British Journal of Earth Sciences Research, 14(1),133-149, 2026
Print ISSN: 2055-0111 (Print)
Online ISSN: 2055-012X (Online)
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development -UK

Comparison of Corneal Topographic Changes and Surgically Induced Astigmatism Following Trabeculectomy Versus Non-Penetrating Deep Sclerectomy in Primary Open-Angle Glaucoma

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doi: https://doi.org/10.37745/bjesr.2013/vol14n1133149 Published February 28, 2026

Citation: Mema V., Metwally A., Gjurasheaj E. (2026) Comparison of Corneal Topographic Changes and Surgically Induced Astigmatism Following Trabeculectomy Versus Non-Penetrating Deep Sclerectomy in Primary Open-Angle Glaucoma, *British Journal of Earth Sciences Research*, 14(1),133-149

Abstract: *Glaucoma filtration surgeries remain the cornerstone of management for patients with primary open-angle glaucoma (POAG) who exhibit inadequate intraocular pressure (IOP) control despite maximal medical therapy. Among the commonly performed procedures, sub-scleral trabeculectomy (SST) and non-penetrating deep sclerectomy (NPDS) are widely utilized for their proven efficacy in lowering IOP. However, beyond IOP reduction, these surgical interventions may induce structural and biomechanical alterations in the cornea due to scleral flap creation, tissue manipulation, suturing techniques, and postoperative wound healing responses. Such changes can influence corneal curvature and induce surgically related astigmatism, thereby affecting visual quality and refractive stability in the postoperative period. Despite the clinical importance of these refractive alterations, the magnitude and pattern of corneal topographic changes following different glaucoma surgical techniques remain incompletely understood. A clearer understanding of these changes is essential to optimize surgical planning, improve postoperative visual outcomes, and provide accurate patient counseling* **:** *The present study aimed to evaluate and compare corneal topographic changes following sub-scleral trabeculectomy (SST) and non-penetrating deep sclerectomy (NPDS) in patients diagnosed with primary open-angle glaucoma (POAG). Specifically, the study sought to quantify surgically induced alterations in keratometric parameters and corneal astigmatism using computerized corneal topography, and to determine whether one surgical technique results in greater refractive impact than the other.This prospective comparative study enrolled 30 eyes of 30 patients diagnosed with primary open-angle glaucoma. Participants were equally allocated into two groups according to the surgical technique performed. Group A comprised patients who underwent sub-scleral trabeculectomy (SST) with intraoperative application of Mitomycin C (MMC) at a concentration of 0.2 mg/ml for 2 minutes. Group B included patients who underwent non-penetrating deep sclerectomy (NPDS), also with intraoperative application of MMC at a concentration of 0.2 mg/ml for 2 minutes. All patients*

underwent a comprehensive preoperative ophthalmic evaluation, including measurement of best-corrected visual acuity, slit-lamp biomicroscopy, intraocular pressure assessment, gonioscopy, and fundus examination. Computerized corneal topography was performed preoperatively and repeated at 3 months postoperatively to assess corneal curvature changes. The primary outcome measures included changes in keratometric parameters: flat keratometry (K1), steep keratometry (K2), average keratometry (Avg K), corneal astigmatism (magnitude and axis), and apical keratometry front (AKf). Surgically induced changes were calculated by subtracting preoperative values from postoperative measurements. The collected data were statistically analyzed to compare topographic changes between the two surgical groups. The study was conducted at the Ophthalmology Department of Mother Theresa University Hospital Center between April 2025 and November 2025. A highly statistically significant increase ($p < 0.001$) was observed in keratometric changes in Group A (SST) compared with Group B (NPDS). Specifically, the mean change in flat keratometry (ΔK1) was 0.47 ± 0.09 D in Group A versus 0.22 ± 0.09 D in Group B. Similarly, the mean change in steep keratometry (ΔK2) was 0.86 ± 0.18 D in Group A compared to 0.46 ± 0.08 D in Group B. Surgically induced corneal astigmatism was also significantly greater in Group A (1.32 ± 0.13 D) than in Group B (0.69 ± 0.10 D). In contrast, no statistically significant differences were detected between the two groups with respect to changes in average keratometry (ΔAvg K) or apical keratometry front (ΔAKf), indicating comparable overall corneal curvature stability in these parameters. Glaucoma filtration surgery is associated with measurable corneal topographic alterations that may influence postoperative refractive outcomes. Surgically induced astigmatism appears to contribute to reduced unaided visual acuity during the early postoperative period. Sub-scleral trabeculectomy demonstrated a significantly greater impact on corneal astigmatism compared to non-penetrating deep sclerectomy. These findings suggest that NPDS may offer a relative refractive advantage in terms of minimizing surgically induced astigmatism.
Keywords: primary open-angle glaucoma, corneal topography, trabeculectomy, deep sclerectomy; surgically induced astigmatism.

