Outcomes of Selective Laser Trabeculoplasty as Primary Treatment for Ocular Hypertension and Mild Open Angle Glaucoma in the Saudi Arabian Population

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Abstract

Objective: To evaluate the effectiveness of selective laser trabeculoplasty (SLT) as a primary treatment modality for lowering intraocular pressure (IOP) in patients with ocular hypertension (OHT) and mild primary open-angle glaucoma (POAG) within the Saudi Arabian popul--ation, and to assess its impact on IOP control, medication use, and associated influencing factors over a one-year period.

Methods: A retrospective cohort design was used. 54 eyes of patients with ocular hypertension (OHT) or mild primary open-angle glaucoma (POAG) underwent SLT. IOP, medication use, and potential influencing factors were monitored over one year.

Results: SLT significantly reduced IOP ($_p < 0.001$ for all comparisons). The mean IOP decreased from 20.57 mmHg at baseline to 14.72 mmHg at one month (a 28.4% reduction) and remained substantially low during the year (15.39 mmHg at six months and 15.44 mmHg at one year). After SLT, the proportion of eyes achieving well-controlled IOP (<21 mmHg) significantly increased from 51.9% at baseline to 96.3% at one year ($_p < 0.001$). This improvement was observed across all patient subgroups, including those with OHT, mild POAG, normal-tension glaucoma, and secondary glaucomas. Before SLT, all patients were medication-free. At one year, 74.1% remained medication-free, while 25.9% required one medication ($_p < 0.001$). Greater IOP reduction was associated with a longer time since SLT, younger age, and diagnoses of mild POAG or normal tension glaucoma (all $_p < 0.05$).

Conclusion: SLT demonstrated significant and sustained IOP reduction in the Saudi Arabian population with OHT and mild POAG. It also led to a substantial decrease in medication use. These findings suggest SLT as a viable primary treatment option for this patient population, though further research is needed to explore long-term outcomes.

Keywords: Selective laser trabeculoplasty (SLT), ocular hypertension, glaucoma, intraocular pressure (IOP), saudi arabia

Introduction

Glaucoma, a group of optic neuropathies characterized by progressive loss of retinal ganglion cells and corresponding visual field defects, is a significant global public health concern.¹ An estimated 57.5 million people worldwide are affected by primary open-angle glaucoma (POAG).² Early diagnosis and effective management of intraocular pressure (IOP) are crucial in preventing vision loss in glaucoma patients.³

Selective laser trabeculoplasty (SLT) is a promising, minimally invasive, non-surgical procedure for lowering IOP in glaucoma patients.⁴ SLT targets the trabecular meshwork, the network of channels responsible for aqueous humor outflow from the eye, by stimulating cellular activation and improving the outflow facility.⁵ Compared to minimally invasive glaucoma surgery (MIGS) for POAG, SLT has several advantages, including a less invasive approach, a reduced risk of complications, and the potential for repeat treatments. SLT is an effective, low-complication method for reducing IOP in mild-to-moderate POAG and is suitable as an initial treatment in a stepwise approach. In contrast, MIGS is typically preferred as a follow-up treatment for mild-to-moderate glaucoma when topical therapy is not sufficient.⁶

While various studies have established the efficacy of SLT in lowering IOP in glaucoma patients,^{7,8} there are limited data on its outcomes as a primary treatment modality in the Saudi Arabian population. Glaucoma presentations and risk factors can vary by region, making it essential to understand the

effectiveness of therapeutic interventions in specific populations to optimize treatment strategies.⁹

The aim of this study is to evaluate the outcomes of SLT as a primary treatment for ocular hypertension (OHT) and mild POAG in the Saudi patient population. We hypothesize that SLT will exhibit significant efficacy in reducing IOP and enhancing pressure control over a one-year follow-up period, potentially decreasing the need for antiglaucoma medications. Additionally, we will examine factors influencing IOP response to SLT to identify patient subgroups that are most likely to benefit from this treatment approach.

This research is important for the ophthalmic community both in Saudi Arabia and globally. By assessing the effectiveness and safety of SLT as a primary treatment for OHT and mild POAG in the Saudi Arabian population, we can provide valuable insights for optimizing glaucoma management strategies in this region. Moreover, identifying factors associated with successful IOP control after SLT can enhance patient selection and result in more personalized treatment decisions.

