Selective Laser Trabeculoplasty as Primary Treatment for Open-angle Glaucoma

A Prospective, Nonrandomized Pilot Study

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Objective: To examine the safety and efficacy of selective laser trabeculoplasty as primary treatment for patients with open-angle glaucoma.

Methods: Forty-five eyes of 31 patients with open-angle glaucoma or ocular hypertension (intraocular pressure [IOP] ≥23 mm Hg on 2 consecutive measurements) underwent selective laser trabeculoplasty as primary treatment. All patients underwent complete ophthalmic evaluation before and at intervals after treatment. This evaluation included visual acuity, slitlamp examination, ophthalmoscopy, gonioscopy, and visual field analysis. The IOP was measured 1 hour, 1 day, 1 week, and 1, 3, 6, 12, 15, and 18 months postoperatively. During the follow-up period, patients were treated with topical antiglaucoma medications as required.

Results: Mean ± SD decreased by 7.7±3.5 mm Hg (30%), from 25.5±2.5 mm Hg to 17.9±2.8 mm Hg ($P<.001$). Only 2 eyes (4%) did not respond to selective laser trabeculoplasty, and 3 eyes (7%) required topical medications to control their IOP at the end of the follow-up period. Forty eyes (89%) had a decrease of 5 mm Hg or more. Visual acuity, visual fields, and gonioscopic findings remained unchanged. Complications included conjunctival redness and injection within 1 day postoperatively in 30 eyes (67%). One hour after selective laser trabeculoplasty, an increase in IOP of more than 5 mm Hg was detected in 5 eyes (11%), while an increase in IOP between 2 and 5 mm Hg was measured in 3 eyes (7%).

Conclusion: Selective laser trabeculoplasty is effective and safe as a primary treatment for patients with ocular hypertension and open-angle glaucoma.

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ARGON LASER trabeculoplasty (ALT) was first described by Wise and Witter[1] and has become accepted as a treatment modality for open-angle glaucoma. Other lasers have also been used for that purpose, including krypton red, diode laser (810 nm), and continuous-wave Nd:YAG (1064 nm), all with similar success rates.[2-4]

Although the mechanism of laser trabeculoplasty in lowering intraocular pressure (IOP) remains unclear, the role of enhanced biological activity in the trabecular meshwork (TM) has been suggested. Histologic studies have shown coagulation damage to the TM treated with photocoagulative lasers.[5-7] A different approach was introduced by Melamed et al[8] and Epstein et al,[9] who used Q-switched Nd:YAG laser to puncture the TM (goniopuncture), but with limited success in primary open-angle glaucoma.

Recently, a new treatment has been proposed that selectively targets pigmented trabecular cells without causing thermal damage to nonpigmented structures. In this treatment, selective laser trabeculoplasty (SLT), a 532-nm, Q-switched, Nd:YAG laser is used, with pulse duration of 3 nanoseconds and spot size of 400 μm. Histologic studies evaluating SLT have shown that, unlike ALT, there is no scarring of the TM.[5-7] Clinical results have shown the treatment to be effective and safe in patients with primary open-angle glaucoma and in patients treated previously with ALT.[10-15]

Since SLT is considered very safe and is not associated with permanent scarring of the TM or other major complications, we thought it might be suitable as primary treatment in open-angle glaucoma. In addition, it is believed that repetition of SLT when needed will not be associated with trabecular scarring, formation of peripheral anterior synechiae, and increase in IOP. The purpose of this study was to evaluate the use of SLT as a primary treatment in patients with open-angle glaucoma.

METHODS

Thirty-one patients with open-angle glaucoma or ocular hypertension (IOP ≥23 mm Hg in 2 consecutive measurements) underwent SLT. Fourteen patients had the procedure performed bilaterally, for a total of 45 treated eyes.

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Table 1. Preoperative Data

Characteristic	Value
Age, mean ± SD (range), y	54 ± 10 (32 to 76)
Diagnosis, No. (%)	
POAG	29 (62)
PXFG	5 (11)
PDG	3 (6)
NTG	2 (4)
OHT	6 (13)
CD ratio, mean ± SD (range)	0.7 ± 0.16 (0.3 to 0.95)
Preoperative IOP, mean ± SD (range), mm Hg	25.6 ± 2.5 (20 to 31)
Preoperative VA	20/30
Preoperative medications	*
Visual field pattern, No. (%)	
Normal	30 (67)
Nasal step	6 (13)
Superior arcuate	5 (11)
Inferior arcuate	1 (2)
Temporal depression	1 (2)
Central island	1 (2)

Abbreviations: CD, cup-disc; IOP, intraocular pressure; NTG, normal-tension glaucoma; OHT, ocular hypertension; PDG, pigmentary dispersion glaucoma; POAG, primary open-angle glaucoma; PXFG, pseudoexfoliation glaucoma; VA, visual acuity.