INTRODUCTION

Glaucoma represents one of the leading causes of irreversible blindness worldwide and remains a major public health concern. It is currently the second most common cause of global blindness after cataract and the leading cause of permanent visual disability (Weinreb et al., 2014; Tham et al., 2014). Primary open-angle glaucoma (POAG) is the most prevalent form, characterized by progressive optic neuropathy associated with corresponding visual field loss. Elevated intraocular pressure (IOP) remains the most significant and modifiable risk factor for the development and progression of POAG, and all currently approved therapeutic strategies primarily aim to reduce IOP to prevent optic nerve damage (Weinreb et al., 2014; Garway-Heath et al., 2015).

Initial management of POAG typically involves topical hypotensive medications and/or laser trabeculoplasty. However, surgical intervention becomes necessary in cases of advanced glaucoma at presentation, documented disease progression despite maximal tolerated medical therapy (usually involving two or more pharmacological classes), or failure of laser treatment. In low-resource settings and developing countries, glaucoma surgery may be considered earlier due to limited access to medications, poor adherence, cost constraints, or inadequate long-term follow-up care (Weinreb & Khaw, 2004; King et al., 2020).

Sub-scleral trabeculectomy (SST) remains the gold standard filtering procedure for surgical IOP reduction. It is a penetrating surgery that lowers IOP by creating a sclerostomy, allowing aqueous humor to drain from the anterior chamber into the subconjunctival space, resulting in bleb formation (Razeghinejad et al., 2012). Long-term success of trabeculectomy depends largely on the formation and maintenance of a functioning subconjunctival filtering bleb (Amar et al., 2008). Despite its proven efficacy, trabeculectomy is associated with a relatively higher rate of postoperative complications, including hypotony, bleb leakage, shallow anterior chamber, choroidal detachment, and infection (Rulli et al., 2013; Gedde et al., 2021).

Non-penetrating deep sclerectomy (NPDS) was developed as an alternative surgical approach aimed at reducing complication rates while maintaining effective IOP control. Unlike trabeculectomy, NPDS preserves the trabeculo-Descemet's membrane, allowing controlled percolation of aqueous humor without full-thickness penetration into the anterior chamber (Mendrinos et al., 2008). Several comparative studies and meta-analyses have demonstrated that NPDS may offer a more favorable safety profile, although sometimes at the expense of slightly lower IOP reduction compared with trabeculectomy (Rulli et al., 2013; Anand et al., 2021).

Beyond IOP control and safety outcomes, increasing attention has been directed toward the refractive consequences of glaucoma surgery. Surgical manipulation of scleral and corneal tissues, flap construction, suturing techniques, and postoperative wound healing may alter corneal biomechanics and curvature. These changes can induce surgically induced astigmatism (SIA), potentially leading to transient or persistent visual acuity reduction during the postoperative period (Chan & Kong, 2017). Although early postoperative visual disturbances are often attributed to fluctuations in IOP, accumulating evidence suggests that corneal topographic alterations play a significant role in refractive instability following filtration surgery (Egrilmez et al., 2021; Sii et al., 2022).

Despite several studies evaluating IOP outcomes and complications of trabeculectomy and NPDS, comparative data regarding their differential impact on corneal topography and astigmatism remain limited and somewhat inconsistent, particularly in the era of refined surgical techniques and adjunctive antimetabolite use. A better understanding of surgically induced corneal changes is clinically relevant, as refractive stability directly influences postoperative visual quality, patient satisfaction, and timing of spectacle prescription.

Therefore, the present study was designed to evaluate and compare corneal topographic changes following sub-scleral trabeculectomy and non-penetrating deep sclerectomy in patients with primary open-angle glaucoma.

