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Original Research Article

ASSESSMENT AND ALTERATIONS IN RETINAL NERVE FIBER LAYER THICKNESS BEFORE AND FOLLOWING GLAUCOMA FILTRATION SURGERY USING OPTICAL COHERENCE TOMOGRAPHY: A CLINICAL STUDY

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ABSTRACT

Background: Glaucoma is a progressive optic neuropathy characterized by irreversible retinal ganglion cell loss and thinning of the retinal nerve fiber layer (RNFL), ultimately leading to visual field defects and blindness. Elevated intraocular pressure (IOP) remains the most important modifiable risk factor, and glaucoma filtration surgery is indicated in patients with uncontrolled disease despite maximal medical therapy. Optical coherence tomography (OCT) has emerged as a reliable, non-invasive imaging modality for quantitative assessment of RNFL thickness and structural changes of the optic nerve head. However, postoperative alterations in RNFL thickness following filtration surgery remain incompletely understood. The objective is to evaluate changes in peripapillary RNFL thickness before and after glaucoma filtration surgery using spectral-domain OCT and to determine their relationship with IOP reduction and visual function. **Materials and Methods:** A prospective clinical study was conducted over 18 months in the Regional Institute of Ophthalmology, Rajendra Institute of Medical Sciences (RIMS), Ranchi, Jharkhand, India. Sixty patients with medically uncontrolled primary open-angle glaucoma or primary angle-closure glaucoma requiring filtration surgery were enrolled. Detailed ophthalmic evaluation included best-corrected visual acuity (BCVA), slit-lamp examination, Goldmann applanation tonometry, gonioscopy, fundus examination, Humphrey visual field analysis, and spectral-domain OCT measurement of average and quadrant-wise RNFL thickness. Patients underwent trabeculectomy with mitomycin-C when indicated and were followed at 1 week, 1 month, 3 months, and 6 months postoperatively. Changes in RNFL thickness, IOP, optic disc parameters, and visual field indices were analyzed using paired t-test, repeated-measures ANOVA, and Pearson correlation. Statistical significance was considered at $p<0.05$. **Results:** The mean age of participants was 57.8±10.6 years, with males constituting 61.7% of the cohort. Mean preoperative IOP significantly decreased from 28.4±5.8 mmHg to 14.2±3.1 mmHg at 6 months ($p<0.001$). Average RNFL thickness demonstrated mild postoperative improvement, particularly in the superior and inferior quadrants, while temporal and nasal quadrants remained relatively stable. Significant correlations were observed between postoperative IOP reduction and stabilization of RNFL thickness. Visual field progression remained stable in the majority of patients during follow-up. **Conclusion:** Glaucoma filtration surgery effectively reduces IOP and contributes to stabilization of RNFL thickness as measured by OCT. OCT serves as a valuable tool for postoperative monitoring and early detection of structural changes, facilitating long-term management of glaucoma patients.

INTRODUCTION

Glaucoma is one of the leading causes of irreversible blindness worldwide and represents a significant public health challenge due to its chronic, progressive, and often asymptomatic nature. According to recent global estimates, more than 80 million individuals are affected by glaucoma, and this number is projected to exceed 110 million by 2040 owing to population aging and increasing life expectancy. The disease is characterized by progressive degeneration of retinal ganglion cells and their axons, resulting in thinning of the retinal nerve fiber layer (RNFL), excavation of the optic nerve head, and corresponding visual field defects. Since visual impairment caused by glaucoma is irreversible, early diagnosis and timely intervention are crucial for preserving vision and improving patients' quality of life. Elevated intraocular pressure (IOP) remains the most important modifiable risk factor for glaucoma progression. Although the disease may occur even with statistically normal IOP, lowering IOP remains the cornerstone of glaucoma management irrespective of disease subtype. Medical therapy with topical hypotensive agents is generally considered the first-line treatment; however, disease progression despite maximal medical therapy, medication intolerance, poor compliance, or advanced disease often necessitates surgical intervention. Trabeculectomy continues to be regarded as the gold standard filtration procedure because of its effectiveness in lowering IOP over the long term. Adjunctive use of antimetabolites such as mitomycin-C has further improved surgical success by reducing subconjunctival fibrosis and bleb failure.[1]

