability and reduce SIA (5). The Straight incision, although simple to perform, may induce more astigmatism due to its linear architecture (6). The Frown incision, which features a curved shape, is often recommended for its astigmatism-neutral effect and wound stability(6,7) .

Despite these findings, a clear consensus on the optimal incision type for minimizing SIA in MSICS remains lacking. Some studies suggest that the Frown incision provides the least amount of SIA, while others have reported comparable results with the Chevron and Straight incisions (8). Variations in surgical techniques, patient corneal biomechanics, and incision location contribute to these discrepancies. Moreover, while phacoemulsification techniques have been extensively studied in terms of incision-related SIA, research on MSICS remains relatively limited. This creates a research gap regarding the comparative effectiveness of different incision shapes in MSICS. Given the increasing global burden of cataract-related visual impairment, particularly in resource-limited settings where MSICS remains a preferred technique, further investigation is essential to optimize post-operative astigmatic outcomes (9).

The aim of this study is to compare the SIA following Chevron, Straight, and Frown incisions in MSICS and to assess their impact on post-operative astigmatism correction. By evaluating the differences in SIA, this research seeks to contribute to the ongoing refinement of MSICS techniques, thereby improving post-operative visual outcomes for cataract patients.

MATERIALS AND METHODS

This was a prospective, hospital-based study conducted at the Department of Ophthalmology, Saveetha Medical College, Chennai. The study was designed to compare the Surgically Induced Astigmatism (SIA) in Chevron, Straight, and Frown incisions in Manual Small-Incision Cataract Surgery (MSICS). Ethical clearance was obtained from the institutional review board, and informed consent was obtained from all participants in accordance with the tenets of the Declaration of Helsinki.Sample Size and Patient Selection

A total of 45 patients aged 50 years and above with uncomplicated senile cataract were included in the study. The patients were divided equally into three groups (n = 15 each) based on the type of incision used:

- Group C (Chevron Incision) – Superior Chevron incision.
- Group S (Straight Incision) – Superior Straight incision.
- Group F (Frown Incision) – Temporal Frown incision.

Inclusion Criteria

- Patients aged ≥50 years diagnosed with senile cataract.
- Patients with nuclear sclerosis of Grade 2 or more**.**
- Patients with preoperative corneal astigmatism ≤2.0D.
- Patients willing to undergo MSICS and provide informed consent.

Exclusion Criteria

- Corneal opacity, keratoconus, or irregular astigmatism.
- History of previous ocular surgery (cataract, glaucoma, or corneal).
- Distorted or oblique mires on keratometry.

- Systemic conditions affecting wound healing (e.g., uncontrolled diabetes, autoimmune disorders**).**

Preoperative Evaluation

A detailed ophthalmic examination was performed for all patients, including:

- Visual Acuity Assessment (Uncorrected Visual Acuity (UCVA) and Best Corrected Visual Acuity (BCVA)).
- Lacrimal Sac Examination to rule out infections.
- Applanation Tonometry to measure intraocular pressure.
- Slit Lamp Biomicroscopy and Fundoscopy.
- Manual Keratometry to assess preoperative astigmatism.
- IOL Power Calculation using the SRK II formula.

Surgical Procedure

All surgeries were performed by an experienced ophthalmic surgeon under peribulbar anesthesia. The pupil was dilated preoperatively using 0.8% Tropicamide and 5% Phenylephrine drops. Flurbiprofen (0.03%) eye drops were used to maintain intraoperative mydriasis.

Based on preoperative keratometric readings, the type of incision was selected:

- Chevron and Straight incisions were performed superiorly for patients with With-the-Rule (WTR) astigmatism.
- Frown incisions were performed temporally for patients with Against-the-Rule (ATR) astigmatism.

Incision Techniques

1. Chevron Incision (Group C):
   - An inverted-V shaped incision was placed superiorly.
   - The apex of the incision was 2 mm from the limbus, and the ends were 5 mm from the limbus.

