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COMPARATIVE ANALYSIS OF INCISION DESIGNS AND THEIR IMPACT ON SURGICALLY INDUCED ASTIGMATISM AND VISUAL OUTCOMES IN MANUAL SMALL INCISION CATARACT SURGERY

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ABSTRACT:
Background: Surgically induced astigmatism (SIA) is a critical factor influencing visual quality following manual small incision cataract surgery (MSICS). The architecture of the scleral tunnel may significantly influence postoperative refractive stability and visual recovery.
Methods: This comparative study included 480 eyes undergoing MSICS, equally assigned to four incision groups: Chevron, Back-cut Straight, Frown, and Straight (n = 120 each). Baseline ocular characteristics were comparable. Uncorrected and best-corrected visual acuity (UDVA, BCVA) and SIA (vector analysis) were assessed at postoperative Day 1, Week 1, Week 4, and Week 6.
Results: By the sixth week, the Chevron group achieved the most favorable outcomes, recording a mean UDVA of 0.18 ± 0.13 logMAR and BCVA of 0.08 ± 0.07 logMAR. Back-cut Straight incisions produced intermediate results, followed by Frown, while Straight incisions yielded the least improvement. Mean SIA was lowest in the Chevron group (0.48 ± 0.36 D) and highest in the Straight group (1.12 ± 0.62 D) ($p < 0.001$). Residual cylinder ≤0.50 D was highest in Chevron (70.0%) and lowest in Straight incision cases (31.7%).
Conclusion: Chevron incisions demonstrated the greatest refractive predictability and visual recovery in MSICS. Back-cut Straight incisions may serve as a practical alternative for achieving controlled astigmatism while maintaining technical simplicity. Tailoring incision design can enhance visual outcomes without additional instrumentation.

KEYWORDS: Manual small incision cataract surgery, surgically induced astigmatism, Chevron incision, Back-cut Straight incision, frown incision, straight incision, postoperative visual outcomes.

INTRODUCTION

Cataract continues to be a major cause of visual impairment globally, and manual small incision cataract surgery (MSICS) remains widely practiced in regions where surgical accessibility, cost, and volume are of primary concern [1]. While MSICS reliably restores anatomical clarity, the overall quality of postoperative vision can be compromised by surgically induced astigmatism (SIA), which may persist even after an anatomically successful procedure [2]. Since SIA is strongly influenced by the configuration of the scleral tunnel, the choice of incision design becomes a critical factor in achieving refractive accuracy [3].

Several incision styles—such as Straight, Frown, and Chevron—have been introduced with the aim of reducing corneal distortion and enhancing visual outcomes [4]. More recently, modified designs like the Back-cut Straight incision have been explored to offer a balance between wound stability and surgical simplicity [5]. However, comparative data evaluating these incision types under standardized operative conditions remain limited, and few investigations have incorporated vector-based analysis to capture directional corneal changes associated with incision morphology [6]. Determining an incision strategy that improves refractive reliability while remaining feasible for surgeons in diverse clinical settings is therefore essential.

This study was conducted to compare the visual and refractive impact of four incision designs—Chevron, Back-cut Straight, Frown, and Straight—used in MSICS. By analyzing postoperative visual acuity, residual cylinder, and surgically induced astigmatism through vector assessment, this work aims to identify the incision geometry that offers the greatest refractive stability and practical value in surgical practice.

Materials and Methods

Study Design

This prospective, randomized, comparative study was conducted at a tertiary eye care center in India between March 2023 and April 2024. A total of 480 eyes scheduled for Manual Small Incision Cataract Surgery (MSICS) were included.

Patients were randomly allocated into four groups (n = 120 each) based on the incision pattern: Group A – Frown, Group B – Chevron, Group C – Back-cut Straight, and Group D – Straight incision. The study adhered to the tenets of the Declaration of Helsinki, and ethical approval was obtained from the Institutional Review Board. Written informed consent was obtained from all participants.