Optical coherence tomography (OCT) has revolutionized glaucoma diagnosis and monitoring by enabling high-resolution, cross-sectional imaging of retinal structures. Spectral-domain OCT provides rapid, reproducible, and quantitative measurements of peripapillary RNFL thickness, macular ganglion cell complex (GCC), and optic nerve head morphology. Since RNFL thinning often precedes detectable visual field defects, OCT has become an indispensable component of glaucoma evaluation. The technology offers objective structural assessment and facilitates early detection of disease progression, especially in pre-perimetric glaucoma. Following successful filtration surgery, substantial reduction in IOP may influence the morphology of the optic nerve head and peripapillary retina. Several investigators have reported postoperative changes including reversal of optic disc cupping, increased neuroretinal rim thickness, alteration in lamina cribrosa position, and mild increase or stabilization of RNFL thickness. These changes are thought to result from relief of mechanical compression on retinal ganglion cell axons, improved axoplasmic transport, and structural remodeling of the optic nerve head. Nevertheless, the magnitude and clinical significance of these postoperative changes remain controversial. While some studies have demonstrated measurable increases in RNFL thickness after trabeculectomy, others have reported minimal or no significant changes, particularly in advanced glaucoma where irreversible axonal loss has already occurred.[2]

The interpretation of postoperative RNFL measurements also requires careful consideration of factors such as postoperative inflammation, transient retinal edema, scan quality, segmentation errors, and duration of follow-up. Short-term fluctuations in RNFL thickness may not necessarily reflect true neural recovery but rather biomechanical changes associated with altered IOP. Longitudinal studies employing standardized OCT protocols are therefore essential to distinguish genuine structural stabilization from measurement variability. Assessment of RNFL thickness before and after glaucoma filtration surgery has important clinical implications. Demonstration of postoperative stabilization may indicate successful control of disease progression, whereas continued RNFL thinning despite adequate IOP reduction may suggest ongoing neurodegeneration requiring closer surveillance or additional therapeutic strategies. Integration of OCT findings with visual field analysis, optic disc evaluation, and clinical examination provides a comprehensive approach for monitoring glaucoma patients.[3]

Despite the increasing use of OCT in glaucoma management, evidence regarding postoperative RNFL alterations in the Indian population remains limited. Variations in ethnicity, disease severity, surgical techniques, and follow-up duration may influence structural outcomes. Regional data from tertiary care centers are therefore valuable for understanding postoperative changes and optimizing patient management. The present prospective clinical study was undertaken at the Regional Institute of Ophthalmology, Rajendra Institute of Medical Sciences (RIMS), Ranchi, to evaluate alterations in RNFL thickness before and after glaucoma filtration surgery using spectral-domain OCT. Additionally, the study aimed to correlate structural changes with intraocular pressure reduction and functional outcomes, thereby contributing to evidence-based postoperative assessment of glaucoma patients.[4]

MATERIALS AND METHODS

Study Design: This was a prospective observational clinical study conducted to evaluate alterations in retinal nerve fiber layer thickness before and after glaucoma filtration surgery using spectral-domain optical coherence tomography.

Study Setting: The study was carried out in the Regional Institute of Ophthalmology, Rajendra Institute of Medical Sciences (RIMS), Ranchi, Jharkhand, India, a tertiary care referral center providing specialized glaucoma services.

Study Duration: The study was conducted over 18 months, including patient recruitment, surgical intervention, postoperative follow-up, data collection, and statistical analysis.

Sample Size: A total of 60 patients diagnosed with medically uncontrolled glaucoma and scheduled for glaucoma filtration surgery were enrolled consecutively after fulfilling the eligibility criteria.

Sampling Technique: Consecutive sampling was employed to recruit eligible patients attending the glaucoma outpatient department during the study period.

Inclusion Criteria

- Age ≥18 years.
- Primary open-angle glaucoma (POAG).
- Primary angle-closure glaucoma (PACG) after laser peripheral iridotomy where indicated.
- Uncontrolled IOP despite maximum tolerated medical therapy.
- Progressive glaucomatous optic neuropathy requiring filtration surgery.
- Clear ocular media permitting reliable OCT imaging.
- Willingness to provide written informed consent.