2. Straight Incision (Group S):
   - A 7–8 mm linear incision was placed 1.5 mm from the superior limbus.

3. Frown Incision (Group F):
   - A 7–8 mm curved incision was placed temporally.
   - The center was 1.5 mm from the limbus, and the periphery was 4 mm away from the limbus.

A 2.8 mm crescent blade was used to create a self-sealing sclerocorneal tunnel extending 1.5–2 mm into the clear cornea. Capsulorhexis was performed using trypan blue staining and a 26G cystitome under viscoelastic protection. The internal wound was enlarged to 8–10 mm for nucleus delivery using an irrigating wire vectis. A single-piece posterior chamber intraocular lens (PCIOL) was implanted in the capsular bag. No sutures were applied as the incision was self-sealing.

Postoperative Care and Follow-Up

Postoperative treatment included:

- Prednisolone acetate 1% eye drops (8 times a day, tapered over 6 weeks).
- Vigamox eye drops (4 times daily for 2 weeks).
- Artificial tears as required.

Each patient was followed up on Day 1, Week 1, and Week 6. The following parameters were recorded at each visit:

- Visual Acuity (UCVA and BCVA).
- Slit Lamp Examination for wound integrity and inflammation.
- Surgically Induced Astigmatism (SIA) calculated using the SIA Calculator (version 2.1).

Statistical Analysis

Data were analyzed using SPSS version 26.0.

- Descriptive statistics were used to summarize SIA values at different time points.
- Repeated Measures ANOVA (RM-ANOVA) was used to compare SIA within each incision group over time.
- One-way ANOVA/Kruskal-Wallis Test was performed to compare SIA between incision groups.
- A p-value <0.05 was considered statistically significant.

RESULTS

Table 1: Demographic Profile of Study Participants

Variable	Mean ± Standard Deviation
Age	65.6 ± 9.22
Gender (Male)	24
Gender (Female)	21
Right Eye	20
Left Eye	25

The table 1 presents the demographic characteristics of the patients included in the study. The mean age of the participants was 65.6 ± 9.22 years, indicating that the study predominantly involved older adults, consistent with the typical age group affected by senile cataracts. The gender distribution showed a slight male predominance, with 24 males and 21 females. Regarding laterality, 20 patients underwent surgery in the right eye, while 25 had procedures in the left eye.

Table 2: Postoperative Visual Acuity Outcomes

Incision Type	UCVA Mean ± SD Day1	UCVA Mean ± SD Week1	UCVA Mean ± SD Week 6	BCVA Mean ± SD Day1	BCVA Mean ± SD Week 1	BCVA Mean ± SD Week 6
Chevron	0.94± 0.24	0.72± 0.194	0.47± 0.17	0.81± 0.19	0.62± 0.179	0.35± 0.141
Frown	0.92± 0.23	0.692± 0.169	0.48± 0.19	0.79± 0.20	0.604± 0.13	0.39± 0.13
Straight	0.86±0.14	0.68± 0.19	0.51± 0.18	0.858 ± 0.19	0.58± 0.20	0.412± 0.17

The table 2 summarizes the Uncorrected Visual Acuity (UCVA) and Best Corrected Visual Acuity (BCVA) outcomes at different time points (Day 1, Week 1, and Week 6) for each incision type (Chevron, Frown, and Straight).

At Day 1, UCVA was highest in the Straight incision group (0.86 ± 0.14), while the Chevron (0.94 ± 0.24) and Frown (0.92 ± 0.23) groups exhibited slightly lower values, indicating higher immediate postoperative astigmatism. By Week

1, UCVA showed significant improvement in all groups, with the Chevron incision group (0.72 ± 0.194) achieving slightly better outcomes. By Week 6, the UCVA was best in the Chevron group (0.47 ± 0.17), suggesting better stabilization of vision over time.

For BCVA, a similar trend was observed. At Day 1, BCVA was comparable across all groups, but the Straight incision group (0.858 ± 0.19) showed slightly better corrected vision. By Week 1, all groups showed improvement, with the Chevron group (0.62 ± 0.179) having the best BCVA. By Week 6, Chevron (0.35 ± 0.141) showed the lowest mean BCVA, indicating better final visual outcomes compared to Frown (0.39 ± 0.13) and Straight (0.412 ± 0.17).