PATIENTS AND METHODS

This study was designed as a randomized prospective observational investigation conducted between April 2025 and November 2025 at the Department of Ophthalmology, Mother Theresa University Hospital Center. The study included 30 eyes of 30 patients diagnosed with primary open-angle glaucoma (POAG) who demonstrated inadequate intraocular pressure (IOP) control despite maximum tolerated antiglaucoma therapy. All patients enrolled in the study exhibited normal corneal topographic parameters prior to surgery.

Inclusion and Exclusion Criteria

Patients were considered eligible if they had a confirmed diagnosis of POAG with uncontrolled IOP despite optimal medical management. Exclusion criteria included: neovascular glaucoma, congenital or juvenile glaucoma, ocular comorbidities other than glaucoma (such as corneal dystrophies, uveitis, or keratopathies), history of ocular trauma or previous intraocular surgery, and systemic conditions that could affect ocular health, including uncontrolled diabetes mellitus or hypertension. Patients who were unable to complete the postoperative follow-up examinations were also excluded to ensure accuracy in longitudinal topographic assessment.

Ethical Considerations

Written informed consent was obtained from all participants prior to surgery. The study protocol adhered to the tenets of the Declaration of Helsinki and was approved by the institutional ethics committee. Patients were informed of the potential risks, benefits, alternatives, and limitations associated with the surgical interventions, including possible complications and expected visual and refractive outcomes.

Study Groups and Surgical Procedures

Eligible patients were randomly assigned into two equal groups (n = 15 per group) based on the type of glaucoma surgery performed:

- **Group A:** Underwent sub-scleral trabeculectomy (SST) with intraoperative application of Mitomycin C (MMC) at a concentration of 0.2 mg/ml for 2 minutes.
- **Group B:** Underwent non-penetrating deep sclerectomy (NPDS) with intraoperative application of MMC at a concentration of 0.2 mg/ml for 2 minutes.

Both procedures were performed by experienced glaucoma surgeons under standardized operating protocols to minimize inter-surgeon variability. Postoperative care, including topical medications and follow-up schedules, was identical for both groups to ensure comparability of outcomes.

Preoperative Assessment

All patients underwent a comprehensive preoperative evaluation, including a detailed medical and ocular history. This included documentation of prior ocular inflammation, trauma, infections, history of ocular or systemic surgeries, bleeding disorders, and current medications that could affect ocular health or surgical outcomes.

A complete ophthalmologic examination was performed for each patient, which included:

- Measurement of best-corrected visual acuity (BCVA)
- Slit-lamp biomicroscopy
- Intraocular pressure (IOP) measurement using Goldmann applanation tonometry
- Gonioscopy
- Dilated fundoscopy
- Corneal topography assessment using the SIRIUS Topographer® (CSO, Firenze, Italy)

Preoperative corneal topographic parameters were carefully documented to ensure baseline normalcy and allow for accurate evaluation of surgically induced changes.

Surgical Techniques

All procedures were performed under peribulbar anesthesia. The surgical site, whether for trabeculectomy or deep sclerectomy, was located in the superior half of the globe in all eyes. A corneal traction suture using 8-0 silk was placed, followed by the creation of a fornix-based conjunctival flap to expose the surgical site.

Sub-scleral Trabeculectomy (SST) with MMC:

- A superficial scleral flap measuring approximately 4 × 5 mm and half-thickness was fashioned.
- Mitomycin C (0.2 mg/mL) was applied beneath the scleral flap and conjunctiva for 2 minutes, then thoroughly irrigated with balanced salt solution.
- A sclerostomy was created, and a peripheral iridectomy was performed.
- The scleral flap was secured using 10-0 nylon sutures, followed by conjunctival closure with 8-0 silk sutures.

Non-penetrating Deep Sclerectomy (NPDS) with MMC:

- A superficial scleral flap measuring 5 × 5 mm, approximately one-third scleral thickness, was created.
- Mitomycin C (0.2 mg/mL) was applied beneath the scleral flap and conjunctiva for 2 minutes and then irrigated.
- A deep scleral flap (4 × 4 mm) was excised, unroofing Schlemm's canal and removing the juxtacanalicular trabeculum to facilitate aqueous percolation.
- The superficial scleral flap was sutured with 10-0 nylon, and the conjunctiva was closed with 8-0 silk sutures.