Methods

Study Design

This retrospective, single-center, interventional study assessed the outcomes of SLT as a primary treatment for OHT and mild POAG in the Saudi Arabian population. The study adhered to the principles of the Declaration of Helsinki and received ethical approval from the Institutional Review Board of King Abdulaziz University Hospital in Saudi Arabia (reference No:247-24). Informed written consent was obtained from all participants after a thorough explanation of the study procedures, potential risks, and benefits.

Study Population

Medical records of patients diagnosed with OHT or mild POAG who underwent SLT between January 2023 and January 2024 at King Abdulaziz University Hospital, Jeddah, Saudi Arabia were reviewed.

Inclusion criteria: age \geq 18 years, a diagnosis of OHT (defined as IOP of \geq 21 mmHg with open anterior chamber angles on gonioscopy and no glaucomatous optic neuropathy) or mild POAG (characterized by glaucomatous optic neuropathy with visual field loss where the mean deviation (VF MD) is not worse than -6 decibels (dB)), absence of a prior history of intraocular surgery (except for uncomplicated cataract surgery), absence of considerable ocular comorbidities (e.g., active uveitis and advanced diabetic retinopathy), and absence of use of topical or systemic medications known to significantly affect IOP (e.g., topical steroids) for at least 4 weeks before the baseline assessment.

Exclusion criteria: Inability to provide informed consent, inability to reliably follow up for the duration of the study, considerable media opacities (e.g., corneal opacity and severe cataract) impeding accurate IOP measurement, or presence of any contraindications to SLT (e.g., uncontrolled iridocorneal angle abnormalities).

Pre-Operative Assessment

A thorough pre-operative ophthalmic evaluation was performed for all study participants. This evaluation encompassed a detailed medical and ocular history assessment (including glaucoma risk factors such as family history), best-corrected visual acuity (BCVA) testing using either a Snellen or early treatment diabetic retinopathy study (ETDRS) chart, slit-lamp biomicroscopy examination (to assess corneal clarity, anterior chamber angle configuration, and the presence of ocular pathology), IOP measurement with Goldman applanation tonometry, gonioscopy to evaluate the anterior chamber angle, central corneal thickness (CCT) measurement using pachymetry, funduscopic examination to assess the optic nerve head for glaucomatous cupping and other abnormalities, and Humphrey visual field testing (e.g., SITA-Fast 24-2) to detect glaucomatous visual field defects. All assessments were performed by experienced ophthalmologists at the institution.

Selective Laser Trabeculoplasty Procedure

SLT procedures were performed by the corresponding author, an experienced glaucoma specialist, using a standardized protocol. All procedures were performed on an outpatient basis under topical anesthesia. The process involved the following steps: application of topical anesthetic, specular gonioscopy to confirm open anterior chamber angles, and laser delivery using a single-mode Nd:YAG laser to target the trabecular meshwork (TM). The protocol included 360degree TM treatment with 100 nonoverlapping shots (25 per quadrant) using a preset 3-ns duration and 400- μ m spot size. The clinician adjusted the laser energy between 0.5 and 1.0 mJ based on observable bubble formation and the degree of TM pigmentation.

Postoperative Follow-up

Patients were followed up at one, six, and twelve months after SLT. At each follow-up visit, the following assessments were performed: IOP measurement using Goldmann applanation tonometry, slit lamp biomicroscopy to check for any postoperative complications, and evaluation of medication use, including the type and number of antiglaucoma medications.

Data Collection

Data were extracted from electronic medical records and anonymized before analysis. Statistical analysis was performed using SPSS version 29 (IBM Corp., Armonk, NY, USA).

Descriptive statistics were employed to summarize the demographic and clinical characteristics of the study population.

Primary outcome: The primary outcome measure was the mean change in IOP from baseline at one, six, and twelve months after SLT.

Secondary outcomes: Secondary outcome measures included the proportion of patients achieving target IOP (defined as IOP of <21 mmHg) at baseline and at each follow-up visit, changes in the need for antiglaucoma medications after SLT, and factors associated with a successful IOP response to SLT, analyzed using multiple linear regression.

