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Real-World Outcomes of Selective Laser Trabeculoplasty in the United Kingdom

Anthony P. Khawaja, PhD, FRCOphth,[1] Joanna H. Campbell, PhD,[2] Nicholas Kirby, BSc,[3] Hitesh S. Chandwani, MBBS, PhD,[4] Ian Keyzor, MSc,[5] Mousam Parekh, MS,[6] Andrew I. McNaught, MD,[7,8] for the UK Glaucoma Real-World Data Consortium

Purpose: Selective laser trabeculoplasty (SLT) is a common treatment option for managing glaucoma and ocular hypertension. We assessed the real-world effectiveness of SLT and baseline factors associated with treatment success in the United Kingdom.

Design: Retrospective observational study of de-identified electronic medical records (Medisoft Glaucoma module [Medisoft Ltd, Leeds, UK]) from 5 UK ophthalmology teaching centers.

Participants: Adult patients undergoing their first recorded SLT. For bilateral SLT (same day), analyses included 1 randomly selected eye.

Methods: Patient demographics, procedure details, and clinical outcomes data were extracted. Factors associated with treatment success were assessed using multivariable Cox regression.

Main Outcome Measures: Change from baseline in intraocular pressure (IOP) and glaucoma medication use at 12 to 18 and 24 to 36 months post-SLT. A Kaplan−Meier survival analysis was also conducted. Failure of SLT was defined as any further glaucoma procedure post-SLT or any of the following at 2 consecutive visits: IOP >21 mmHg, IOP reduction <20% from baseline, or increase in glaucoma medications from baseline.

Results: A total of 831 SLT-treated eyes (mean baseline IOP 22.0 mmHg) of 831 patients were analyzed. At 12 to 18 and 24 to 36 months post-SLT, respectively, significant reductions in IOP (−4.2 [95% confidence interval {CI}, −4.7 to −3.7] and −3.4 [95% CI, −4.1 to −2.7] mmHg; both $P < 0.0001$) and significant increases in the number of glaucoma medications (0.13 [95% CI, 0.04−0.23], $P = 0.007$, and 0.20 [95% CI, 0.06−0.33], $P = 0.005$) were observed. Survival analysis demonstrated treatment success in 70%, 45%, and 27% of eyes at 6, 12, and 24 months post-SLT, respectively. Higher baseline IOP was strongly associated with treatment success (hazard ratio [HR], 0.67 for baseline IOP >21 mmHg vs. ≤21 mmHg, 95% CI, 0.57−0.80; $P < 0.001$). Selective laser trabeculoplasty success was not significantly associated with age ($P = 0.78$), baseline visual field mean deviation ($P = 1.00$), or concurrent use of IOP-lowering medication ($P = 0.52$).

Conclusions: Most patients initially responded to SLT, but the majority failed within 1 year. Efficacy of SLT was better in patients with higher baseline IOP but did not differ by glaucoma severity or concurrent use of IOP-lowering medication. These findings may help inform which patients are suitable for SLT therapy. *Ophthalmology 2019;■:1−10 © 2019 by the American Academy of Ophthalmology. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).*

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Intraocular pressure (IOP) is the cardinal modifiable risk factor for glaucoma,[1] and lowering of IOP remains the only proven treatment to prevent vision loss from the disease.[2,3] Traditionally, treatment is initiated with topical medication to avoid the risks associated with incisional surgery, but patient adherence to daily medication is poor,[4] particularly among older patients and the infirm.[5] Selective laser trabeculoplasty (SLT), which selectively targets pigmented cells of the trabecular meshwork (TM) and improves aqueous outflow, is an alternative IOP-lowering procedure that has a good safety profile and does not require daily patient adherence.[6,7] The use of SLT in the management of glaucoma has been increasing over the past 2 decades, both as first-line treatment in newly diagnosed patients and as adjunctive treatment in patients requiring additional IOP lowering beyond that achieved with topical medication.[7] The Laser in Glaucoma and Ocular Hypertension (LiGHT) Trial compared initial SLT with initial topical medication for treatment-naïve patients with primary open-angle glaucoma (POAG) or ocular hypertension (OHT).[8] There was no significant difference between the groups for the primary outcome (quality of life as measured by the EuroQol-5D questionnaire). Notably, 74% of patients randomized to initial SLT remained drop-free at 36 months, suggesting SLT to be a particularly efficacious treatment in treatment-naïve patients. It is equally important to know the real-world efficacy of SLT in routine clinical care. These outcomes may differ from trial outcomes and may be more applicable to glaucoma clinics generally.

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The objective of our study was to assess the efficacy of SLT in routine clinical care of patients with glaucoma and OHT in the United Kingdom using real-world data collected by electronic medical records (EMRs). We also aimed to identify factors associated with treatment success.

Methods

Study Design and Data Source

This was an observational, multicenter, retrospective analysis involving patients who had undergone SLT at 5 participating secondary and tertiary care ophthalmology centers in the United Kingdom. It is expected that these centers manage the majority of local patients with glaucoma, as part of the National Health Service. All centers used the Medisoft Ophthalmology (Medisoft Ltd, Leeds, UK) EMR for routine clinical care. The Medisoft Ophthalmology EMR is used daily by more than 150 hospitals in the United Kingdom to record clinic visits, ophthalmic procedures, and clinical outcomes. Data are recorded within a number of specialist modules, including a glaucoma module.[9] Extracted data from the glaucoma module of the Medisoft EMRs of the participating centers were anonymized by the EMR provider, at source, before release to the investigator team. Socioeconomic status of the area where the center was located was measured using the English Index of Multiple Deprivation (IMD) 15.[10] Patient demographics, including ethnicity, were sourced from the local hospital Patient Administration System using Medisoft EMR software at each participating center.

The study was conducted in accordance with the guidelines of the European Network of Centres for Pharmacoepidemiology and Pharmacovigilance (http://www.encepp.eu/index.shtml) and the International Society for Pharmacoepidemiology (https://www.pharmacoepi.org/resources/guidelines_08027.cfm). Our study did not require institutional review board approval, and the Declaration of Helsinki does not apply given it did not directly involve human subjects, identifiable human material, or identifiable data, and as advised by the Moorfields Eye Hospital Research Management Committee.