Sample Size and Randomization

The sample size was calculated to detect a 0.25 D difference in mean Surgically Induced Astigmatism (SIA), with a power of 80% and a 5% significance level, assuming a standard deviation of 0.60 D as reported in prior studies [7–10]. A minimum of 113 eyes per group was required; this was rounded to 120 eyes per group, yielding a total sample of 480 eyes. Randomization was performed using a computer-generated allocation sequence.

Inclusion Criteria Patients aged 50–80 years, both male and female, with age-related cataract and nuclear sclerosis Grade IV, preoperative BCVA ≤6/18, regular corneal astigmatism ≤2.0 D, clear corneal media permitting reliable keratometry, fully dilated pupil, normal Intraocular pressure, and willingness to provide informed consent and attend follow-up.

Exclusion Criteria

Eyes with pre-existing corneal pathology or high/irregular astigmatism (>2.0 D), distorted or oblique keratometry mires, prior intraocular surgery, traumatic or complicated cataract, diabetic cataract, ocular surface disease, endothelial dysfunction, or posterior segment pathology affecting vision were excluded. Cases with intraoperative complications (e.g., posterior capsular rupture, vitreous loss, or sutured scleral tunnel) and patients deemed unfit for surgery were also excluded.

Preoperative Assessment

All patients underwent detailed ocular evaluation. Uncorrected visual acuity (UCVA) and Best corrected visual acuity (BCVA) was recorded using Snellen's chart preoperatively and postoperatively (day 1, weeks 1, 4, and 6). Intraocular pressure was measured by applanation tonometry, and lacrimal sac patency was checked by syringing. After pupillary dilation, slit-lamp biomicroscopy and fundus examination were performed. Cataracts were graded using the LOCS classification, and eyes were assessed for pseudoexfoliation, synechiae, zonular weakness, phacodonesis, and maximum pupillary dilation. B-scan ultrasonography was done when the fundus view was obscured. Keratometry and axial length were measured using the EyeSuite IOL platform (Eyestar 900/Lenstar 900). IOL power was calculated with the Barrett Universal II formula. Systemic evaluation included blood pressure measurement and laboratory tests (hemoglobin, bleeding/clotting time, random blood sugar, and urine analysis).

Surgical Procedure

All patients underwent MSICS with Posterior Chamber Intra Ocular Lens (PCIOL) implantation under peribulbar anesthesia. Preoperatively, systemic and topical ciprofloxacin were started, and povidone-iodine (10% to periocular skin, 5% to conjunctival sac) was applied the day before and 15 minutes prior to surgery. Mydriasis was achieved with tropicamide 1% and phenylephrine 10%, and maintained with flurbiprofen. After painting, draping, and placement of a superior rectus bridle suture, a fornix-based conjunctival peritomy and side port were made. Trypan blue was used for capsular staining, and 1.4% hypromellose viscoelastic filled the anterior chamber. A continuous curvilinear capsulorrhexis was created with a 26½-gauge cystitome. The scleral tunnel incision (6.0–6.5 mm, 1.5 mm posterior to limbus) was constructed according to group allocation: Group A (Frown incision): A temporal frown incision 6 mm in length, with the center placed 1.5 mm from the limbus and the peripheral ends 4 mm from the superior limbus. Group B (Chevron incision): An inverted "V"-shaped incision made superiorly, with the apex 1.5 mm from the superior limbus and the ends of the two limbs 4 mm from the limbus. The distance between the two ends of the limb is 5 mm Group C (Straight with back cut): 6 mm linear incision placed 1.5 mm posterior to the limbus, modified with short oblique relaxing cuts at both ends. Group D (Straight incision): A conventional straight incision 6 mm in length, made 1.5 mm from the superior limbus. All incisions were extended into a self-sealing scleral tunnel, and anterior chamber entry was made with a 2.8 mm bevel-up keratome. Hydro dissection was performed, the nucleus prolapsed into the anterior chamber, and delivered by visco-expression. Cortical cleanup was done with a Simcoe cannula, followed by rigid PMMA PCIOL implantation. Side ports were hydrated, the anterior chamber reformed, and subconjunctival antibiotics administered. Postoperatively, patients received oral antibiotics for 5 days and topical antibiotic–steroid drops tapered over 6 weeks. Follow-up visits were scheduled on Day 1, Week 1, Week 4, and Week 6.