Exclusion Criteria

- Secondary glaucomas (neovascular, uveitic, traumatic, congenital).
- Previous glaucoma surgery.
- Significant retinal disease affecting OCT measurements (diabetic retinopathy, retinal vein occlusion, macular degeneration).
- High myopia (>6 diopters).
- Dense cataract precluding OCT imaging.
- Optic neuropathies other than glaucoma.
- Active ocular infection or inflammation.
- Patients unwilling to participate or unlikely to complete follow-up.

Preoperative Evaluation

Each participant underwent a comprehensive ophthalmic examination including:

- Demographic profile and detailed ocular history.
- Best-corrected visual acuity (BCVA).
- Slit-lamp biomicroscopy.
- Goldmann applanation tonometry.
- Gonioscopy using a Goldmann three-mirror lens.
- Dilated fundus examination.
- Cup-to-disc ratio assessment.
- Humphrey automated visual field analysis (24-2 SITA Standard).
- Spectral-domain OCT assessment of average and quadrant-wise RNFL thickness (superior, inferior, nasal, and temporal).
- Central corneal thickness measurement by pachymetry.

Data Collection

Data were entered into a predesigned case record form and subsequently transferred to Microsoft Excel for validation. OCT scans with signal strength <7 or segmentation errors were excluded from analysis.

Statistical Analysis

Data analysis was performed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages. Normality was assessed using the Shapiro–Wilk test. Paired Student's *t*-test was used to compare preoperative and postoperative continuous variables. Repeated-measures ANOVA evaluated changes over follow-up visits. Pearson correlation coefficient assessed the relationship between IOP reduction and RNFL thickness changes. Categorical variables were analyzed using the Chi-square or Fisher's exact test as appropriate. A p-value <0.05 was considered statistically significant.

Ethical Considerations

The study protocol was reviewed and approved by the Institutional Ethics Committee of Rajendra Institute of Medical Sciences (RIMS), Ranchi before initiation. The study adhered to the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants before enrollment. Confidentiality of patient information was maintained throughout the study, and participation was entirely voluntary without affecting clinical care.

RESULTS

A total of 60 eyes of 60 patients with medically uncontrolled glaucoma underwent glaucoma filtration surgery and completed the 6-month follow-up. No patient was lost to follow-up. The mean age of the participants was 57.8 ± 10.6 years (range: 34–78 years). Males constituted 61.7% of the study population. Primary open-angle glaucoma (POAG) was the predominant diagnosis (70.0%), followed by primary angle-closure glaucoma (PACG) (30.0%).

Postoperatively, a statistically significant reduction in intraocular pressure (IOP) was observed at each follow-up visit. Optical coherence tomography (OCT) demonstrated stabilization with mild improvement in average retinal nerve fiber layer (RNFL) thickness. Superior and inferior quadrants showed greater postoperative changes compared to nasal and temporal quadrants. Visual field indices also demonstrated stabilization during the follow-up period.

Table 1: Baseline Demographic and Clinical Characteristics (n=60)

Variable	Number (%) / Mean ± SD
Age (years)	57.8 ± 10.6
31–40 years	6 (10.0)
41–50 years	11 (18.3)
51–60 years	19 (31.7)

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61–70 years	17 (28.3)
>70 years	7 (11.7)
Male	37 (61.7)
Female	23 (38.3)
Primary Open-Angle Glaucoma	42 (70.0)
Primary Angle-Closure Glaucoma	18 (30.0)
Duration of glaucoma (years)	5.1 ± 2.4
Baseline BCVA (logMAR)	0.48 ± 0.21

Interpretation
Most patients belonged to the 51–70-year age group, with a male predominance. POAG was the most common diagnosis. The demographic profile is consistent with the typical clinical presentation of glaucoma patients requiring filtration surgery.

Table 2: Changes in Intraocular Pressure Following Surgery

Follow-up	Mean IOP (mmHg)	Mean Reduction	p-value
Preoperative	28.4 ± 5.8	—	—
1 Week	15.8 ± 3.7	12.6	<0.001
1 Month	14.8 ± 3.3	13.6	<0.001
3 Months	14.3 ± 3.2	14.1	<0.001
6 Months	14.2 ± 3.1	14.2	<0.001

Repeated Measures ANOVA: F = 186.4, p <0.001

Interpretation
There was a highly significant reduction in intraocular pressure following trabeculectomy. Mean IOP decreased by approximately **50%**, indicating excellent surgical efficacy.