Patient Selection Criteria

Patients who had undergone an SLT procedure were identified from the EMR data and screened for study eligibility. For study inclusion, patients were required to be ≥18 years of age at the time of their first recorded SLT (index date) and to have had at least 3 months post-SLT follow-up. In addition, patients were required to have had a baseline IOP assessment within 180 days before the index event and at least 2 IOP assessments post-SLT. We required IOP measurements to be Goldmann applanation tonometry. We considered the first recorded SLT procedure for patients undergoing multiple SLT procedures as index and included 1 eye per patient. For patients undergoing SLT on both eyes on the same day, the study eye was selected at random using Stata version 15.1 (StataCorp LP, College Station, TX).

Outcome Measures

Our primary outcomes were change in IOP and number of glaucoma medications and treatment success survival. Given the real-world nature of the data, IOP assessments were not taken at specific time points. Therefore, to examine changes in IOP and medication use, we used time windows. Baseline IOP was defined as the last IOP measurement before SLT. The main outcome time windows were at 12 to 18 months and 24 to 36 months post-SLT; we considered the most recent assessment if the patient had multiple assessments in the time window. To minimize bias, rather than excluding eyes that underwent a post-SLT glaucoma procedure before the outcome time window (which would result in differentially excluding eyes that did not respond sufficiently to SLT), we carried forward the last IOP measurement before the glaucoma procedure and considered this value as the time window IOP value. We similarly carried forward the number of glaucoma medications being used at the last time point before the glaucoma procedure. In a sensitivity analysis, we examined change in IOP and change in number of medications after exclusion of eyes undergoing a post-SLT procedure. Given that not all participants had an assessment in the post-SLT time windows, analyses comparing 12- to 18-month and 24- to 36-month measurements with baseline are on subsets of patients with data available.

We also conducted a survival analysis. We defined SLT treatment failure as 1 or more of the following: (1) the need for a subsequent glaucoma procedure, including repeat SLT; (2) on any 2 consecutive visits: IOP >21 mmHg or IOP reduction <20% from baseline; or (3) on any 2 consecutive visits, an increase from baseline in the number of glaucoma medications. In the event of an additional glaucoma procedure being performed post-SLT, patients were censored at this time point in the survival analysis.

Secondary outcomes of interest included changes in visual field and visual acuity and the use of additional glaucoma procedures post-SLT. Visual field mean deviation (MD) was automatically extracted from Humphrey Field Analyzers into the Medisoft Ophthalmology EMR at each center and change in MD was calculated by comparing the last visual field before SLT with the last visual field (if done) in the respective time window.

Statistical Analysis

Summary statistics (means, standard deviations, and 95% confidence intervals [CIs]) were presented for continuous variables and frequencies and percentages for categoric variables. Intergroup comparisons were performed using the chi-square test and Student *t* test. We conducted a Kaplan−Meier survival analysis and used univariable and multivariable Cox regression to examine the associations between study variables (i.e., age, sex, diagnosis, grade of clinician performing the SLT procedure, pre-SLT IOP, and pre-SLT use of glaucoma medication) and treatment success. Those variables showing an association with treatment success in a univariable regression model with $P < 0.2$ were carried forward together into a multivariable model. Data were analyzed using Stata version 15.1 (StataCorp LP, College Station, TX).

Results

Study Sample and Baseline Characteristics

A total of 831 patients (831 study eyes) undergoing SLT between October 2011 and March 2017 met the study eligibility criteria. The mean duration of patient follow-up was 19.4 months (range, 3−67 months). Baseline demographic and clinical characteristics are presented in Table 1. The mean age of the study population was 70.7 years, and 48.5% were women. Most patients were treated by a staff-grade ophthalmologist (43%), followed by consultant grade (29%) and trainee grade (28%). Overall, 37% (n = 307/831) of study eyes were recorded as receiving no glaucoma medication at the time of index SLT, and the majority of patients (57%) underwent bilateral SLT on the index day. At baseline, before SLT, the mean IOP (treated or untreated) was 22.0 (standard deviation, 5.8) mmHg (Table 1). Eyes undergoing index SLT without concurrent glaucoma medication (n = 307) had significantly higher baseline

IOP than corresponding eyes with concurrent medication (n = 524) (mean 23.9 vs. 20.9 mmHg, $P < 0.001$) but showed significantly less visual field loss (mean MD −4.8 vs. −7.3 decibels [dB], $P < 0.001$).

Change in Intraocular Pressure

There were 439 eyes with IOP measurement data available in the 12- to 18-month time window and 243 eyes with IOP measurement data available in the 24- to 36-month time window; change in IOP and number of glaucoma medication analyses were based on these subsets of patients. The mean reduction in IOP from baseline was 4.2 mmHg (95% CI, 3.7−4.7) at 12 to 18 months and 3.4 mmHg (95% CI, 2.7−4.1) at 24 to 36 months (both $P < 0.00001$; Table 2). For most of these study eyes, IOP was lower at 12 to 18 months (n=351/439, 80.0%) and 24 to 36 months (n=166/243, 68.3%) post-SLT than at baseline (Fig 1). Fewer eyes had a 20% reduction in IOP at follow-up (48% at 12−18 months and 42% at 24−36 months; Fig 1). Significant ($P < 0.0001$) reductions in IOP were observed at 12 to 18 and 24 to 36 months post-SLT, both in patients without concurrent glaucoma medication at the time of SLT (mean change −5.3 and −4.7 mmHg, respectively) and in patients with concurrent glaucoma medication (mean change −3.4 and −2.4 mmHg, respectively). There was an approximate 4-fold reduction in the number of patients with an IOP >21 mmHg after 12 to 18 months (reduced from 48.5% to 10.7%) and 24 to 36 months (reduced from 47.7% to 12.8%) post-SLT compared with baseline (Table 2). In the sensitivity analysis excluding eyes that underwent a post-SLT glaucoma procedure (rather than carrying forward the last IOP measurement before the additional procedure), the magnitude of IOP lowering was 4.7 mmHg and 4.5 mmHg at the 12- to 18-month and 24- to 36-month time windows, respectively (Tables S1 and S2, available at www.aaojournal.org).

