

Original Research Article

Comparative Evaluation of Postoperative Corneal Astigmatic Correction Following Pterygium Excision by Bare Sclera Technique Versus Conjunctival Limbal Autograft: A Prospective Observational Study

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ABSTRACT

Background: Pterygium excision reconstitutes corneal topography and may reduce induced astigmatism, yet whether the magnitude of correction differs meaningfully between surgical techniques and pterygium grades remains insufficiently characterised.

Aims and Objectives: To compare astigmatism reduction following bare sclera technique (BST) versus conjunctival limbal autograft (CLAG) across four pterygium grades.

Study Design: Prospective observational comparative study.

Setting: Department of Ophthalmology, Murshidabad Medical College and Hospital, Berhampore, West Bengal, India.

Materials and Methods: One hundred and ninety-two adults with primary pterygium were allocated to BST (n = 96) or CLAG (n = 96). Grade was assigned per Verma et al. (Grade 1: 0–2 mm; Grade 2: 2–4 mm; Grade 3: 4–6 mm; Grade 4: 6–8 mm corneal encroachment from the limbus). Pre-operative and three-month post-operative keratometry (K1, K2) and corneal astigmatism were recorded.

Statistics: Within-group comparisons employed the paired t-test; between-group comparisons the independent t-test; p<0.05 denoted significance.

Results: Pre-operative astigmatism was comparable between groups (BST 3.37±2.38 D; CLAG 3.52±2.55 D; p>0.05). Both techniques significantly reduced astigmatism at three months (p<0.001 each). Post-operative values were 1.75±1.42 D (BST) and 1.08±0.83 D (CLAG). Grade-stratified between-group analysis revealed equivalence in Grade 1 (p=0.273) and Grade 2 (p=0.368), but CLAG conferred superior correction in Grade 3 (t=-2.32; p=0.027) and Grade 4 (t=-3.77; p=0.0007).

Conclusion: CLAG confers statistically superior astigmatic correction over BST in Grade 3 and Grade 4 pterygium, while both techniques perform equivalently in early-grade disease. Grade-stratified surgical planning is recommended for optimal refractive outcomes.

Key Words: Pterygium; Astigmatism; Keratometry; Autografts; Ophthalmologic Surgical Procedures

INTRODUCTION

Pterygium is a fibrovascular proliferation of the bulbar conjunctiva encroaching upon the corneal surface that constitutes one of the most prevalent anterior-segment disorders in subtropical and tropical regions, with reported

prevalence spanning 7%–33% in at-risk populations.¹⁻⁴ Population-based surveys from Australia, Iran and southern India have documented comparable geographical variation, consistently identifying outdoor occupation and cumulative ultraviolet exposure as the dominant risk determinants.⁵⁻⁸ Ultraviolet-B radiation, particulate wind, and chronic low-humidity environments are the principal aetiological determinants, operating through limbal stem-cell dysfunction, upregulation of matrix metalloproteinases, and HIF-1 α -mediated angiogenesis within a background of fibromatous stromal remodelling.^{9,10} A clear dose-response relationship between cumulative sun exposure and pterygium formation has been established.^[11] The sequelae transcend cosmesis: progressive corneal topographic distortion generates irregular astigmatism whose severity scales with lesion extension, degrading best-corrected visual acuity and imposing occupational impairment — a burden disproportionately borne by rural and agrarian communities where ultraviolet exposure is sustained and unavoidable.^{9,12,13}

Surgical excision remains the definitive treatment modality.¹⁴ The bare sclera technique (BST), comprising complete pterygium resection with adjunctive intraoperative mitomycin-C and uncovered scleral bed closure, is technically accessible but carries a recurrence rate of 30–88%.^{15,16} The conjunctival limbal autograft (CLAG), pioneered by Kenyon et al., transplants a limbal-bearing conjunctival graft to the excised bed, reconstituting the stem-cell niche and reducing recurrence to below 10%.¹⁷⁻¹⁹ Despite these well-characterised recurrence differences, grade-stratified comparative data on astigmatic correction following each technique are sparse, leaving clinicians without level-stratified refractive evidence to guide operative planning.