Statistical Analysis

The Wilcoxon signed-rank test was used to compare IOP at different time points owing to the non-normal distribution of the data. The chi-square test was used to assess changes in the proportion of patients with IOP of <21 mmHg and ≥21 mmHg before and after treatment. Kaplan–Meier survival analysis, with the log-rank test, was used to evaluate the success rate over time. Multiple linear regression analysis identified factors associated with IOP reduction. All statistical analyses were performed using IBM SPSS Statistics version 29.0.0.0, with statistical significance set at P < 0.05.

Results

Table 1 demonstrates the effectiveness of SLT in reducing IOP among the Saudi Arabian population over a one-year follow-up period. The mean pre-SLT IOP was 20.57 ± 3.57 mmHg (range: 13–28 mmHg). A significant reduction in IOP was observed at all follow-up time points (P < 0.001 for all comparisons).

One month after SLT, the mean IOP decreased to 14.72 \pm 2.81 mmHg, representing a 28.4% reduction from baseline. This substantial initial decrease in IOP was largely maintained during the follow-up period. At six months, the mean IOP was 15.39 \pm 2.76 mmHg (a 25.2% reduction). At one year, it was 15.44 \pm 2.99 mmHg (a 24.9% reduction).

The slight increase in mean IOP from the one-month to six-month and one-year follow-up time points (0.67 and 0.72 mmHg, respectively) may suggest a gradual reduction in the treatment effect over time. However, the overall pressure reduction remained substantial and statistically significant during the study period (Table 1 and Figure 1).

Table 2 and figure 2 demonstrates the considerable effect of SLT on IOP control in the Saudi Arabian population over a 12-month follow-up period. Tabla 1

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Table 1. Changes in IVP after SLI in the Saudi Arabian population					
	Mean ± SD	Mean decrease compared to pre-laser IOP (%)	P-value*		
IOP pre-SLT	20.57 ± 3.57				
IOP 1 month	14.72 ± 2.81	5.85 (28.4)	< 0.001		
IOP 6 months	15.39 ± 2.76	5.18 (25.2)	< 0.001		
IOP 1 year	15.44 ± 2.99	5.13 (24.9)	< 0.001		

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*Using the Wilcoxon rank test pairwise comparisons between pre-SLT IOP and each follow-up time point.

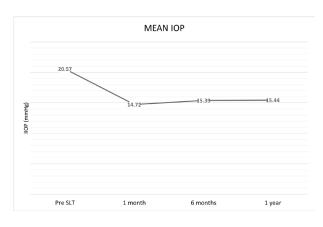


Fig. 1 Mean IOP (mmHg) at different time points.

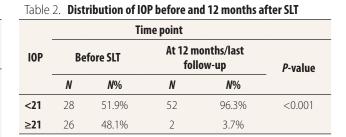
Before SLT treatment, 51.9% (28 eyes) had an IOP of <21 mmHg, while 48.1% (26 eyes) had an IOP of ≥21 mmHg. This distribution changed dramatically 12 months after SLT. At the final follow-up, 96.3% (52 eyes) had achieved an IOP of <21 mmHg, and only 3.7% (2 eyes) had an IOP of ≥21 mmHg. This shift in IOP distribution was statistically significant (P < 0.001).

These results demonstrate a substantial improvement in IOP control after SLT. The proportion of eyes with wellcontrolled IOP (<21 mmHg) nearly doubled from baseline to the 12-month follow-up, while the percentage of eyes with elevated IOP (\geq 21 mmHg) decreased considerably from 48.1% to just 3.7%.

For patients with OHT, there was a considerable improvement in IOP control. Before SLT, only 4 eyes had an IOP of <21 mmHg, while 12 eyes had an IOP of >21 mmHg. One month after SLT, 14 eyes achieved an IOP of <21 mmHg, with only 2 eyes still having an IOP of >21 mmHg. By 6 months and at 1 year, all 16 eyes maintained an IOP of <21 mmHg, indicating the sustained efficacy of SLT in this group.