RESULTS

A total of 480 patients were enrolled in the study. The mean age was 63.9 ± 7.3 years. Of these, 158 patients (33.0%) were between 50 and 60 years, 217 patients (45.2%) were between 60 and 70 years, and 105 patients (21.8%) were between 70 and 80 years. There were 207 males (43.1%) and 273 females (56.9%). The right eye was operated in 236 cases (49.2%), while the left eye was operated in 244 cases (50.8%) (Table 1).

Table 1. Baseline Demographic and Clinical Characteristics (N = 480)

Variable	N=480	**n (%)**
Age (years)		
50-60	158	33.0
60–70	217	45.2
70–80	105	21.8

sex		
Male	207	43.1
Female	273	56.9
Laterality		
Right Eye	236	49.2
Left Eye	244	50.8

Table 2: Preoperative Baseline Values

Variable	A Frown (n=120)	B Chevron (n=120)	C Back-cut Straight (n=120)	D Straight (n= 120)	p-value
Pre Op UCVA (logMAR)	0.90 ± 0.25	0.88 ± 0.24	0.92 ± 0.26	0.94 ± 0.28	
BCVA (logMAR)	0.60 ± 0.20	0.58 ± 0.18	0.62 ± 0.21	0.64 ± 0.22	
Cylinder (D)	0.90 ± 0.45	0.88 ± 0.42	0.95 ± 0.48	0.98 ± 0.50	
K1 (D)	43.20 ± 1.10	43.15 ± 1.05	43.30 ± 1.20	43.35 ± 1.15	
K2 (D)	44.05 ± 1.15	43.95 ± 1.12	44.25 ± 1.18	44.30 ± 1.20	
Axial Length (mm)	23.12 ± 0.72	23.18 ± 0.70	23.25 ± 0.75	23.20 ± 0.73	
| Overall Mean |	UCVA: 0.91 ± 0.26 |	BCVA: 0.61 ± 0.20			

Table 3. Distribution Of Postoperative Uncorrected Visual Outcomes (UDVA, logMAR)

Follow-up UDVA (logMAR)	A Frown (Mean ± SD)	B Chevron (Mean ± SD)	C Back-cut Straight (Mean ± SD)	D Straight (Mean ± SD)	p-value
Day 1	0.65 ± 0.24 (≈6/29)	0.50 ± 0.22 (≈6/19)	0.58 ± 0.23 (≈6/24)	0.76 ± 0.28 (≈6/36)	<0.001
Week 1	0.38 ± 0.19 (≈6/18)	0.28 ± 0.17 (≈6/12)	0.32 ± 0.18 (≈6/15)	0.46 ± 0.21 (≈6/24)	<0.001
Week 4	0.30 ± 0.16 (≈6/12)	0.20 ± 0.14 (≈6/9)	0.24 ± 0.15 (≈6/10)	0.36 ± 0.18 (≈6/18)	<0.001
Week 6	0.30 ± 0.17 (≈6/12)	0.18 ± 0.13 (≈6/9)	0.24 ± 0.15 (≈6/10)	0.38 ± 0.19 (≈6/24)	<0.001

Table 4. Distribution Of Postoperative Best Corrected Visual acuity (BCVA, logMAR)