Table 3: Postoperative Inflammation and Wound Healing

Incision Type	Inflammation Mean ± SD Day1	Inflammation Mean ± SD Week1	Inflammation Mean ± SD Week 6	Wound Integrity Mean ± SD Day1	Wound Integrity Mean ± SD Week 1	Wound Integrity Mean ± SD Week 6
Chevron	1.13 ± 0.74	0.466 ± 0.63	0.26 ± 0.59	2 ± 1	1.93 ± 0.9	2.66±0.61
Frown	1.03 ± 0.8	0.533 ± 0.63	0.4 ± 0.63	2 ± 1.30	2.26 ± 0.88	2.46±0.63
Straight	0.53 ± 0.63	0.2 ± 0.414	0.33 ± 0.48	1.66 ± 1.11	2.06 ± 1.03	2.47 ±0.74

Table 3 shows postoperative inflammation was initially highest in the Chevron incision group (1.133 ± 0.74 on Day 1), followed by Frown (1 ± 1) and lowest in the Straight group (0.533 ± 0.63), indicating that the Straight incision caused the least early inflammation. By Week 6, inflammation reduced significantly across all groups, with Chevron (0.26 ± 0.59) and Straight (0.33 ± 0.48) showing better recovery than Frown (0.4 ± 0.63).

Wound integrity was comparable at Day 1, with Frown (2 ± 1.3) and Chevron (2 ± 1) having slightly better initial stability than Straight (1.66 ± 1.11). By Week 6, all incisions showed good healing, with Chevron (2.666 ± 0.617) demonstrating the best wound stability, followed by Frown (2.466 ± 0.639) and Straight (2.47 ± 0.743). These results suggest that Straight incisions cause the least inflammation, while Chevron incisions offer superior long-term wound stability, making them the preferred choice for better postoperative recovery.

Table 4: Surgically Induced Astigmatism (SIA) Outcomes

Incision Type	SIA Mean ± SD Day 1	SIA Mean ± SD Week1	SIA Mean ± SD Week 6
Chevron	0.554 ± 0.138	0.301 ± 0.134	0.255 ± 0.090
Frown	0.56 ± 0.165	0.460 ± 0.11	0.242 ± 0.112
Straight	0.798 ± 0.255	0.554 ± 0.19	0.462 ± 0.16

The table 4 shows the SIA values (Mean ± SD) at Day 1, Week 1, and Week 6 for each incision type. On Day 1, the Straight incision group had the highest SIA (0.798 ± 0.255D), followed by Frown (0.56 ± 0.165D) and Chevron (0.554 ± 0.138D), indicating that the Straight incision induced the most initial astigmatism.

By Week 1, all groups showed a reduction in SIA, with Chevron (0.301 ± 0.134D) demonstrating the most significant improvement, while Frown (0.460 ± 0.11D) and Straight (0.554 ± 0.19D) maintained higher residual astigmatism.

At Week 6, the Chevron incision showed the lowest final SIA (0.255 ± 0.090D), closely followed by Frown (0.242 ± 0.112D), whereas the Straight incision still had the highest SIA (0.462 ± 0.16D). These findings suggest that Chevron and Frown incisions result in better long-term astigmatic stability, while the Straight incision is associated with higher residual SIA, making it less favorable for minimizing postoperative astigmatism.

Table 5: Postoperative Astigmatism Axis Shift

Incision Type	Preop Axis Mean ± SD	Postop Axis Mean ± SD Day1	Postop Axis Mean ± SD Week 1	Postop Axis Mean ± SD Week 6
Chevron	87.86±50.93	84.4 ± 49.79	85.8 ± 51.59	83.33± 50.59
Frown	85.93 ± 58.93	87.86 ± 53.54	83.8 ± 57.36	85.46 ± 58.06
Straight	86 ± 60.49	87.6 ± 56.61	84.4 ± 57.65	85.86 ± 63.66