In patients with mild POAG, 20 eyes had an IOP of <21 mmHg, and 8 eyes had an IOP of ≥21 mmHg before SLT. After treatment, all 28 eyes achieved an IOP of <21 mmHg at both 1 and 6 months. By 1 year, 26 eyes continued to maintain an IOP of <21 mmHg, while 2 eyes reverted to an IOP of ≥21 mmHg, indicating a high success rate with some potential for IOP increase over time.

All 4 eyes with normal tension glaucoma consistently maintained an IOP of <21 mmHg during the study period, indicating that SLT effectively preserved IOP control in these patients. For pseudoexfoliation and pigment dispersion with



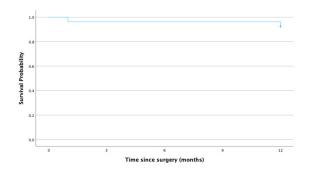


Fig. 2 Kaplan–Meier survival curve (the entire cohort).

ocular hypertension, all eyes (4 and 2, respectively) changed from an IOP of \geq 21 mmHg before SLT to an IOP of <21 mmHg at all post-SLT time points, demonstrating SLT's effectiveness in these secondary glaucomas (Table 3).

The overall success rate was 96.3% at the one-year followup. There were no statistically significant differences between the OHT and mild POAG groups (P = 0.520, log-rank test; Figure 3).

Before SLT, all 54 eyes (100%) were not using any medication, indicating that SLT was the primary treatment. At the 12-month follow-up, 40 eyes (74.1%) remained medicationfree, while 14 eyes (25.9%) required one drop of medication. This change was statistically significant (P < 0.001). These results demonstrate that SLT effectively maintained intraocular pressure control without medication in nearly three-quarters of the treated eyes at one year. However, the need to introduce medication in approximately a quarter of the eyes suggests that SLT alone may not provide sufficient long-term pressure control for all patients (Table 4).

Table 5 shows the results of a multiple linear regression analysis evaluating factors influencing IOP after SLT. Time since SLT was significantly associated with IOP reduction ($\beta = -0.430$, P < 0.001), indicating a sustained treatment effect over the follow-up period. Age exhibited a weak but significant negative association with IOP ($\beta = -0.125$, P = 0.047). Compared to OHT (reference group), mild POAG and normal tension glaucoma were significantly associated with lower IOP ($\beta = -0.325$, P < 0.001 and $\beta = -0.336$, P < 0.001, respectively). Eye laterality, gender, and secondary glaucomas (pseudoexfoliation and pigment dispersion) did not have a significant effect on post-SLT IOP.

Discussion

This study assessed the effectiveness of SLT as a primary treatment for OHT and mild POAG in the Saudi Arabian

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Table 3. Distribution of IOP by diagnosis before and after SLT								
	IOP (mmHg)							
Diagnosis	Pre-SLT		1 month		6 months		1 year	
Diagnosis	<21	≥21	<21	≥21	<21	≥21	<21	≥21
OHT	4	12	14	2	16	0	16	0
Mild POAG	20	8	28	0	28	0	26	2
Normal tension glaucoma	4	0	4	0	4	0	4	0
Pseudo exfoliation w/ OHT	0	4	4	0	4	0	4	0
Pigment dispersion w/ OHT	0	2	2	0	2	0	2	0

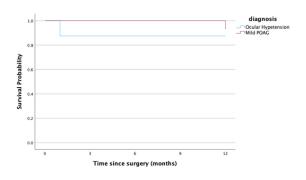


Fig. 3 Kaplan–Meier survival curve (OHT vs. glaucoma).

population. The findings provide valuable insights into SLT's efficacy and potential benefits for this specific patient group.

Efficacy of SLT in IOP Reduction

This study demonstrated a significant and sustained reduction in IOP after SLT, aligning with previous research that supports SLT's effectiveness in lowering IOP in glaucoma patients.^{10,11} A considerable strength of our study is its focus on the Saudi Arabian population because glaucoma presentations and risk factors can vary by geographic region.¹² Our results contribute to the expanding body of evidence on SLT's effectiveness across diverse populations.