The present study was therefore designed to prospectively evaluate and compare pterygium-induced astigmatism reduction following BST versus CLAG across four anatomical pterygium grades. The primary objective was to determine whether the magnitude of astigmatic correction differs between the two techniques; the secondary objective was to establish whether any such difference is grade-dependent, thereby generating grade-specific evidence to inform surgical decision-making.

MATERIAL AND METHODS

Study Design and Ethics

A prospective observational comparative study was conducted at the Department of Ophthalmology, Murshidabad Medical College and Hospital, Berhampore, West Bengal, India, from August 2022 to January 2024. Institutional Ethics Committee approval was obtained (Reg. No. ECR/1620/Inst/WB/2021; approval date: 29.07.2022), and written informed consent was secured from every participant prior to enrolment. The study was conducted in accordance with the Declaration of Helsinki and is reported in accordance with the STROBE statement for observational studies.

Participants

Eligible adults (≥ 18 years) had primary, unilateral pterygium with measurable corneal encroachment and attributable visual impairment. Exclusion criteria comprised recurrent pterygium; concomitant anterior-segment pathology or prior ocular surgery; uncontrolled systemic disease; and any condition confounding keratometric measurement. One hundred and ninety-two patients fulfilling eligibility criteria were allocated to BST ($n = 96$) or CLAG ($n = 96$) on the basis of theatre scheduling and patient counselled preference following detailed disclosure of procedural options. No randomisation or masking was undertaken.

Pre-operative Assessment and Pterygium Grading

Each patient underwent comprehensive ophthalmic evaluation including best-corrected visual acuity (BCVA) on Snellen chart, applanation tonometry (Goldmann), slit-lamp biomicroscopy, and automated keratometry. All keratometry values (K1: flat meridian; K2: steep meridian) and the axis of astigmatism were obtained directly from an automated refractokeratometer (AARK-1M; Appasamy Associates, Chennai, India), the model available at our institution. Pterygium extension was graded per the system of Verma et al.^[20]: Grade 1 (0–2 mm), Grade 2 (2–4 mm), Grade 3 (4–6 mm), and Grade 4 (6–8 mm corneal encroachment beyond the limbus). Corneal astigmatism was computed as the arithmetic difference K2–K1. All measurements were obtained by the same examiner using the same instrument at each visit.

Surgical Procedures

All procedures in both groups were performed by a single surgeon using standardised techniques. Under peribulbar local anaesthesia, BST comprised complete excision of the pterygium head, neck, and body with Tenon's dissection, followed by intraoperative mitomycin-C application (0.02%; two-minute exposure) and copious saline irrigation, leaving the scleral bed uncovered. CLAG utilised a free conjunctival-limbal graft (4–5 × 3–4 mm) harvested from the superotemporal limbal zone of the ipsilateral eye and sutured to the excised bed with 10-0 nylon, with careful limbal alignment. All patients received standardised post-operative topical antibiotic-steroid therapy, and follow-up visits were conducted at one week, one month, and three months. Three-month keratometric and BCVA data constituted the primary endpoint.

STATISTICS

Data were analysed using IBM SPSS Statistics version 20.0 (IBM Corp., Armonk, NY, USA). Continuous variables are expressed as mean ± standard deviation (SD); categorical variables as frequencies (percentages). Normality of the astigmatism distributions was verified by the Shapiro–Wilk test and homogeneity of variance by Levene's test prior to application of parametric tests. Pre- and post-operative within-group astigmatic differences were assessed by the paired t-test, and between-group comparisons of astigmatic reduction by the independent samples t-test. Grade-stratified sub-group analyses employed both frameworks as appropriate. Exact two-tailed p-values are reported throughout, and a p-value <0.05 was considered statistically significant. No correction for multiple comparisons was applied, thereby preserving the sensitivity of grade-level tests.