Table 3: Average RNFL Thickness Before and After Surgery

Follow-up	Mean RNFL Thickness (µm)	p-value
Preoperative	72.8 ± 12.6	—
1 Month	74.1 ± 12.2	0.032
3 Months	75.0 ± 11.8	0.011
6 Months	75.6 ± 11.4	0.004

Repeated Measures ANOVA: F = 5.91, p =0.002

Interpretation
Average RNFL thickness showed a modest but statistically significant increase after surgery, suggesting structural stabilization following effective IOP reduction

Table 4: Quadrant-wise RNFL Thickness Changes (µm)

Quadrant	Baseline	6 Months	Mean Change	p-value
Superior	88.4 ± 15.3	91.2 ± 14.8	+2.8	0.008
Inferior	82.6 ± 16.2	85.1 ± 15.9	+2.5	0.014
Nasal	59.1 ± 11.4	59.9 ± 11.0	+0.8	0.241
Temporal	60.8 ± 10.7	61.5 ± 10.2	+0.7	0.314

Interpretation
The superior and inferior RNFL quadrants exhibited statistically significant postoperative thickening, whereas nasal and temporal quadrants remained largely unchanged.

Table 5: Visual Field Parameters

Parameter	Baseline	6 Months	p-value
Mean Deviation (dB)	−10.8 ± 5.3	−10.3 ± 5.2	0.041
Pattern Standard Deviation (dB)	7.2 ± 2.8	6.9 ± 2.7	0.089
Visual Field Index (%)	73.4 ± 15.6	75.1 ± 14.8	0.038

Table 6: Correlation Between IOP Reduction and RNFL Thickness Improvement

Variable	Correlation Coefficient (r)	p-value
IOP reduction vs Average RNFL	0.61	<0.001
IOP reduction vs Superior RNFL	0.58	<0.001
IOP reduction vs Inferior RNFL	0.53	0.002

Interpretation
A significant positive correlation was observed between reduction in IOP and postoperative RNFL stabilization, indicating that greater pressure reduction was associated with better preservation of retinal nerve fibre layer thickness.

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Table 7: Postoperative Complications

Complication	Number	Percentage
No complication	46	76.7
Transient hypotony	5	8.3
Shallow anterior chamber	3	5.0
Bleb leak	2	3.3
Hyphema	2	3.3
Choroidal detachment	1	1.7
Encapsulated bleb	1	1.7

Chi-square = 4.82, p =0.186

Interpretation

Most patients had an uneventful postoperative recovery. The complications observed were infrequent and managed successfully with conservative measures or minor interventions.

Table 8: Surgical Success at Six Months

Outcome	Number	Percentage
Complete Success (IOP ≤18 mmHg without medication)	46	76.7
Qualified Success (with medication)	11	18.3
Failure	3	5.0

Interpretation

Trabeculectomy achieved a high surgical success rate, with over three-fourths of patients attaining complete success without additional antiglaucoma medication.

Statistical Summary

Test	Purpose
Shapiro–Wilk Test	Normality assessment
Paired Student's t-test	Pre- and postoperative comparisons
Repeated Measures ANOVA	Longitudinal comparison across follow-up
Pearson Correlation	Association between IOP reduction and RNFL thickness
Chi-square Test	Comparison of categorical variables

Software Used: IBM SPSS Statistics Version 26.0

Level of significance: p <0.05

DISCUSSION

The current prospective clinical study used spectral-domain optical coherence tomography (SD-OCT) to assess changes in retinal nerve fibre layer (RNFL) thickness prior to and during glaucoma filtration surgery. The results show that throughout the six-month follow-up period, a successful trabeculectomy led to a significant decrease in intraocular pressure (IOP), stabilisation, and a slight improvement in RNFL thickness. Effective IOP control may reduce mechanical stress on the optic nerve head and help preserve retinal ganglion cell axons, according to these structural alterations. The study population was primarily male (61.7%) and had a mean age of 57.8 years. Seventy percent of individuals had primary open-angle glaucoma, which is consistent with the epidemiological pattern found in tertiary eye care facilities in India. Recent research has reported similar demographic data, showing that the frequency of glaucoma rises with age and is somewhat higher in men. Due to glaucoma's chronic nature and delayed presentation in developing nations, patients frequently need surgery when medication therapy fails.[5,6]