Change in Glaucoma Medication Use

There was a significant increase from baseline in the mean number of glaucoma medications received per eye of 0.13 (95% CI, 0.04−0.23; $P = 0.007$) at 12 to 18 months and 0.20 (95% CI, 0.06−0.33; $P = 0.005$) at 24 to 36 months (Table 2). The number of patients receiving ≥1 glaucoma medications increased from 268 (61.0%) pre-SLT to 285 (64.9%) at 12 to 18 months post-SLT and from 138 (56.8%) pre-SLT to 147 (60.5%) at 24 to 36 months post-SLT (Fig 2). Of the 439 patients with data available for the 12- to 18-month time window, 82 (19%) had a reduction in medications, 101 (23%) had an increase in number of medications, and 256 (58%) had no change in the number of medications. Of the 243 patients with data available for the 24- to 36-month time window, 39 (16%) had a reduction in medications, 68 (28%) had an increase in number of medications, and 136 (56%) had no change in the number of medications. In the sensitivity analysis excluding eyes that underwent a post-SLT glaucoma procedure, the increase in glaucoma medications was 0.15 and 0.28 at the 12- to 18-month and 24- to 36-month time windows, respectively (Tables S3 and S4, available at www.aaojournal.org).

Glaucoma Procedures Post-Selective Laser Trabeculoplasty

For the subsets of study eyes with IOP readings at baseline and 12 to 18 months (n = 439) or 24 to 36 months (n = 243) post-SLT, 53 (12.1%) and 63 (25.9%) underwent a post-SLT glaucoma procedure before the follow-up time window, respectively. The most commonly performed glaucoma procedures post-SLT were repeat SLT, trabeculectomy, and viscocanulostomy (Table 2).

Visual Field and Visual Acuity

For those patients with visual field data available at both baseline and 12 to 18 months (n = 132) or 24 to 36 months (n = 71) post-SLT, significant deterioration was evident at both time windows, as reflected in mean MD changes from baseline of −0.46 dB (95% CI, −0.84 to −0.08; $P = 0.018$) and −1.07 dB (95% CI, −1.71 to −0.43; $P = 0.0013$), respectively (Table 2). The pre-SLT versus post-SLT distribution of MD values for individual patients is shown in Figure 3. Also, a small but statistically significant deterioration in visual acuity was observed among patients with available visual acuity data at both baseline and 12 to 18 months (n = 378) or 24 to 36 months (n = 205) post-SLT, with mean changes from baseline of +0.02 logarithm of the minimum angle of resolution (95% CI, 0.00−0.04; $P = 0.043$) and +0.04 logarithm of the minimum angle of resolution (95% CI, 0.01−0.07; $P = 0.013$), respectively (Table 2).

Survival Analysis

All 831 study eyes were included in the survival analysis. A Kaplan−Meier survival graph of SLT treatment success is shown in Figure 4. The estimated probability of treatment success was 70% at 6 months, declining to 45%, 34%, 27%, and 18% at 12, 18, 24, and 36 months post-SLT, respectively (Fig 4). For all eyes that failed SLT before last follow-up assessment (n = 550), the reasons for failure that were evident on the date of failure were as follows: further glaucoma procedure required (n = 43, 8%), IOP >21 mmHg (n = 153, 28%), IOP reduction <20% (n = 403, 73%), and increase in number of medications (n = 139, 25%). Given that patients may have satisfied more than 1 failure criterion on the failure date, the percentages add up to greater than 100.

Univariable associations with treatment failure are presented in Table 3. Higher baseline (pre-SLT) IOP was strongly associated with treatment success ($P < 0.001$); every 1 mmHg increase in baseline IOP was associated with a 3% reduction in risk of treatment failure. Also, considering dichotomized pre-SLT IOP, eyes with baseline IOP >21 mmHg were at 32% lower risk of treatment failure than eyes with baseline IOP ≤21 mmHg (Table 3). Failure of SLT was less likely with a trainee grade compared with a consultant grade (hazard ratio [HR], 0.75; 95% CI, 0.60−0.94; $P = 0.013$). There were no significant associations of treatment success with age, sex, ethnicity, IMD score, number of glaucoma medications at time of SLT, baseline visual field MD, or diagnosis.

Table 4 presents the multivariable adjusted associations with SLT treatment success. Higher pre-SLT IOP remained strongly and highly significantly associated with a lower risk of treatment failure (HR, 0.96 per mmHg; 95% CI, 0.95−0.98; $P < 0.001$). A trainee grade compared with consultant grade performing the SLT was still associated with a reduced risk of failure (HR, 0.73; 95% CI, 0.58−0.91; $P = 0.005$). The association between sex and treatment failure was not statistically significant ($P = 0.21$). We also created a multivariable model containing sex, grade, and dichotomized pre-SLT IOP rather than pre-SLT IOP as a continuous trait. A pre-SLT IOP >21 mmHg was associated with a 33% reduced risk of failure (HR, 0.67; 95% CI, 0.57−0.80; $P < 0.001$).

Analysis of Prostaglandin Analogue Users

Of the 524 patients using IOP-lowering medication at baseline, 449 (86%) were using a prostaglandin analogue (PGA). There was no crude association of PGA use with SLT failure when compared with the 75 patients using any other IOP-lowering medication (HR, 0.95; 95% CI, 0.70−1.30; $P = 0.76$) or all the 382 patients not using PGAs (HR, 0.95; 95% CI, 0.8−1.12; $P = 0.56$). Likewise,

Table 1. Baseline Demographic, Clinical, and Procedure Characteristics for 831 Patient Eyes Undergoing Selective Laser Trabeculoplasty