The table 5 summarizes the Preoperative and Postoperative Astigmatism Axis (Mean ± SD) at Day 1, Week 1, and Week 6 for each incision type. The Chevron group had a preoperative axis of 87.86 ± 50.93°, with a slight variation in postoperative values, stabilizing at 83.33 ± 50.59° by Week 6, indicating minimal axis shift. The Frown group had a preoperative axis of 85.93 ± 58.93°, with a moderate fluctuation postoperatively but remained stable at 85.46 ± 58.06° by Week 6. The Straight group showed the largest variability, starting at 86 ± 60.49°, shifting to 87.6 ± 56.61° on Day 1, and stabilizing at 85.86 ± 63.66° by Week 6.

Table 6: Correlation Analysis of Surgical and Demographic Factors

Correlation Pair	Correlation Coefficient	p-value
Preoperative Astigmatism vs SIA Day 1	0.0526	0.7309
Preoperative Astigmatism vs SIA Week 1	-0.221	0.1434
Preoperative Astigmatism vs SIA Week 6	-0.028	0.8506
Incision Type vs SIA Reduction Day 1 to Week 1	-0.392	0.0077
Incision Type vs SIA Reduction Week 1 to Week 6	0.3867	0.0086
Age vs Inflammation Week 1	-0.020	0.8962
Age vs Wound Integrity Week 1	-0.186	0.2203

The table 6 presents the correlation coefficients and p-values for various relationships between preoperative astigmatism, surgically induced astigmatism (SIA), incision type, and patient demographics. Preoperative astigmatism showed weak and non-significant correlations with SIA at all time points (Day 1, Week 1, and Week 6), indicating that preoperative corneal curvature had minimal influence on surgically induced astigmatism.

Incision type was significantly correlated with SIA reduction from Day 1 to Week 1 ($r = -0.39$, $p = 0.0077$) and Week 1 to Week 6 ($r = 0.39$, $p = 0.0087$), suggesting that different incision techniques affect the rate at which astigmatism stabilizes over time. Age had weak, non-significant correlations with inflammation ($r = -0.02$, $p = 0.89$) and wound integrity ($r = -0.18$, $p = 0.22$) at Week 1, indicating that age was not a major determinant of postoperative healing response.

Table 7: ANOVA Results for Surgically Induced Astigmatism (SIA)

Test	F-Statistic	p-value
One-way ANOVA Day 1	7.745118	0.00137
One-way ANOVA Week 1	10.6512	0.000181
One-way ANOVA Week 6	14.15325	0.0002

The table 7 presents the One-way ANOVA results comparing SIA across Chevron, Frown, and Straight incision groups at different time points (Day 1, Week 1, and Week 6). At Day 1, there was a statistically significant difference in SIA among incision types ($F = 7.75$, $p = 0.00137$), indicating that incision type had a notable effect on early postoperative astigmatism. At Week 1, the effect remained significant ($F = 10.65$, $p = 0.000181$), suggesting that different incisions continued to influence astigmatic stability as healing progressed. By Week 6, the difference was even more pronounced ($F = 14.15$, $p < 0.00002$), reinforcing that incision type significantly impacts long-term astigmatic outcomes.

DISCUSSION

Surgically Induced Astigmatism (SIA) is a critical factor influencing post-operative visual outcomes in manual small-incision cataract surgery (MSICS). The present study compared the impact of Chevron, Straight, and Frown incisions on SIA, wound healing, and visual recovery over a six-week follow-up period. Our findings indicate that Chevron and Frown incisions provide better long-term astigmatic stability, whereas the Straight incision induces the highest residual astigmatism postoperatively.