All surgeries were performed by experienced glaucoma surgeons under standardized protocols to minimize variability.

Postoperative Follow-Up

Patients were examined on the first postoperative day, at one week, and then monthly for three months. Each follow-up included:

- BCVA measurement
- Slit-lamp examination
- IOP assessment using Goldmann applanation tonometry

Corneal topography was repeated at 3 months postoperatively using the SIRIUS Topographer® to assess changes in corneal curvature and astigmatism.

Postoperative management included intensive topical corticosteroid therapy, gradually tapered according to clinical response. Topical antibiotics and cycloplegic agents were administered as indicated to prevent infection and maintain anterior chamber stability. Any postoperative complications were documented and managed according to standard clinical protocols.

Statistical Analysis

Data were collected, coded, and analyzed using **SPSS version 24.0** (IBM Corp., Armonk, NY, USA). Quantitative variables were presented as **mean ± standard deviation (SD)** for normally distributed data and as **median with interquartile range (IQR)** for non-normally distributed data. Qualitative variables were expressed as **frequencies and percentages**.

Comparisons between groups were performed using appropriate statistical tests based on data type and distribution:

- **Independent-samples t-test:** Used to compare means of two groups when the data were normally distributed.
- **Mann–Whitney U test:** Used to compare two groups when the data were not normally distributed.
- **One-way analysis of variance (ANOVA):** Used for comparisons of more than two group means for normally distributed data.
- **Kruskal–Wallis test:** Applied for comparisons of more than two group medians when the data were not normally distributed.
- **Chi-square (χ^2) test:** Employed to analyze associations between categorical variables.

Statistical significance was defined as **$p < 0.05$**, while **$p < 0.001$** was considered highly significant. Values of **$p > 0.05$** were considered statistically non-significant.

All tests were two-tailed, and assumptions for parametric tests, including normality and homogeneity of variance, were verified before application. Graphical methods and descriptive statistics were used to support data interpretation and illustrate findings.

RESULTS

This prospective observational study was conducted between April 2025 and November 2025 at the Ophthalmology Department of Mother Theresa University Hospital Center, Tirana. Patients were recruited from the outpatient clinic and scheduled for glaucoma filtration surgery. A total of **30 patients (30 eyes)** with primary open-angle glaucoma were enrolled and randomly allocated into two comparable groups:

- **Group A (n = 15):** Patients underwent sub-scleral trabeculectomy (SST) with intraoperative application of Mitomycin C (MMC) 0.2 mg/mL for 2 minutes.
- **Group B (n = 15):** Patients underwent non-penetrating deep sclerectomy (NPDS) with intraoperative MMC 0.2 mg/mL for 2 minutes.

All patients underwent comprehensive corneal topography using the **SIRIUS Topographer® (CSO, Firenze, Italy)** preoperatively and at 3 months postoperatively. These measurements allowed for quantitative assessment of corneal curvature, keratometric values, and surgically induced astigmatism.

Demographic Characteristics

The demographic characteristics of the study groups, including age and sex distribution, are summarized in Table 1. Both groups were comparable with no statistically significant differences, ensuring homogeneity and minimizing potential confounding factors.

Table 1. Comparison of Age and Sex between Study Groups

Parameter	Group A (SST) (n = 15)	Group B (NPDS) (n = 15)	P-value
Age (years, mean ± SD)	56.8 ± 8.2	55.3 ± 7.9	0.63
Sex (Male/Female)	9 / 6	8 / 7	0.71

Note: P-values calculated using independent-samples t-test for age and chi-square test for sex distribution.

The results indicate that both groups were well-matched in terms of age and sex, supporting the validity of subsequent comparisons of surgical outcomes.

Best-Corrected Visual Acuity (BCVA)

The changes in best-corrected visual acuity (BCVA) before and three months after surgery in both study groups are summarized in **Table 2**.

Table 2. Comparison of Preoperative and Postoperative BCVA (LogMAR) in Study Groups

Group	Pre-BCVA (Mean ± SD)	Post-BCVA (Mean ± SD)	t-value	p-value
Group A (SST, n = 15)	0.66 ± 0.29	0.54 ± 0.26	1.18	0.244 NS
Group B (NPDS, n = 15)	0.59 ± 0.28	0.49 ± 0.26	1.08	0.289 NS

NS = not significant; Independent-samples t-test.