*Only 3 patients (10%) were treated with a single medication, which was stopped before the laser procedure.

Table 2. Postoperative IOP and VA

Characteristic	Value
Follow-up time, mo	11 ± 5.3 (3 to 24)*
Final IOP, mm Hg	17.9 ± 2.8 (13 to 25)*
Mean IOP decrease, mm Hg	7.7 ± 3.5 (−2.0 to +14.0)*
Final VA	20/30

Abbreviations: IOP, intraocular pressure; VA, visual acuity.
*Mean ± SD (range).

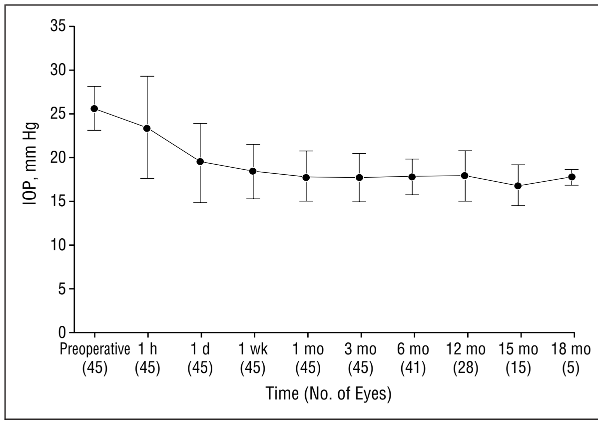

Figure 2. Intraocular pressure (IOP) over time.

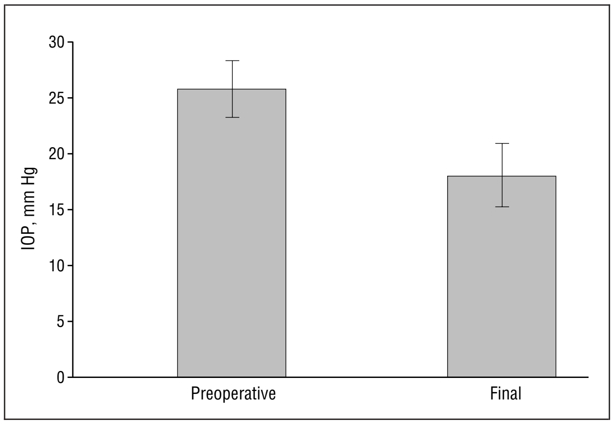

Figure 1. Mean ± SD preoperative and final intraocular pressure (IOP) in millimeters of mercury.

All procedures were performed by one of us (S.M.). In 8 eyes (18%) that were treated with 1 topical antiglaucoma medication (7 with β-blocker, 1 with latanoprost), the drugs were washed out for 3 months before SLT. Before laser treatment, a full ophthalmologic examination was performed that included Snellen visual acuity, IOP measurement, slitlamp examination, gonioscopy, fundus examination, and visual field analysis (Humphrey 24-2). Information regarding age, sex, type of glaucoma, cup-disc ratio, and visual field pattern was collected (**Table 1**). Informed consent was obtained from all patients before each procedure. The follow-up period chosen for evaluation of the short-term results of the procedure was 6 to 18 months postoperatively.

SURGICAL TECHNIQUE

Patients were treated while under topical anesthesia with a frequency-doubled Q-switched Nd:YAG laser (Coherent Selecta 7000; Coherent, Inc, Santa Clara, Calif) emitting at 532 nm with pulse duration of 3 nanoseconds and a spot size of 400 µm, coupled to a slitlamp delivery system. A low-power helium-neon laser served as an aiming beam to provide easy targeting of the treatment area. A Goldmann 3-mirror goniolens was placed on the eye with 1% methylcellulose. The helium-neon aiming beam was focused onto the pigmented TM. The 400-µm spot size was large enough to irradiate the entire anteroposterior height of the TM. In all eyes, the nasal 180° was treated. Approximately 50 adjacent but nonoverlapping laser spots were placed over 180° of the TM. The end point of each laser application was minibubble formation or no visible tissue response. Mean energy level was set to 1.0 mJ and changed according to the level of TM pigmentation.