Characteristics	All Patients (n=831)*
Demographics	
Age at time of SLT, mean ± SD (range), y	70.7±12.2 (20−94)
Women, n (%)	403 (48.5)
Ethnicity, n (%)	
White	606 (73)
Black	6 (1)
Asian	8 (1)
Not stated	211 (25)
Index of multiple deprivation ± SD (range)	23.8±17.9 (1.7−78.8)
Clinical characteristics	
Diagnosis in study eye, n (%)	
POAG	482 (58.0)
OHT	125 (15.0)
Normal-tension glaucoma	56 (6.7)
Glaucoma suspect	45 (5.4)
Other	106 (12.8)
Not recorded	17 (2.0)
Pre-SLT treatment status, n (%)	
Study eyes receiving no glaucoma medication	307 (36.9)
Study eyes receiving ≥1 glaucoma medication	524 (63.1)
No. of pre-SLT medications per patient, mean ± SD (range)	1.3±1.2 (0 − 4)
IOP mean ± SD, mmHg	
All patients	22.0±5.8
Patients with 0 glaucoma medication pre-SLT	23.9±5.7 (n=307)
Patients with ≥1 glaucoma medication pre-SLT	20.9±5.5 (n=524)
Cup-to-disc ratio, mean ± SD	0.66±0.20 (n=704)
Visual field MD, mean ± SD, dB	−4.87±6.11 (n=736)
>−6 dB, n (%)	534 (73)
−6 to −12 dB, n (%)	125 (17)
<−12 dB, n (%)	77 (10)
Index SLT parameters	
Grade of clinician performing SLT, n (%)	
Associate specialist/staff grade	356 (43)
Consultant	240 (29)
Trainee	235 (28)
Bilateral SLT on index date, n (%)	477 (57.4)
No. of laser shots, mean	98.3±13.6
Degrees treated, n (%)	
360	798 (96)
180, 90, or 60	17 (2)
Not reported	16 (2)
Lens used, n (%)	
Latina	773 (93.0)
Goldmann (1 or 2 mirrors)	56 (6.7)
Other	2 (0.2)

dB = decibels; IOP = intraocular pressure; MD = mean deviation; OHT = ocular hypertension; POAG = primary open-angle glaucoma; SD = standard deviation; SLT = selective laser trabeculoplasty.
*Unless otherwise specified.

when adjusted for sex, grade, and baseline IOP, there was no association of PGA use with SLT failure when compared with the patients using any other IOP-lowering medication (HR, 0.90; 95% CI, 0.67−1.23; $P = 0.53$) or all the patients not using PGAs (HR, 0.88; 95% CI, 0.74−1.05; $P = 0.16$). We also compared IOP lowering between the 237 patients using PGAs and the 202 patients not using PGAs who had data available for the 12- to 18-month time window (total n = 439). The absolute IOP reduction was less in the PGA group (3.6 mmHg; 95% CI, 2.9−4.2; $P < 0.0001$) compared with the non-PGA group (4.9 mmHg; 95% CI, 4.2−5.6; $P < 0.0001$). However, although this crude difference was statistically significant ($P = 0.008$), there was no significant difference after adjusting for pre-SLT IOP ($P = 0.81$).

Analysis of Patients Undergoing Bilateral Selective Laser Trabeculoplasty

Of the 477 patients undergoing bilateral SLT on the same day, 130 had SLT success in both eyes at last follow-up, 244 had failed SLT in both eyes during follow-up, and 103 had success in 1 eye at last follow-up but failed in the other eye (Table 5). Failure in a patient's left eye was strongly associated with failure in the right eye and vice versa (odd ratio, 14.6; 95% CI, 9.4−22.7; $P < 0.001$).

Discussion

Our study represents one of the largest to date examining the IOP-lowering efficacy of SLT in the management of glaucoma and OHT. In this real-world UK glaucoma clinic patient population, the majority of eyes responded to SLT treatment initially (70% success at 6 months), but the majority had failed treatment by 2 years (27% success at 24 months) because of an inadequate reduction in IOP (>21 mmHg or <20% reduction) or an increase in the number of glaucoma medications or by undergoing a subsequent glaucoma procedure. Failure of SLT in 1 eye was strongly associated with failure in the fellow eye of patients. The reductions in IOP we observed of 4 mmHg at 12 to 18 months and 3 mmHg at 24 to 36 months were in the context of an average increase in the number of glaucoma medications. Separating out the IOP-lowering effect of SLT alone from the effects of concurrent medication is not possible in a real-world study and is realistically only possible in prospective studies if designed to avoid medication use or by implementing medication washout periods. Additionally, because there was no untreated comparator group, it is not possible to determine if the increase in IOP over time after the initial reduction post-SLT is due to a waning in SLT effect or an increase in IOP secondary to ongoing pathological processes unrelated to SLT.

Although there is considerable variation in the reported IOP-lowering efficacy of SLT, our results are in keeping with the general reported pattern of the majority of eyes demonstrating an initial response with a gradual decline in efficacy over time.[6] Our finding of 70% treatment success at 6 months is in agreement with previous studies, which reported similar success at 6 months (75%,[11] 73%,[12] and 67%[13]). Although other studies have reported higher SLT success rates at 24 months (53%[14] and 40%[15]) than for our study (27%), the definitions of success in these studies were less stringent. For example, these studies did not consider an increase of topical medication as a failure[14,15] and excluded participants requiring a further glaucoma procedure,[14] which can bias toward more successful results (assuming patients going on to have a glaucoma procedure were less likely to have had a successful SLT).

Table 2. Intraocular Pressure, Glaucoma Medication Use, Glaucoma Procedures, Visual Field, and Visual Acuity Outcomes at 12−18 and 24−36 Months after Selective Laser Trabeculoplasty