The results indicate a slight improvement in BCVA in both groups postoperatively; however, the changes were **not statistically significant** (p > 0.05). This suggests that, at three months post-surgery, both sub-scleral trabeculectomy and non-penetrating deep sclerectomy had minimal impact on overall visual acuity, despite potential alterations in corneal topography.

Intraocular Pressure (IOP)

The preoperative and postoperative intraocular pressure (IOP) measurements for both study groups are presented in **Table 3**.

Table 3. Comparison of Preoperative and Postoperative IOP (mmHg) in Study Groups

Group	Pre-IOP (Mean ± SD)	Post-IOP (Mean ± SD)	t-value	p-value
Group A (SST, n = 15)	28.13 ± 4.26	14.07 ± 2.91	10.5	<0.001 HS
Group B (NPDS, n = 15)	26.93 ± 3.95	13.33 ± 2.89	10.7	<0.001 HS

HS = highly significant; Independent-samples t-test.

Both surgical procedures resulted in a **highly significant reduction in IOP** at three months postoperatively compared to baseline values. In **Group A (SST)**, mean IOP decreased from 28.13 ± 4.26 mmHg preoperatively to 14.07 ± 2.91 mmHg postoperatively ($p < 0.001$). Similarly, in **Group B (NPDS)**, mean IOP decreased from 26.93 ± 3.95 mmHg to 13.33 ± 2.89 mmHg ($p < 0.001$).

These findings confirm that both sub-scleral trabeculectomy and non-penetrating deep sclerectomy are **effective in lowering IOP** in patients with primary open-angle glaucoma, with comparable outcomes in the early postoperative period.

Corneal Topography: Flat Keratometry (K1)

The preoperative and postoperative flat keratometry (K1) values for both study groups are summarized in **Table 4**.

Table 4. Comparison of Preoperative and Postoperative K1 (diopters) in Study Groups

Group	Pre-K1 (Mean ± SD)	Post-K1 (Mean ± SD)	t-value	p-value
Group A (SST, n = 15)	42.38 ± 1.10	41.91 ± 1.10	1.17	0.248 NS
Group B (NPDS, n = 15)	41.20 ± 1.30	40.98 ± 1.29	0.47	0.640 NS

NS = not significant; Independent-samples t-test.

The analysis demonstrates that there was **no statistically significant change** in flat keratometry (K1) three months postoperatively in either group ($p > 0.05$). This indicates that both sub-scleral trabeculectomy and non-penetrating deep sclerectomy had **minimal effect on the flat corneal curvature** in the early postoperative period.

Corneal Topography: Steep Keratometry (K2)

The preoperative and postoperative steep keratometry (K2) values for both study groups are summarized in **Table 5**.

Table 5. Comparison of Preoperative and Postoperative K2 (diopters) in Study Groups

Group	Pre-K2 (Mean ± SD)	Post-K2 (Mean ± SD)	t-value	p-value
Group A (SST, n = 15)	43.43 ± 0.46	44.29 ± 0.57	4.5	<0.001 HS
Group B (NPDS, n = 15)	42.81 ± 0.95	43.27 ± 0.95	0.92	0.192 NS

HS = highly significant; NS = not significant; Independent-samples t-test.

In **Group A (SST)**, there was a **highly significant increase in K2** three months postoperatively (from 43.43 ± 0.46 D to 44.29 ± 0.57 D; $p < 0.001$), indicating a steepening of the cornea along the steep meridian. In contrast, **Group B (NPDS)** showed a **non-significant change** in K2 ($p = 0.192$), suggesting minimal alteration of the steep corneal curvature following non-penetrating deep sclerectomy.

These findings indicate that **sub-scleral trabeculectomy induces more pronounced changes in corneal steepness**, which may contribute to surgically induced astigmatism in the early postoperative period.

Corneal Topography: Average Keratometry (Avg K)

The average keratometry (Avg K) values before and three months after surgery are summarized in **Table 6**.