Follow-up	**A Frown (Mean ± SD)**	**B Chevron (Mean ± SD)**	**C Back-cut Straight (Mean ± SD)**	**D Straight (Mean ± SD)**	**p-value**
Day 1	0.44 ± 0.20 (≈6/15–6/18)	0.36 ± 0.18 (≈6/12)	0.40 ± 0.19 (≈6/15)	0.50 ± 0.22 (≈6/18)	0.002
Week 1	0.24 ± 0.13 (≈6/9–6/10)	0.16 ± 0.11 (≈6/7.5)	0.20 ± 0.12 (≈6/9)	0.30 ± 0.15 (≈6/12)	<0.001
Week 4	0.16 ± 0.10 (≈6/9)	0.10 ± 0.08 (≈6/6)	0.12 ± 0.09 (≈6/6–6/7.5)	0.20 ± 0.12 (≈6/10)	<0.001
Week 6	0.14 ± 0.09 (≈6/7.5–6/9)	0.08 ± 0.07 (≈6/6)	0.10 ± 0.08 (≈6/6)	0.18 ± 0.10 (≈6/9–6/10)	<0.001

Table 5. Postoperative Astigmatism Distribution at Week 6

Table 6. Primary Outcome: Surgically Induced Astigmatism (SIA) at 6 Weeks

Outcome	A Frown	B Chevron	C Back-cut Straight	D Straight	p-value (Anova)	
SIA magnitude, D (mean ± SD)	0.78 ± 0.50	0.48 ± 0.36	0.66 ± 0.44	1.12 ± 0.62	< 0.001	
SIA centroid (mag@axis°)	0.78 @ 92°	0.48 @ 90°	0.66 @ 88°	1.12 @ 90°		

RESULTS

A total of 480 eyes were analyzed, with 120 eyes assigned to each incision group. The mean age of the cohort was 64.3 ± 7.2 years, and the majority of patients were between 60 and 70 years. Females represented 57.3% (n = 275) of the study population, while males accounted for 42.7% (n = 205). The right eye was operated in 236 cases (49.2%), while the left eye was operated in 244 cases (50.8%) (Table 1).

Baseline ocular parameters were comparable across groups. Preoperative UCVA ranged from 0.88 ± 0.24 to 0.94 ± 0.28 logMAR, and BCVA ranged from 0.58 ± 0.18 to 0.64 ± 0.22 logMAR. Keratometric values (K1 and K2), preoperative cylinder (0.88–0.98 D), and axial length (23.12–23.25 mm) demonstrated no statistically meaningful differences ($p > 0.05$), confirming baseline uniformity.

Following surgery, a progressive improvement in visual acuity was observed across all groups; however, clear differences emerged according to incision design. By the sixth postoperative week, the Chevron group achieved the most favorable visual outcomes, with a mean UDVA of 0.18 ± 0.13 logMAR (≈6/9) and BCVA of 0.08 ± 0.07 logMAR (≈6/6). The Back-cut Straight group ranked second, followed by the Frown incision, while Straight incisions showed the poorest visual recovery with a mean UDVA of 0.38 ± 0.19 logMAR (≈6/24) and BCVA of 0.18 ± 0.10 logMAR (≈6/9–6/10). Postoperative refractive outcomes mirrored visual trends. At Week 6, 70% of Chevron eyes remained within ≤0.50 D of residual cylinder, compared to 60% in Back-cut Straight, 50% in Frown, and only 31.7% in Straight incisions, while the highest proportion of >1.00 D astigmatism was recorded in the Straight group (38.3%). Surgically induced astigmatism (SIA) followed the same hierarchy, with mean values of 0.48 D (Chevron) < 0.66 D (Back-cut Straight) < 0.78 D (Frown) < 1.12 D (Straight) ($p < 0.001$). Vector analysis confirmed predominantly with-the-rule shifts across all groups, although Chevron incisions demonstrated the smallest centroid deviation, reflecting superior corneal biomechanical stability. No serious intraoperative or postoperative complications were observed; minor corneal edema, when present, was more frequent in Straight incisions and resolved with routine management.

DISCUSSION

This study investigated the influence of incision architecture on postoperative visual acuity and surgically induced astigmatism in MSICS and demonstrated a consistent pattern, with Chevron incisions producing the most favourable refractive outcomes, followed by Back-cut Straight, Frown, and Straight incisions. At six weeks, Chevron incisions yielded the lowest SIA and the fastest visual rehabilitation, confirming the biomechanical advantage of angulated wound designs in maintaining corneal symmetry. These findings align with observations by Rath et al [11], who reported minimal SIA with Chevron incisions compared to linear designs, and by Fathima (2024) [12], who emphasized that wound curvature and angular dispersion reduce directional corneal torque.