	Patients with Follow-up Assessment at Months 12−18	Patients with Follow-up Assessment at Months 24−36
IOP	n=439*	n=243†
IOP, mmHg, mean ± SD (95% CI)		
Pre-SLT (baseline)	21.5±5.3 (21.0−22.0)	21.3±5.3 (20.7−22.0)
Post-SLT	17.3±4.7 (16.9−17.8)	17.9±4.8 (17.3−18.5)
Change from baseline	−4.2±5.2 (−4.7 to −3.7) [$P < 0.0001$]	−3.4±5.7 (−4.1 to −2.7) [$P < 0.0001$]
Patients with IOP >21 mmHg, n (%)		
Pre-SLT	213 (48.5)	116 (47.7)
Post-SLT	47 (10.7)	31 (12.8)
Glaucoma medication use	n=439*	n=243†
No. of glaucoma medications used‡ mean ± SD (95% CI)		
Pre-SLT (baseline)	1.21±1.17 (1.10−1.32)	1.07±1.13 (0.93−1.22)
Post-SLT	1.34±1.21 (1.23−1.46)	1.27±1.22 (1.12−1.43)
Change from baseline	+0.13±1.04 (0.04−0.23) [$P = 0.007$]	+0.20±1.1 (0.06−0.33) [$P = 0.005$]
Additional glaucoma procedures		
All procedures, No. patients (% of total)	53 (100)	63 (100)
Repeat SLT	18 (34.0)	23 (36.5)
Trabeculectomy	12 (22.6)	17 (27.0)
Viscocanulostomy	10 (18.9)	14 (22.2)
XEN gel stent (Allergan, Dublin, Ireland)	9 (17.0)	3 (4.8)
Deep sclerectomy with spacer	3 (5.7)	2 (3.2)
iStent trabecular micro-bypass implant (Glaukos, San Clemente, CA)	–	4 (6.4)
Cyclodiode	1 (1.9)	–
Visual field	n=132	n=71
MD, dB mean ± SD (95% CI)		
Pre-SLT (baseline)	−6.22±6.43 (−7.33 to −5.11)	−5.53±5.83 (−6.91 to −4.15)
Post-SLT	−6.68±6.86 (−7.86 to −5.50)	−6.60±6.11 (−8.05 to −5.15)
Change from baseline	−0.46±2.21 (−0.84 to −0.08) [$P = 0.018$]	−1.07±2.69 (−1.71 to −0.43) [$P = 0.0013$]
Visual acuity	n=378	n=205
logMAR mean ± SD (95% CI)		
Pre-SLT (baseline)	0.15±0.22 (0.13−0.17)	0.13±0.18 (0.11−0.16)
Post-SLT	0.17±0.23 (0.15−0.19)	0.17±0.25 (0.14−0.21)
Change from baseline	+0.02±0.17 (0.00−0.04) [$P = 0.043$]	+0.04±0.23 (0.01−0.07) [$P = 0.013$]

CI = confidence interval; dB = decibels; IOP = intraocular pressure; logMAR = logarithm of the minimum angle of resolution; MD = mean deviation; SD = standard deviation; SLT = selective laser trabeculoplasty.
*Includes 53 patients who had a post-SLT procedure (repeat SLT or other); IOP values and number of glaucoma medications for those patients were carried forward from the last assessment before the procedure.
†Includes 63 patients who had a post-SLT procedure (repeat SLT or other); IOP values and number of glaucoma medications for those patients were carried forward from the last assessment before the procedure.
‡Fixed combinations were counted as 2 medications.

Despite the mean reduction in IOP after SLT, significant deterioration in visual field MD was evident at 12 to 18 months and 24 to 36 months post-SLT (mean changes of ∼−0.5 and −1 dB, respectively). This is consistent with the observation that even patients with treated glaucoma progress and the effect of treatment is often to slow progression rather than completely halt it.[3,16] We are not able to infer whether SLT-treated eyes have a different rate of progression than eyes receiving other glaucoma treatments in our study, because we did not have a comparator group.

The major baseline factor associated with SLT treatment success in our study was pre-SLT IOP. This association was strong and apparent whether pre-SLT was considered as a continuous variable or dichotomized at a threshold of 21 mmHg. Patients with a pre-SLT IOP of greater than 21 mmHg were 33% more likely to have successful treatment. This finding is in keeping with previous studies that have examined factors predicting SLT success.[13,17-19] It is unlikely that this association is simply due to the statistical fact that a larger absolute reduction may be possible with a higher starting IOP; our reduction criterion was relative (percentage reduction) rather than absolute. Furthermore, the failure criterion of IOP >21 mmHg may bias against success in patients with pre-SLT IOP >21 mmHg (a patient with pre-SLT IOP <21 mmHg is less likely to fail because of this criterion). It is more likely the association we observed is due to the mechanism of action of SLT. Selective laser trabeculoplasty targets the TM, improving aqueous outflow.[20,21] However, overall aqueous outflow will remain limited by resistance of the post-TM pathway, including Schlemm's canal, collector channels, and episcleral venous pressure.[22,23] Therefore, regardless of how

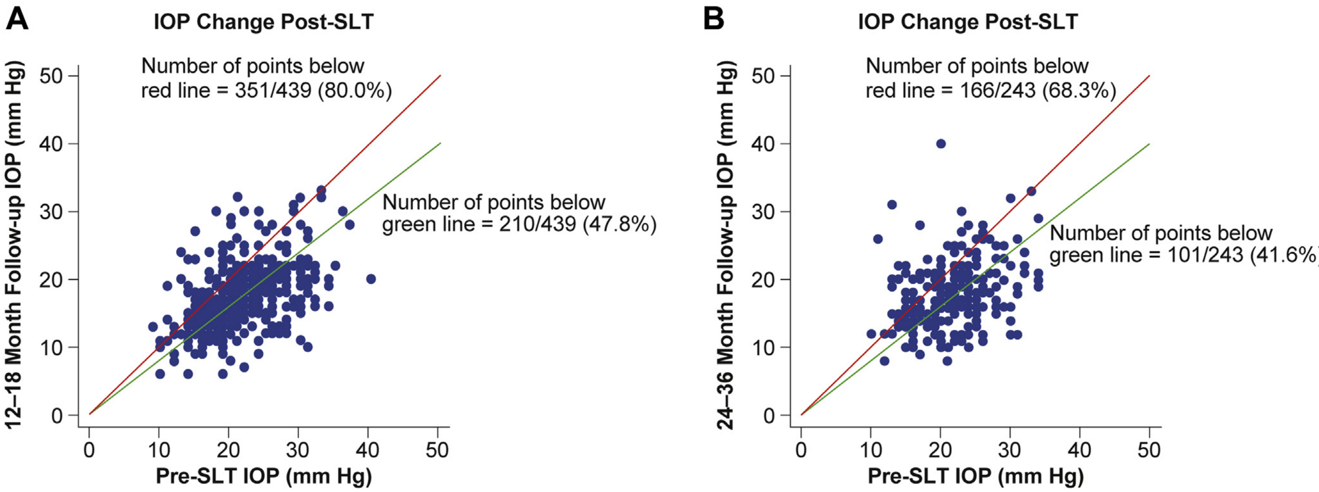

Figure 1. Scatterplot of intraocular pressure (IOP) pre-selective laser trabeculoplasty (SLT) and at 12–18 months **(A)** and 24–36 months **(B)** post-SLT. The red line (x=y) represents no change in IOP, and the green line represents a 20% reduction in IOP. For patients with a post-SLT procedure before the time window, the last IOP reading before the procedure was carried forward.

successful SLT is at improving flow through TM, there will be a floor effect to IOP lowering determined by the post-TM pathway.