Table 6. Comparison of Preoperative and Postoperative Avg K (diopters) in Study Groups

Group	Pre-Avg K (Mean ± SD)	Post-Avg K (Mean ± SD)	t-value	p-value
Group A (SST, n = 15)	42.90 ± 0.75	43.10 ± 0.80	0.69	0.495 NS
Group B (NPDS, n = 15)	42.00 ± 1.10	42.12 ± 1.09	0.30	0.763 NS

NS = not significant; Independent-samples t-test.

No statistically significant differences were observed in Avg K pre- and postoperatively in either group ($p > 0.05$). These findings suggest that **the overall mean corneal curvature remained stable** after both sub-scleral trabeculectomy and non-penetrating deep sclerectomy.

Corneal Topography: Apical Keratometry Front (AKF)

Apical keratometry front (AKF) values pre- and postoperatively are summarized in **Table 7**.

Table 7. Comparison of Preoperative and Postoperative AKF (diopters) in Study Groups

Group	Pre-AKF (Mean ± SD)	Post-AKF (Mean ± SD)	t-value	p-value
Group A (SST, n = 15)	44.41 ± 0.53	44.41 ± 0.47	0.00	1.000 NS
Group B (NPDS, n = 15)	43.42 ± 0.93	43.51 ± 0.92	0.26	0.792 NS

NS = not significant; Independent-samples t-test.

No significant changes in AKF were observed in either group ($p > 0.05$), indicating that the **central corneal apex curvature remained essentially unchanged** following both types of glaucoma surgery.

Corneal Astigmatism

The preoperative and postoperative corneal astigmatism (magnitude) in both study groups are summarized in **Table 8**.

Table 8. Comparison of Preoperative and Postoperative Corneal Astigmatism (diopters)

Group	Pre-Astigmatism (Mean ± SD)	Post-Astigmatism (Mean ± SD)	t-value	p-value
Group A (SST, n = 15)	1.06 ± 0.75	2.38 ± 0.70	4.96	<0.001 HS
Group B (NPDS, n = 15)	1.61 ± 0.62	2.30 ± 0.61	3.06	0.005 S

HS = highly significant; S = significant; Independent-samples t-test.

In **Group A (SST)**, corneal astigmatism increased significantly from **1.06 ± 0.75 D** preoperatively to **2.38 ± 0.70 D** postoperatively ($p < 0.001$). Similarly, **Group B (NPDS)** showed a statistically significant increase from **1.61 ± 0.62 D** to **2.30 ± 0.61 D** (p = 0.005). These results indicate that both glaucoma surgeries induce an increase in corneal astigmatism, with SST producing a larger magnitude of change.

Axis of Flat Keratometry (K1 Axis)

Changes in the axis of flat keratometry pre- and postoperatively are summarized in **Table 9**.

Table 9. Comparison of Preoperative and Postoperative K1 Axis (degrees)

Group	Pre-K1 Axis (Mean ± SD)	Post-K1 Axis (Mean ± SD)	t-value	p-value
Group A (SST, n = 15)	66.40 ± 75.89	66.33 ± 76.44	0.002	0.998 NS
Group B (NPDS, n = 15)	105.53 ± 79.16	106.73 ± 77.86	0.042	0.967 NS

NS = not significant; Independent-samples t-test.

No statistically significant changes in the K1 axis were observed in either group (p > 0.05), suggesting that while the **magnitude of astigmatism increased**, the **orientation of the corneal steep and flat meridians remained largely unchanged** following both surgical procedures.

Magnitude of Changes in Studied Parameters (Δ)

The changes in key clinical and corneal parameters (Δ = postoperative − preoperative values) for both study groups are summarized in **Table 10**. The Mann–Whitney U test was used for group comparisons.

Table 10. Comparison of Postoperative Changes (Δ) in Clinical and Corneal Parameters

Parameter	Group A (SST, n = 15)	Group B (NPDS, n = 15)	MW U	p-value
Δ BCVA (LogMAR)	0.12 ± 0.05	0.11 ± 0.06	91.5	0.389 NS
Δ IOP (mmHg)	14.07 ± 1.91	13.60 ± 1.88	101	0.653 NS
Δ K1 (D)	0.47 ± 0.09	0.22 ± 0.09	10	<0.001 HS
Δ K2 (D)	0.86 ± 0.18	0.46 ± 0.08	1	<0.001 HS
Δ Avg K (D)	0.20 ± 0.12	0.12 ± 0.07	71.5	0.089 NS
Δ Astigmatism (D)	1.32 ± 0.13	0.69 ± 0.10	0	<0.001 HS
Δ AKF (D)	0.00 ± 0.25	0.09 ± 0.05	81.5	0.202 NS

HS = highly significant; NS = not significant; MW = Mann–Whitney U test.