The considerable postoperative reduction in IOP from 28.4 ± 5.8 mmHg to 14.2 ± 3.1 mmHg at six months, or almost a 50% decrease, was one of the study's main findings. This decrease was comparable to results from other clinical trials assessing trabeculectomy with mitomycin-C and was highly significant (p<0.001). Since lowering IOP is the only strategy that has been consistently shown to slow the progression of glaucoma, it continues to be the primary treatment target in glaucoma therapy. At six months, the average RNFL thickness had slightly increased from 72.8 µm before surgery to 75.6 µm. Although the loss of retinal ganglion cells in glaucoma is irreversible, postoperative thickening has been reported in the literature and is typically explained by the lamina cribrosa's mechanical deformation being reversed, axoplasmic flow being restored, and tissue compression being reduced rather than by actual neural tissue regeneration. While the nasal and temporal quadrants showed little change, the superior and inferior quadrants showed statistically significant increases in RNFL thickness. These findings align with the typical pattern of glaucomatous damage, which mostly affects the bundles of superior and inferior arcuate nerve fibres.[7,8]

Visual field indices stabilised after surgery, according to functional evaluation. While the pattern standard deviation stayed mostly intact, the mean deviation exhibited a slight but statistically significant improvement. Stabilisation rather than improvement is regarded as a desirable result because visual field recovery is typically restricted following established glaucomatous impairment. Effective disease control after filtration surgery is shown by the lack of further worsening over the research period. The substantial positive connection between postoperative IOP reduction and RNFL stabilisation was one of the study's key findings. The idea that structural advancement and pressure control are closely associated is supported by the fact that patients who experienced larger IOP decreases showed better preservation of RNFL thickness. In postoperative surveillance, OCT thus functions as an objective supplement to traditional clinical assessment and visual field tests.[9,10]

With 76.7% of patients recovering without incident, the postoperative complication profile was favourable. Rarely, bleb leak, hyphema, shallow anterior chamber, and transient hypotony occurred; these conditions were successfully treated without long-term visual effects. This study's 76.7% overall surgical success rate is in line with documented success rates for trabeculectomy with concomitant mitomycin-C. The current results demonstrate the complementing function of SD-OCT in evaluating structural results following glaucoma surgery. OCT offers repeatable quantitative data that aid in the early detection of disease stabilisation or development, even if it cannot take the place of clinical examination or perimetry. Long-term glaucoma care may be improved by longer follow-up with bigger multicenter cohorts and the use of OCT angiography and ganglion cell complex analysis to better understand postoperative optic nerve remodelling.[11,12]

CONCLUSION

The current prospective clinical investigation showed that glaucoma filtration surgery is very successful in stabilising structural deterioration and significantly lowering intraocular pressure (IOP) in individuals with medically uncontrolled glaucoma. For assessing postoperative changes in retinal nerve fibre layer (RNFL) thickness, spectral-domain optical coherence tomography (SD-OCT) has shown itself to be a dependable, objective, and repeatable imaging method. The average RNFL thickness improved slightly but statistically significantly after surgery, especially in the superior and inferior quadrants, indicating reversal of pressure-induced structural deformation and preservation of retinal ganglion cell axons rather than actual neural regeneration. Throughout the six-month follow-up, visual field measurements stayed constant, demonstrating effective disease progression management.

The need of efficient pressure control in maintaining optic nerve integrity is further shown by a strong positive connection between postoperative IOP reduction and RNFL stabilisation. With few and controllable postoperative problems, the treatment showed a high surgical success rate. For postoperative surveillance of glaucoma patients, SD-OCT should be used as a standard supplement to clinical evaluation and perimetry. To further understand long-term structural changes, longer follow-up studies with larger multicentric populations and the use of cutting-edge imaging modalities as OCT angiography and ganglion cell complex analysis are advised. ural changes after glaucoma filtration surgery and optimize patient management strategies.

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