We did not find an association between concurrent glaucoma medication use at the time of SLT and treatment success or between PGA use specifically and SLT success. This is in agreement with most previous reports,[13,24] although one study has reported reduced efficacy of SLT in eyes previously treated with PGAs.[25] Of note, a study of 33 Chinese patients with POAG found increased efficacy of SLT in patients using more topical medications;[26] this may be a chance finding given the small sample size. Our study is strongly powered for examining the association of concurrent glaucoma medications with treatment success and suggests that SLT is a reasonable treatment option even in patients already using drop therapy.

We found that SLT was more efficacious if carried out by a trainee grade compared with a consultant grade. This is counterintuitive given we might expect a more experienced laser operator to achieve more successful results. The better outcome observed in trainee-performed SLT was not due to these patients having a higher pre-SLT IOP; in fact, pre-SLT IOP was 1.5 mmHg lower in the trainee group compared with the consultant group (95% CI, 0.5–2.5; $P = 0.004$). It is possible this association is due to confounding rather than to any true effect of the grade of laser operator. For example, patients who were deemed at higher risk of treatment failure may have been allocated for a consultant-performed SLT, and it is their higher baseline risk rather than the grade of operator that led to the increased risk of failure. Certainly, our data do not suggest an increased chance of success with more experienced laser operators, and this is in keeping with a study of resident-performed SLT in the United States that

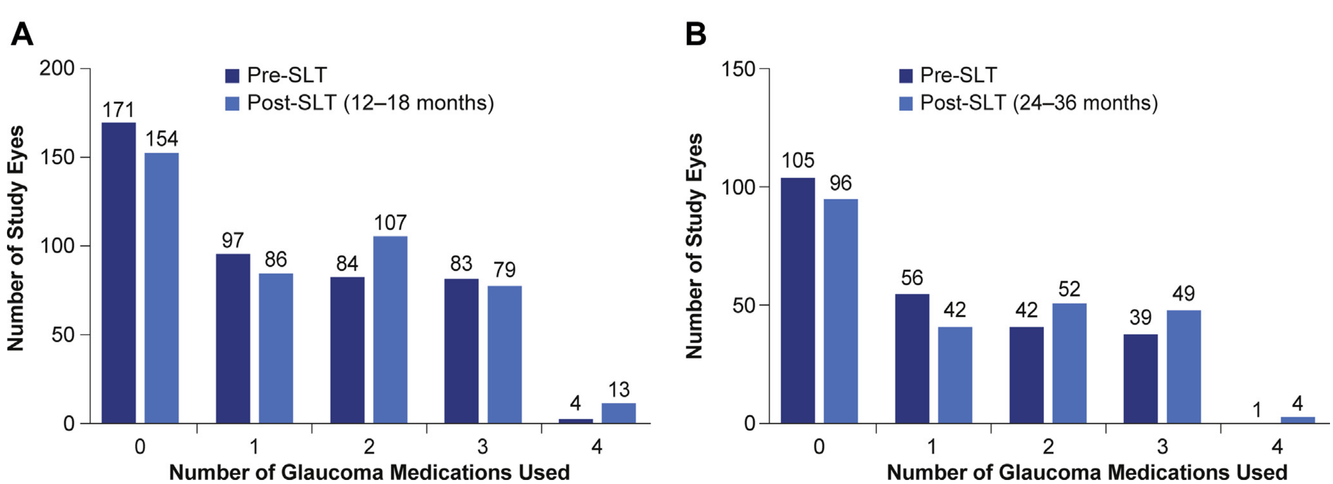

Figure 2. Frequency distribution of number of glaucoma medications used pre-selective laser trabeculoplasty (SLT) and at 12–18 months **(A)** and 24–36 months **(B)** post-SLT.

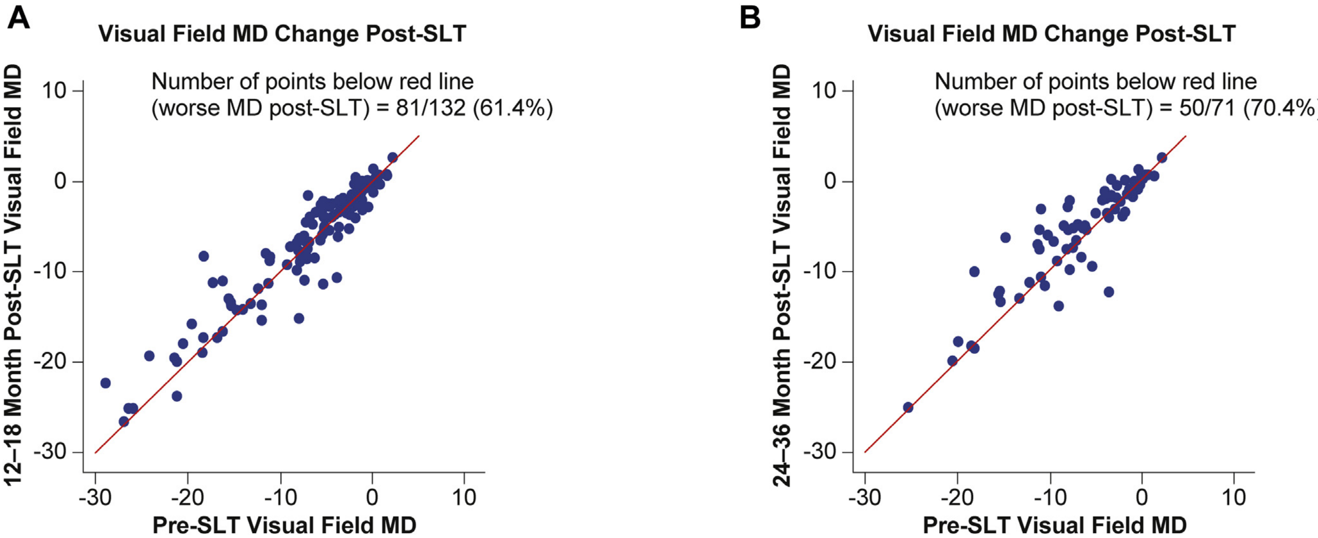

Figure 3. Visual field mean deviation (MD) pre-selective laser trabeculoplasty (SLT) and at 12–18 months **(A)** and 24–36 months **(B)** post-SLT. Anything below the red line indicates a worsening of the visual field MD post-SLT compared with pre-SLT.