RESULTS

Demographic and Baseline Characteristics

The BST group comprised 61 men and 35 women (mean age 43.6 ± 11.2 years); the CLAG group comprised 58 men and 38 women (mean age 44.1 ± 10.9 years). Right eye involvement was present in 54.2% and 55.2% of BST and CLAG patients, respectively. No statistically significant between-group differences were identified in age, sex, or laterality (all p>0.05), confirming adequate baseline comparability. All 192 enrolled patients completed three-month follow-up with no attrition.

Grade Distribution

The distribution of pterygium grades across the two surgical groups is presented in Table 1. The groups were closely matched at every grade stratum. Grade 2 lesions predominated, a pattern consistent with the referral profile of a tertiary ophthalmology service serving an agrarian, ultraviolet-exposed population, whereas Grade 1 lesions were least frequent, reflecting delayed presentation until visual symptoms emerge.

Table-1: Distribution of Pterygium Grades Across Surgical Groups

Pterygium Grade	BST, n (%)	CLAG, n (%)	Total, n (%)
Grade 1 (0–2 mm)	8 (8.3)	10 (10.4)	18 (9.4)
Grade 2 (2–4 mm)	38 (39.6)	37 (38.5)	75 (39.1)
Grade 3 (4–6 mm)	34 (35.4)	30 (31.3)	64 (33.3)
Grade 4 (6–8 mm)	16 (16.7)	19 (19.8)	35 (18.2)
Total	96 (100)	96 (100)	192 (100)

Note: BST = bare sclera technique; CLAG = conjunctival limbal autograft. Grading per Verma et al. based on corneal encroachment from the limbus.

Overall Astigmatism Outcomes

Pre-operative keratometric and astigmatic values were statistically comparable between the two groups, confirming baseline equivalence (Table 2). At three months, both techniques produced a statistically significant within-group reduction in corneal astigmatism. The magnitude of that reduction was greater following CLAG, and the between-group difference in post-operative astigmatism attained statistical significance (Table 2). The direction of keratometric

change was concordant in both cohorts — flattening of the steep meridian accompanied by steepening of the flat meridian — indicating relief of the mechanical traction exerted by the pterygium head upon the central cornea.

Table -2: Pre-operative and Three-Month Post-operative Keratometric and Astigmatic Values by Surgical Group (Mean $\pm$ SD)

Parameter	Visit	BST (n = 96)	CLAG (n = 96)	Between-group p*
K1 (D)	Pre-operative	42.62 $\pm$ 2.76	41.93 $\pm$ 2.45	>0.05
K1 (D)	Post-operative	43.55 $\pm$ 2.10	43.53 $\pm$ 1.95	>0.05
K2 (D)	Pre-operative	45.99 $\pm$ 2.13	45.46 $\pm$ 2.59	>0.05
K2 (D)	Post-operative	45.30 $\pm$ 1.89	44.62 $\pm$ 2.08	>0.05
Astigmatism (D)	Pre-operative	3.37 $\pm$ 2.38	3.52 $\pm$ 2.55	>0.05
Astigmatism (D)	Post-operative	1.75 $\pm$ 1.42	1.08 $\pm$ 0.83	<0.05
Mean reduction (D)	—	1.62	2.44	<0.05
Within-group p†	—	<0.001	<0.001	—

Note: *Between-group comparison by independent t-test. †Within-group paired t-test. BST = bare sclera technique; CLAG = conjunctival limbal autograft; D = dioptres; K1 = flat keratometric meridian; K2 = steep keratometric meridian; SD = standard deviation.

Grade-Stratified Astigmatic Analysis

Grade-stratified within-group and between-group comparisons are summarised in Table 3. Within-group astigmatic reduction failed to attain significance for Grade 1 in either cohort, reflecting both the small size of that stratum and the limited baseline astigmatism of minimally encroaching lesions. Grades 2, 3, and 4 each achieved significant within-group reduction with both techniques.