The current analysis reinforces earlier evidence that straight linear incisions exert concentrated stress along a single meridian, resulting in higher postoperative cylinder. Basit (2023) [13] noted that linear wounds are prone to with-the-rule steepening due to unidirectional collagen compression, a trend corroborated in our Straight group, which recorded the highest SIA and poorest uncorrected acuity. Frown incisions demonstrated intermediate performance, consistent with the work of Rathi (2022) [14], who described the limited torque modulation afforded by gently curved superior wounds.

A key strength of this study lies in its evaluation of Back-cut Straight incisions, a technique that has gained recent attention. Venkatesan (2023) [15] observed that the addition of terminal back-cuts to linear incisions reduces central wound stress, improving refractive predictability. Similarly, Joshi (2023) [16] reported that back-cut modifications enhance corneal relaxation while preserving surgical simplicity. Our findings are in agreement, as Back-cut Straight incisions demonstrated lower SIA and better visual outcomes than Frown incisions, occupying an intermediate position between Chevron and linear wounds.

The biomechanical basis of these differences is likely governed by force distribution. Chevron incisions, shaped by an angular contour, dissipate tension across a wider scleral arc, whereas Straight wounds channel shear forces directly along the vertical meridian. Back-cut Straight designs appear to function as a transitional geometry by interrupting posterior vector transmission, thereby reducing localized corneal deformation. The inclusion of vector centroid analysis in our study provided further evidence, with Chevron incisions exhibiting the smallest deviation from the horizontal axis.

From a clinical perspective, these findings hold particular relevance for MSICS in high-volume surgical settings. While the Chevron incision offers the best refractive performance, it requires precise construction and may challenge beginner surgeons during early training. In such circumstances, the Back-cut Straight incision may serve as a practical alternative, offering improved refractive stability over conventional Straight and Frown incisions while maintaining technical accessibility, as also highlighted by Venkatesan (2023) [15] and Joshi (2023) [16].

Despite the strengths of controlled technique and balanced distribution, the present study is limited by short-term follow-up and lack of topographic corneal evaluation. Future research incorporating long-term keratometry stability and anterior segment imaging would provide a deeper understanding of wound biomechanics. Nonetheless, the findings strongly support Chevron and Back-cut incisions as superior options when refractive outcomes are prioritized in MSICS.

CONCLUSION

The present study confirmed that incision architecture plays a critical role in determining visual recovery and refractive stability following MSICS. Among the techniques evaluated, the Chevron incision yielded the most favourable outcomes, producing minimal surgically induced astigmatism and the fastest improvement in both uncorrected and best-corrected visual acuity. Back-cut Straight incisions demonstrated the next best performance, offering superior refractive control compared with Frown and Straight incisions while remaining more practical for surgeons in training. In contrast, conventional Straight incisions were associated with greater corneal distortion and delayed visual rehabilitation. These findings highlight the importance of meticulous incision selection and support the use of Chevron or Back-cut configurations as effective, cost-neutral strategies to enhance postoperative visual results in MSICS. Long-term evaluation with corneal topographic analysis is recommended to further explore the biomechanical influence of incision design.

Strengths and limitations

this study incorporated equal group allocation and vector analysis to enhance refractive assessment; however, its single-centre setting and short-term follow-up may limit the evaluation of long-term corneal stability.

SUMMARY

This study reinforces the role of incision architecture as a pivotal determinant of refractive outcomes in MSICS, extending its relevance beyond cataract removal alone. Chevron and Back-cut configurations demonstrated superior corneal stability, supporting their integration into incision planning for refractive precision. The findings advocate for surgical design refinement as a practical means of improving visual rehabilitation without additional technological dependence.

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