reported IOP-lowering efficacy similar to that in the existing literature.[19]

We found no significant association between SLT success and age, sex, ethnicity, IMD, baseline visual field MD, or diagnosis. The study was underpowered to detect an association with ethnicity given the small proportion of nonwhite patients in our study. It is possible that SLT is more effective in nonwhite patients with more pigmented TMs. This is supported by the West Indies Glaucoma Laser Study, which reported treatment success at 12 months of 78%.[27] Unfortunately, there was an inadequate number of black patients in our study to conduct a stratified analysis. Likewise, our study was underpowered to look for differential success rates across diagnosis, because the majority of patients in our study had POAG. We were also unable to examine the association of SLT success with degrees of TM treated or the total number of laser shots, because these parameters were remarkably consistent across all contributing centers. The majority of lasers were 100 shots over 360° of TM.

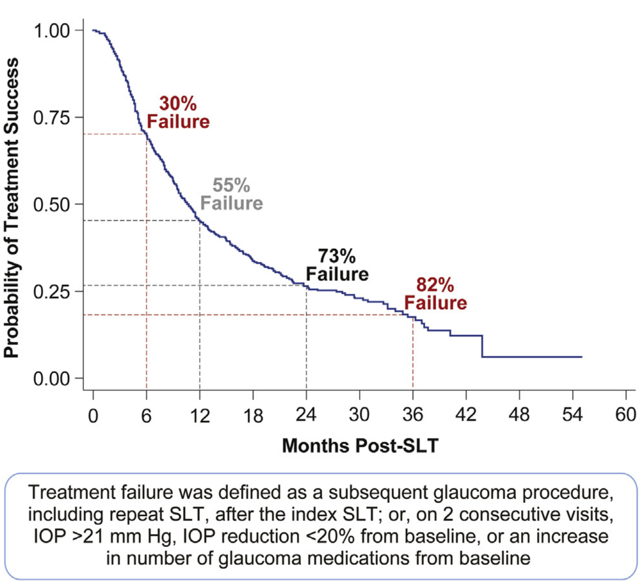

Figure 4. Kaplan–Meier graph of probability of treatment success with selective laser trabeculoplasty (SLT) over time. IOP = intraocular pressure.

Of interest are the characteristics of patients undergoing SLT in UK glaucoma teaching centers. Selective laser trabeculoplasty was not reserved for mild glaucoma only; more than 25% of eyes had a visual field MD worse than −6 dB. Notably, as detailed previously, we did not find baseline visual field MD to be a predictor of SLT success. We also observed that SLT is being used both early and late in the treatment pathway of patients with glaucoma, as evidenced by the spread of the number of topical medications patients were using. Treatment was not limited to open-angle disease, with approximately 5% of patients having a recorded diagnosis of angle-closure disease. It is presumed that these patients had open drainage angles at the time of SLT after treatment for angle-closure; SLT has been shown to be an effective treatment in such patients.[28,29]

Evidence from 2 meta-analyses suggests the IOP-lowering efficacy of SLT is equivalent to that of topical medication;[30,31] most contributing studies to the meta-analyses considered prostaglandin monotherapy, although 2 studies did permit multiple medications.[32,33] Our results are broadly in agreement because the mean reduction in IOP observed 24 months post-SLT of 3.4 mmHg is similar to the mean IOP reduction of 3.8 mmHg observed in the latanoprost-treated arm of the UK Glaucoma Treatment Study.[3] However, the reduction we observed post-SLT was in the context of an increase in the number of glaucoma medications; this might mean the reduction due to SLT alone was smaller than 3.4 mmHg.

Although the LiGHT trial[8] has not specifically reported longer-term IOP-lowering efficacy after SLT as yet (the IOP reduction at 2 months follow-up has recently been

Table 3. Univariable Associations with Failure of Selective Laser Trabeculoplasty Treatment

	Hazard Ratio	LCI	UCI	*P* Value
Age (per year)	1.00	0.99	1.01	0.78
Sex				
Women	Reference			
Men	0.89	0.75	1.05	0.18
Ethnicity				
White	Reference			
Black	0.99	0.37	2.65	0.97
Asian	1.81	0.81	4.05	0.15
Not stated	1.14	0.94	1.38	0.17
Index of multiple deprivation (per unit)	0.99	0.99	1.00	0.76
No. of glaucoma medications at time of SLT				
≥1 medication(s)	Reference			
No medication	1.06	0.89	1.26	0.52
Baseline visual field MD (per dB)	1.00	0.99	1.01	1.00
Grade of ophthalmologist				
Consultant	Reference			
Staff grade	0.88	0.72	1.07	0.20
Trainee	0.75	0.60	0.94	**0.013**
Baseline IOP (per mmHg)	0.97	0.95	0.98	**<0.001**
Baseline OHT				
Pre-SLT IOP ≤21 mmHg	Reference			
Pre-SLT IOP >21 mmHg	0.68	0.57	0.80	**<0.001**
Diagnosis				
POAG	Reference			
OHT	0.96	0.75	1.22	0.72
Normal-tension glaucoma	0.97	0.69	1.35	0.85
Glaucoma suspect	0.91	0.62	1.34	0.63
Angle-closure disease	1.10	0.77	1.59	0.60
Pigment dispersion syndrome and glaucoma	0.97	0.57	1.66	0.91
Exfoliation syndrome and glaucoma	1.41	0.79	2.52	0.24
Other	1.05	0.58	1.92	0.87

dB = decibels; IOP = intraocular pressure; LCI = lower confidence interval; MD = mean deviation; OHT = ocular hypertension; POAG = primary open-angle glaucoma; SLT = selective laser trabeculoplasty; UCI = upper confidence interval.
P values less than 0.05 appear in boldface.