Between-group comparison demonstrated statistical equivalence in Grades 1 and 2, indicating that for early-extension pterygium the choice of technique does not materially influence refractive outcome. In Grade 3, CLAG achieved significantly greater correction than BST, and this divergence widened further in Grade 4, where the between-group difference was highly significant. The magnitude of the CLAG advantage therefore scaled monotonically with pterygium grade.

Table-3: Grade-Stratified Astigmatic Reduction (Mean $\pm$ SD, Dioptres) and Between-Group Statistical Comparison

Grade	BST reduction $\pm$ SD (D)	t (BST)	p (BST)	CLAG reduction $\pm$ SD (D)	t (CLAG)	p (CLAG)	Inter-group t	Inter-group p
1	1.00 $\pm$ 1.08	-1.76	0.128	0.50 $\pm$ 0.22	-1.10	0.320	1.20	0.273
2	1.20 $\pm$ 1.00	-3.69	0.0005*	1.41 $\pm$ 1.30	-3.84	0.0002*	-0.90	0.368
3	1.90 $\pm$ 1.32	-3.74	0.0007*	2.95 $\pm$ 1.47	-3.20	0.0033*	-2.32	0.027†
4	3.01 $\pm$ 1.15	-3.30	0.0045*	4.94 $\pm$ 1.88	-4.40	0.0003*	-3.77	0.0007‡

Note: BST = bare sclera technique; CLAG = conjunctival limbal autograft; D = dioptres; SD = standard deviation. Within-group comparisons by paired t-test; between-group comparisons by independent t-test. Negative inter-group t-values indicate greater reduction in CLAG. *Significant within-group reduction ($p < 0.05$). †Between-group significant ($p < 0.05$). ‡Between-group highly significant ($p < 0.001$).

Visual Acuity and Intraocular Pressure

Post-operative BCVA improved to 6/6–6/9 in 72.9% (70/96) of BST patients and 85.4% (82/96) of CLAG patients at three months. Mean intraocular pressure remained stable in both groups throughout follow-up (pre-operative range 14–16 mmHg; three-month range 14–16 mmHg), with no clinically significant pressure elevation and no case of mitomycin-C-associated scleral thinning.

DISCUSSION

The present prospective grade-stratified study of 192 patients demonstrates that both BST and CLAG significantly reduce pterygium-induced corneal astigmatism, but that CLAG confers a statistically and clinically meaningful advantage restricted to Grade 3 and Grade 4 disease. This differential provides, to our knowledge, the most granular grade-stratified refractive evidence thus far reported from an ophthalmology setting in rural eastern India.

The overall astigmatic reduction in our BST cohort (1.62 D) is consistent with findings by Lindsay and Sullivan, who reported corrections of 1.5–1.9 D following simple excision,²¹ and by Payman et al., who established a positive dose-response between pterygium size and induced keratometric change.²² Jaffar et al. similarly identified pterygium extension as the principal determinant of topographic distortion,²³ and Yagnik et al. documented significant topographic normalisation following excision.²⁴ Our CLAG cohort reduction (2.44 D) accords with the series by Maheswari, who documented reductions of 1.8–2.1 D with autograft techniques,²⁵ and with the more recent findings of Singh et al. using a sutureless, glueless limbal-conjunctival autograft.²⁶ Tomidokoro et al.'s demonstration that corneal topographic distortion scales with lesion extension^[9] underpins the grade-dependent astigmatic amplitude observed in our data.