The analysis shows:

- **Highly significant increases** in ΔK1, ΔK2, and Δastigmatism in **Group A (SST)** compared to **Group B (NPDS)** ($p < 0.001$), indicating that sub-scleral trabeculectomy induces greater corneal curvature changes and surgically induced astigmatism.
- **Non-significant differences** were observed between groups regarding ΔBCVA, ΔIOP, ΔAvg K, and ΔAKF, indicating that both surgeries were equally effective in lowering IOP and preserving overall visual acuity and mean corneal curvature.

These results support that while SST is highly effective in IOP reduction, it is also associated with **more pronounced changes in corneal topography**, which may contribute to temporary or persistent changes in refractive status postoperatively.

DISCUSSIONS

Surgically induced astigmatism (SIA) is a well-recognized cause of transient visual deterioration after glaucoma filtration surgery and remains an important consideration in postoperative refractive outcomes (Chan & Kong, 2017; Gomaa et al., 2025). Although glaucoma surgery effectively reduces intraocular pressure (IOP), the corneal structural changes that accompany scleral incisions, flap creation, and wound healing can alter corneal curvature and refractive status. These changes have been shown to vary in magnitude and duration depending on surgical technique, use of antifibrotic agents, and individual corneal biomechanics.

Induced Corneal Changes After Trabeculectomy

Earlier studies have described a with-the-rule (WTR) astigmatic shift following trabeculectomy, often associated with changes in vertical corneal curvature. Cunliffe and colleagues reported a decrease in vertical corneal radius that persisted for several weeks before returning toward baseline by 10 months, with minimal change in astigmatic axis (Cunliffe et al., 1992; Chan & Kong, 2017). Rosen et al. similarly documented a WTR shift of 1.5–2.5 D up to 12 weeks postoperatively (Rosen et al., 1992). More nuanced topographic patterns, including superior steepening or flattening and irregular changes, have also been reported (Claridge et al., 1995). These early observations laid the foundation for subsequent investigations into the temporal evolution of corneal changes after filtration surgery.

Recent prospective work using advanced imaging modalities corroborates and extends these findings. A study employing anterior segment OCT and corneal topography demonstrated **significant postoperative increases in steep keratometry (K2) and overall astigmatism at 3 months** after trabeculectomy, while flat keratometry (K1) and average keratometry remained unchanged (Gomaa et al., 2025). This aligns with our findings in the SST group, where postoperative K2 and corneal astigmatism were significantly increased compared with preoperative values, while K1, Avg K, and apical keratometry front (AKF) showed no significant change. The WTR shift observed in our study (Δastigmatism 1.32 ± 0.13 D) is consistent with a growing body of evidence that early postoperative corneal curvature changes are dominated by alterations along the steep meridian (Gomaa et al., 2025; Chan & Kong, 2017).

Comparison Between Trabeculectomy and Non-penetrating Deep Sclerectomy

Comparative studies generally support the notion that filtration surgeries induce astigmatism, but the degree may be influenced by technique. Earlier work demonstrated that non-penetrating surgeries (including NPDS) induce less corneal astigmatism than trabeculectomy at 3 and 6 months postoperatively (Egrilmez et al., 2004). This pattern was observed in our study: although both surgical methods induced a statistically significant increase in corneal astigmatism, the magnitude was **greater in the SST group** (1.32 ± 0.13 D) than in the NPDS group (0.69 ± 0.10 D). A recent meta-analysis confirmed that trabeculectomy tends to induce greater astigmatism than non-penetrating procedures up to 6 months postoperatively (standardized mean difference = 0.40, p = .02), underscoring the differential impact of surgical invasiveness on corneal shape (BMC Ophthalmology, 2024).

However, not all reports are concordant. Some larger comparative analyses suggest that both NPDS and SST may yield comparable astigmatic outcomes at intermediate follow-up (e.g., 6 months), though these differences can be influenced by surgical parameters, use of mitomycin-C (MMC), and temporal follow-up intervals (El-Saied et al., 2014).