Table 4. Multivariable Associations with Failure of Selective Laser Trabeculoplasty Treatment

	Hazard Ratio	LCI	UCI	*P* Value
Sex				
Male	0.90	0.76	1.06	0.21
Grade				
Consultant	Reference			
Associate specialist/staff grade	0.89	0.73	1.09	0.25
Trainee	0.73	0.58	0.91	**0.005**
Baseline IOP (per mmHg)	0.96	0.95	0.98	**<0.001**

IOP = intraocular pressure; LCI = lower confidence interval; UCI = upper confidence interval.
P values less than 0.05 appear in boldface.

reported),[34] the finding that the majority of SLT patients were drop-free at 36 months suggests superior efficacy than found in our study and other reports.[14,15,35] There are several possible reasons for the potential discrepancy in SLT efficacy between LiGHT and our study. First, the LiGHT trial population was significantly different from our real-world population. For example, patients with active ocular comorbidities were excluded from LiGHT, whereas our study population represents all SLT patients with available data at 5 glaucoma centers. Additionally, LiGHT trial patients were treatment-naïve, whereas the majority of patients in our study cohort were using glaucoma medication at the time of SLT. However, we did not find superior SLT success in patients not using glaucoma medication at the time of SLT (Table 3). Second, the mean baseline IOP in LiGHT was 24.5 mmHg compared with 22.0 mmHg in our study. Given how strongly baseline IOP affects SLT success, this will likely cause differential success rates between the studies. Third, it is possible that SLT carried out in a trial is more effective than SLT carried out in routine clinical care, in part due to the effect of known observation and assessment. Fourth, we remain uncertain of the IOP-lowering efficacy of SLT in LiGHT because this has not been specifically reported. Although the 74% of patients undergoing SLT who were drop-free at 36 months were at "target IOP," this may not represent a 20% reduction in IOP. The LiGHT study protocol enabled target IOP to be increased if there was no evidence of deterioration. Given that more than 80% of eyes had OHT or mild POAG, it is possible that many eyes did not measurably progress and had target IOPs revised to be less stringent than a 20% reduction. Supporting the potential low rate of detectable deterioration is that 75% of the placebo arm in the UK Glaucoma Treatment Study did not measurably progress in 24 months, despite no active treatment.[3] This issue was highlighted in the editorial accompanying the LiGHT trial report,[36] and this stated that the authors plan to publish the rates of revised target IOP in future studies.

Study Strengths and Limitations

Strengths of our study include the large sample size and real-world nature of the data. In contrast to a prospective trial or selected case series, our study examined all SLT procedures captured using routinely collected EMR data at 5 centers across the United Kingdom; this may make our results more generalizable to patients in glaucoma clinics in the United Kingdom. However, limitations of our study

Table 5. Selective Laser Trabeculoplasty Failure Status for Right and Left Eyes of the 477 Patients Undergoing Bilateral Selective Laser Trabeculoplasty on the Same Day

	Right Eye SLT Failure	
	No	*Yes*
Left eye SLT failure		
No	130	43
Yes	60	244

SLT = selective laser trabeculoplasty.

include those inherent to analyses of EMRs, such as incomplete or incorrect data entry. For example, we assumed a patient was not using glaucoma medication if none was recorded, but this may have simply been a documentation error. Also, post-SLT assessments were not at regular time points for all patients, and this meant that assessments at the 12- to 18-month and 24- to 36-month time windows were only for subsets of the full cohort. Compared with a well-designed prospective study, our study is more susceptible to bias. For example, clinicians measuring IOP were probably not masked to the fact that the patient had undergone SLT, and this may have affected measurement readings. Bias arising from knowledge of prior SLT treatment might tend in the direction of an apparent enhanced response to the laser treatment, although may bias toward failure at later follow-up if the clinician is aware of the time after SLT and believes SLT has only a limited duration of effect. Selection bias may be an issue if our 5 study centers are not representative of the UK population and if these centers have different patient populations, treatment practices, and outcomes than other centers in general. Our patient population was mostly white, and thus our results may not be generalizable to nonwhite patients. Unmeasured or residual confounding is always a potential issue in observational studies. For example, as discussed previously, the better outcome we observed with SLT carried out by a trainee may be confounded by baseline risk of failure, which influenced selection of the grade of operator. Another limitation of our study was that post-SLT anti-inflammatory medications were not routinely recorded in the EMR glaucoma module and could not be accounted for in our analysis. Recently reported findings from the Steroids after Laser Trabeculoplasty trial suggest that IOP reduction is better in eyes treated with topical nonsteroidal anti-inflammatory drug or steroid therapy compared with placebo.[37] Additionally, we were unable to determine if a patient had received prior glaucoma therapy, including SLT, at another center before moving their care to one of our study centers.

In conclusion, in this real-world setting, the majority of eyes responded initially to SLT, but approximately three quarters of eyes failed treatment within 2 years post-SLT. Many patients required increased glaucoma medication or a subsequent glaucoma procedure after SLT. A major factor associated with treatment success was higher pre-SLT IOP, and this likely reflects the floor effect of the IOP lowering achieved with SLT. This suggests that SLT is a better treatment option for patients with OHT or high-tension POAG than for patients with normal-tension glaucoma.

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[1] NIHR Biomedical Research Centre for Ophthalmology, Moorfields Eye Hospital and University College London, London, United Kingdom.

[2] Allergan plc, Irvine, California.

[3] Medisoft Limited, Leeds, United Kingdom.

[4] Allergan Singapore Pte. Ltd., Singapore.

[5] Allergan plc, Marlow, United Kingdom.

[6] Allergan plc, Madison, New Jersey.

[7] Gloucestershire Hospitals NHS Foundation Trust, Cheltenham, United Kingdom.

[8] Medical Sciences, Plymouth University, Plymouth, United Kingdom.

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CI = confidence interval; **dB** = decibels; **EMR** = electronic medical record; **HR** = hazard ratio; **IMD** = Index of Multiple Deprivation; **IOP** = intraocular pressure; **LiGHT** = Laser in Glaucoma and Ocular Hypertension; **MD** = mean deviation; **OHT** = ocular hypertension; **PGA** = prostaglandin analogue; **POAG** = primary open-angle glaucoma; **SLT** = selective laser trabeculoplasty; **TM** = trabecular meshwork.

Correspondence:
Anthony P. Khawaja, PhD, FRCOphth, NIHR Biomedical Research Centre for Ophthalmology, Moorfields Eye Hospital and University College London, London, UK. E-mail: anthony.khawaja@gmail.com.