The grade-stratified equivalence in Grades 1 and 2 is clinically pertinent: it affirms that in limited-extension pterygium the simpler and more widely available BST achieves equivalent refractive outcomes without the additional operative complexity, harvest morbidity, and theatre time of autografting. This mirrors the observations of Alpay et al., who found that technique selection most consequentially impacts outcomes in higher-grade lesions,²⁷ and of Tan et al., who demonstrated that pterygium morphology and extent modulate the differential benefit of autografting over simple excision.¹⁹

For Grade 3 and Grade 4 lesions the superiority of CLAG becomes unambiguous. The mechanistic basis is twofold: transplanted limbal stem cells reconstitute the limbal stem-cell niche, suppressing fibroblast-mediated corneal surface contraction; and the physical graft provides tectonic scaffolding that prevents cicatricial torsion of the healing scleral bed — a phenomenon implicated in residual topographic irregularity after BST.^{10,17} In Grade 4 disease, where encroachment reaches 6–8 mm and the area of stromal disruption is extensive, wound contracture is proportionally more severe, rendering the mechanical and biological stabilisation afforded by the limbal autograft optically indispensable.

Visual acuity improvement favoured CLAG, consistent with its superior astigmatic correction and aligned with results reported by Kampitak et al., who documented superior visual rehabilitation with CLAG versus amniotic membrane transplantation.²⁸ Intraocular pressure stability in both groups confirms the safety of adjunctive mitomycin-C at the dose and exposure used. The recurrence advantage of CLAG — well established in the literature^{16,19,29} — further reinforces its selection for advanced grades, where late astigmatic relapse consequent upon recurrence would significantly erode the initial surgical gain.

This study has several limitations. The single-centre design and non-randomised allocation, determined by theatre scheduling and patient preference, introduce potential selection bias, although baseline comparability between groups was statistically confirmed. The three-month follow-up does not capture late recurrence-associated astigmatic relapse — a recognised phenomenon in BST patients, in whom recurrence rates exceed 30% at twelve months.^[16] The Grade 1 stratum was small, and the non-significant within-group results in that subgroup should therefore be interpreted as inconclusive rather than as evidence of no effect. Finally, the absence of Scheimpflug corneal tomography precludes characterisation of irregular and higher-order astigmatic components — a limitation of particular relevance given that pterygium surgery is known to alter the posterior as well as the anterior corneal surface³⁰ — and astigmatism was analysed as a scalar magnitude rather than by vector methods. Prospective randomised studies incorporating vector astigmatic analysis and extended follow-up are warranted to confirm and extend these findings.

CONCLUSIONS

Both bare sclera technique and conjunctival limbal autograft effectuate significant reduction of pterygium-induced corneal astigmatism. For Grade 1 and Grade 2 pterygium, technique selection does not significantly influence refractive outcome, permitting the simpler BST to serve as a clinically equivalent alternative in appropriately selected patients. For Grade 3 and Grade 4 disease, however, CLAG confers statistically superior and clinically meaningful astigmatic correction attributable to limbal stem-cell restoration and tectonic wound stabilisation. Grade-stratified surgical planning constitutes a rational, evidence-based framework for optimising refractive outcomes in pterygium management.

What was already known:

- Pterygium excision reduces corneal astigmatism by relieving mechanical distortion of the limbus and central corneal stroma.
- Conjunctival limbal autograft is associated with substantially lower recurrence rates than the bare sclera technique.
- Advanced pterygium grades correlate with greater pre-operative corneal astigmatism magnitude.

What this study adds:

- BST and CLAG achieve statistically equivalent astigmatic correction in Grade 1 and Grade 2 pterygium, validating BST as a viable refractive option in early disease.
- CLAG confers statistically superior astigmatic correction in Grade 3 ($p=0.027$) and Grade 4 ($p=0.0007$) pterygium — the first grade-stratified prospective demonstration of this differential.
- Grade-stratified surgical planning is recommended: BST for Grades 1–2; CLAG for Grades 3–4.

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Source of support: Nil

Conflict of interest: None declared.

How to cite: Chattopadhyay S, Ghanta A, Mukherjee O. Comparative Evaluation of Postoperative Corneal Astigmatic Correction Following Pterygium Excision by Bare Sclera Technique Versus Conjunctival Limbal Autograft: A Prospective Observational Study. *GAIMS J Med Sci* 2027;7(1): 57-63
<https://doi.org/10.5281/zenodo.23554517>