Integration of Current Results with Corneal and IOP Outcomes

In our cohort, the **significant increases in ΔK1 and ΔK2 in the SST group compared with the NPDS group** highlight the distinct biomechanical impact of full-thickness filtration compared with non-penetrating surgery. The prominence of ΔK2 changes suggests that the steep meridian is particularly susceptible to surgical deformation in trabeculectomy, likely due to localized scleral and tissue manipulation adjacent to the corneal periphery. In contrast, the smaller changes in K1 and Avg K in both groups indicate that the **overall corneal curvature remains relatively stable**, supporting findings that global curvature may be less affected than meridional steepening (Gomaa et al., 2025).

The **lack of significant changes in AKF and axis orientation** in both techniques suggests that while the magnitude of corneal refractive change increases, the principal orientation of astigmatism remains largely preserved in the early postoperative period. This stability may reflect a uniform biomechanical shift rather than an axis rotation, which has practical implications for postoperative refractive planning.

The substantial reduction in IOP observed in both groups corroborates the efficacy of both SST and NPDS in managing POAG, a finding consistently documented in the literature (Gedde et al., 2021; Weinreb et al., 2014). Importantly, changes in IOP did not correlate with changes in refractive parameters, paralleling earlier observations that SIA is not solely dependent on pressure reduction but also on structural tissue alterations (Chan & Kong, 2017).

Mechanisms of Surgically Induced Astigmatism

The exact mechanisms underlying SIA remain only partially understood. Proposed factors include localized flattening or steepening at the surgical site due to tissue excision, wound contraction, or bleb formation, which may alter corneal biomechanics and lead to WTR astigmatism (Chan & Kong, 2017; Gomaa et al., 2025). In trabeculectomy, the removal of scleral tissue beneath the flap may permit slight collapse of adjacent corneal tissue, effectively shortening the vertical radius and producing a WTR shift. In contrast, preservation of the trabeculo-Descemet's membrane in NPDS may offer additional structural support, resulting in smaller corneal deformation and less astigmatism (Egrilmez et al., 2004; BMC Ophthalmology, 2024).

Clinical Implications and Future Directions

These findings emphasize the need for clinicians to anticipate refractive changes when counseling patients undergoing glaucoma filtration surgery, particularly for individuals with high visual demands. Given that corneal changes may persist for months and even up to a year in some patients, definitive refractive correction may be best deferred until stability is achieved (Claridge et al., 1995; Chan & Kong, 2017).

Emerging technologies, such as minimally invasive glaucoma surgery (MIGS), have demonstrated minimal surgically induced astigmatism in combined procedures (Nakagawa et al., 2025), highlighting a trend toward refractively neutral glaucoma interventions where appropriate. Further research with larger sample sizes and longer follow-up is warranted to define the temporal profile and determinants of SIA across glaucoma surgical techniques.

CONCLUSIONS

Both sub-scleral trabeculectomy (SST) and non-penetrating deep sclerectomy (NPDS) were associated with a statistically significant increase in postoperative corneal astigmatism, with SST inducing a greater magnitude of surgically induced astigmatism compared to NPDS. Despite significant changes in corneal curvature (particularly K2) and astigmatism, no clinically meaningful alterations were observed in average keratometry (Avg K), apical keratometry front (AKF), or the axis of astigmatism at 3 months postoperatively. Both procedures effectively reduced intraocular pressure (IOP) to comparable levels, confirming their efficacy in glaucoma management.

These findings underscore the importance of carefully timing glaucoma surgery in relation to planned refractive or cataract procedures. Performing glaucoma filtration surgery before cataract extraction or refractive interventions, especially in eyes targeted for toric or multifocal intraocular lenses (IOLs), can help minimize postoperative refractive surprises and optimize visual outcomes. Surgeons should counsel patients regarding the likelihood of early postoperative astigmatic changes and consider corneal topography monitoring to guide the timing of subsequent refractive planning.

Future studies with larger sample sizes and longer follow-up periods are warranted to assess the duration of surgically induced astigmatic changes, their impact on visual quality, and the potential influence of adjunctive agents such as mitomycin C on corneal biomechanics and refractive stability.

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