The Chevron incision showed the lowest SIA values across all time points, with a mean SIA of 0.554 ± 0.138D on Day 1, reducing to 0.255 ± 0.090D by Week 6. This finding aligns with studies by Arthur et al. (2016), which reported that Chevron incisions provide better wound stability and faster astigmatic resolution due to their V-shaped design (10). In contrast, the Straight incision group exhibited the highest initial SIA (0.798 ± 0.255D on Day 1), with a slower reduction over time (0.462 ± 0.16D at Week 6). This is consistent with Borkenstein et al. (2023), who found that linear incisions induce greater corneal distortion, leading to higher residual astigmatism (11) . The Frown incision performed well in long-term astigmatic control, with SIA decreasing from 0.56 ± 0.165D on Day 1 to 0.242 ± 0.112D by Week 6, supporting findings by Rajappa et al. (2020), which suggested that curved incisions are more effective in minimizing long-term astigmatism(12) .

Postoperative Uncorrected Visual Acuity (UCVA) and Best Corrected Visual Acuity (BCVA) improved significantly across all groups. The Chevron group showed the best final UCVA (0.47 ± 0.17) and BCVA (0.35 ± 0.141) at Week 6, reinforcing its superior corneal stability. The Straight incision group had the least improvement, with higher residual

refractive error at six weeks. These trends are in line with Young et al. (2020), who observed that greater SIA in MSICS is directly correlated with delayed visual recovery .(13)

Postoperative inflammation was highest in the Chevron incision group on Day 1 (1.133 ± 0.74) but decreased significantly by Week 6 (0.26 ± 0.59). The Straight incision had the lowest inflammation at all time points, likely due to reduced corneal tension. However, wound integrity was best in the Chevron group at Week 6 (2.666 ± 0.617), supporting findings by Kruger et al. (2021) that angled incisions promote better wound stability over time (14). The Preoperative vs. Postoperative Astigmatism Axis Shift showed minimal variation over six weeks, with Chevron incisions demonstrating the most stable astigmatic axis shift (87.86° preoperatively to 83.33° postoperatively). This result supports findings from Yin et al. (2024), who emphasized that angled incisions help maintain corneal curvature, reducing fluctuations in the astigmatic axis(15) .

Weak correlations were found between preoperative astigmatism and postoperative SIA ($p > 0.05$), indicating that initial corneal curvature does not significantly impact incision-related SIA. However, incision type significantly influenced SIA reduction over time, with a negative correlation (-0.39, $p = 0.0077$) between incision type and early SIA reduction, confirming that Chevron and Frown incisions promote faster stabilization. ANOVA results showed significant differences in SIA between incision types at all time points ($p < 0.05$), emphasizing the importance of incision design in postoperative astigmatic control.

When compared to previous studies, our findings align with those of Malik et al. (2012), who found that Frown incisions minimized SIA in MSICS(16) , and Jauhari et al. (2014), who reported that Chevron incisions reduce early postoperative astigmatism due to better wound stability (4). Soumya et al. (2022) also explained that Straight incisions result in higher postoperative astigmatism, which our study confirms, showing significantly higher SIA in the Straight group compared to Chevron and Frown (17). Similarly, Tan et al. (2019) emphasized that linear incisions are associated with greater corneal distortion, which aligns with our observation that the Straight incision had the highest initial and residual SIA(18) . The results further support Dupps et al. (2006), who suggested that incision choice should be tailored based on patient corneal biomechanics, as our study demonstrates different incision types stabilize at different rates (19).

Our study confirms previous findings while adding new insights on the percentage reduction in SIA over time and its correlation with wound healing and visual outcomes. These results contribute to the ongoing refinement of MSICS incision techniques, ensuring better visual recovery for cataract patients.

CONCLUSION

This study compared Chevron, Straight, and Frown incisions in MSICS, evaluating their impact on SIA, wound healing, and visual recovery. The Chevron incision demonstrated the lowest SIA and best wound stability, making it the preferred choice for minimizing postoperative astigmatism. Frown incisions provided good long-term astigmatic control, while Straight incisions induced the highest residual SIA, leading to delayed stabilization. Incision type significantly influenced SIA reduction, with Chevron and Frown incisions promoting faster stabilization. Based on these findings, Chevron incisions are ideal for minimizing SIA, while Frown incisions offer long-term stability. The choice of incision should be tailored to patient-specific corneal biomechanics to optimize postoperative visual outcomes. Further studies with larger sample sizes and extended follow-ups are recommended.

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