However, it is important to note that some studies have reported a slightly greater reduction in IOP with SLT in patients with POAG compared to those with OHT.^{13,14} Our study had a relatively small sample size. Thus, further research with a larger cohort may be necessary to confirm this observation in the Saudi Arabian population. Future studies employing a stratified design that compare OHT and POAG groups may provide more detailed insights into the IOP-lowering effects of SLT in these subgroups.

Achievement of Target IOP

A considerable proportion of patients in our study achieved the target IOP of <21 mmHg after SLT. These results are consistent with previous studies that have reported similar success rates for SLT in reaching target IOP.^{15,16} This indicates that SLT is an effective strategy for achieving optimal pressure control in patients with OHT and mild POAG.

Table 4. Changes in medication use before and 12 months after SLT

Medication	Be	fore SLT	At 12 n fol	<i>P</i> -value	
	N	N%	N	N%	_
0 drops	54	100.0%	40	74.1%	<0.001
1 drop	0	0.0%	14	25.9%	

Table 5. Multiple linear regression analysis of factors influencing IOP after SLT

	Standardized coefficients	t Sig.		95.0% CI for B				
	Beta		-	Lower	Upper			
Time since surgery	430	-7.641	<.001	-1.852	-1.092			
Eye, OS	071	-1.268	.206	-1.396	.303			
Gender, Male	077	-1.168	.244	-1.738	.445			
Age	125	-1.997	.047	073	.000			
OHT	Reference							
Mild POAG	325	-4.762	<.001	-3.527	-1.462			
Normal tension glaucoma	336	-5.442	<.001	-6.698	-3.136			
Pseudo exfoliation w/ OHT	019	259	.796	-2.351	1.806			
Pigment dispersion w/ OHT	060	-1.017	.310	-3.554	1.135			

However, our study also highlights that not all patients achieved the target IOP. This finding aligns with other research suggesting that some patients may require additional treatment modalities, such as topical medications, for long-term management.¹⁷ Future studies examining factors associated with non-response to SLT could be essential for refining patient selection criteria and customizing treatment plans. For example, incorporating baseline IOP measurements and specific glaucoma subtypes into the analysis may help identify patients who are more likely to benefit from SLT as a primary intervention.¹⁸

Impact on Medication Use

Our study observed a decrease in the number of antiglaucoma medications required by patients after SLT. This finding is consistent with previous research showing that SLT can potentially reduce reliance on medication to control IOP.^{19,20} This is an important advantage of SLT because topical medications can have side effects and require ongoing adherence.

Factors Affecting IOP Response

Our investigation into factors associated with successful IOP response to SLT did not reveal any statistically significant relationships. Previous research indicates that baseline IOP, diagnosis type (OHT vs. POAG), and certain demographic

characteristics may affect the extent of IOP reduction achieved with SLT.^{21,22} The lack of significant findings in our study may be attributed to the small sample size. Further research with a larger cohort is needed to examine these potential associations in the Saudi context. Future studies using multivariable analysis that includes relevant demographic and clinical characteristics may offer a more comprehensive understanding of the factors influencing IOP response to SLT.

Limitations

Our study has several limitations inherent to its retrospective design. Selection bias and potential confounding variables that were not accounted for in the analysis may affect the results. Furthermore, the generalizability of our findings may be limited by the single-center design and the specific patient population studied in Saudi Arabia.

Conclusion

SLT demonstrated considerable efficacy in reducing IOP as an initial treatment for Saudi patients with OHT and mild POAG.

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The treatment achieved a sustained IOP reduction of approximately 25% over a one-year follow-up period, with 96.3% of eyes reaching an IOP of <21 mmHg at the final follow-up. SLT also decreased medication dependence, with 74.1% of eyes remaining medication-free at one year. Additionally, SLT exhibited a favorable safety profile, supporting its use as an effective and safe treatment modality for the Saudi Arabian population.

List of Abbreviations

- SLT Selective laser trabeculoplasty
- IOP Intraocular pressure
- OHT Ocular hypertension
- POAG Primary open-angle glaucoma
- MIGS Minimally invasive glaucoma surgery
- TM Trabecular meshwork

Conflict of Interest

None.

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