No α-agonists were instilled before SLT, and 1% prednisone acetate was administrated only in eyes with increased inflammation after SLT. The IOP in the treated eye was assessed and recorded 1 hour, 1 day, 1 week, 1 month, and every 3 months after treatment. Complete ophthalmic examination, gonioscopy, and visual field analysis were performed before, 6 months after, and 1 year after treatment.

STATISTICAL ANALYSIS

A paired t test for paired data was used for assessing changes in IOP from baseline values and differences in these changes between treated and untreated eyes and between treatment groups.

RESULTS

Selective laser trabeculoplasty was performed in 45 eyes (31 patients; 13 men and 18 women). The mean ± SD IOP decreased from 25.5±2.5 mm Hg to 17.9±2.8 mm Hg ($P=<.001$; 95% confidence interval, 6.6-8.7 mm Hg; 2-tailed paired t test) (**Figure 1**). Only 2 eyes (4%) did not respond to treatment, and 3 eyes (7%) required topical medications to control their IOP at the end of the follow-up period. Visual acuity, gonioscopic findings, and

Table 3. IOP Decrease in Different Types of Glaucoma

Diagnosis	No. of Eyes	Preoperative IOP, mm Hg*	Final IOP, mm Hg*	% IOP Decrease	*P* Value†
POAG	29	25.5 ± 2.0	18.5 ± 2.8	27	<.001
OHT	6	25.5 ± 1.1	17.0 ± 2.6	31	<.001
PXFG	5	28.6 ± 3.2	16.8 ± 0.8	41	.001
PDG	3	26.0 ± 2.6	19.7 ± 2.3	24	NA‡
NTG	2	20.5 ± 0.7	14.5 ± 2.1	29	NA‡

Abbreviations: IOP, intraocular pressure; NA, not available; NTG, normal-tension glaucoma; OHT, ocular hypertension; PDG, pigmentary dispersion glaucoma; POAG, primary open-angle glaucoma; PXFG, pseudoexfoliation glaucoma.
*Mean ± SD.
†Paired *t* test.
‡The *P* value could not be calculated because of the small number of patients in the group.

visual field remained unchanged during the follow-up period. Postoperative data are summarized in **Table 2**.

An IOP reduction of at least 20% after SLT was defined as a successful treatment. Mean ± SD decrease in IOP was 7.7±3.5 mm Hg (30%). Mean IOP during the follow-up period is presented in **Figure 2**. The IOP reduction was sustained after SLT, when successful. Forty-three (95%) of 45 eyes treated had IOP reduction on 2 consecutive visits (±2 mm Hg).

An IOP reduction after SLT was detected in all subtypes of glaucoma (primary open-angle glaucoma, pseudoexfoliation glaucoma, pigmentary dispersion glaucoma, and normal-tension glaucoma) and ocular hypertension. However, the small number of eyes with diagnoses other than primary open-angle glaucoma and ocular hypertension did not allow a statistical comparative analysis between the groups. The specific response to SLT in each group is described in **Table 3**.

Absolute IOP reduction from baseline is shown in **Figure 3**. Two eyes (4%) had a decrease of 2 mm Hg or less (one had an increase of 2 mm Hg and another a decrease of 1 mm Hg in final IOP), 3 (7%) had an IOP decrease of 2 to 4 mm Hg, and 40 eyes (89%) had an IOP decrease of 5 mm Hg or more. Interestingly, 1 hour after SLT, 15 eyes (33%) had IOP reduction of 5 mm Hg or more.

Complications included conjunctival redness and injection and mild anterior chamber flare within 1 day postoperatively in 30 eyes (67%). Eighteen patients (58%) complained of ocular pain in the first day after SLT. One hour after SLT, an increase in IOP of more than 5 mm Hg was detected in 5 eyes (11%), while an IOP increase between 2 and 5 mm Hg was measured in 3 eyes (7%).

COMMENT

Our study has shown that SLT is effective in reducing the IOP as a primary treatment in patients with open-angle glaucoma. The mean±SD baseline IOP for all eyes was 25.5±2.5 mm Hg and the final IOP was 17.9±2.8 mm Hg, a decrease of 30%. Most patients (40 eyes [89%]) had an IOP decrease equal to or greater than 5 mm Hg at the end of the follow-up period. An IOP elevation of more than 5 mm Hg 1 hour after treatment was noticed in only 5 eyes (11%). No serious adverse effects were related to SLT. Only 3 eyes required topical ocular hypotensive medications to reduce the IOP after SLT.

Although the mechanism of action of laser trabeculoplasty is not completely understood, several investigators have suggested that enhanced biological activity[7-9] and repopulation of trabecular cells[16] may play an important role in IOP reduction.

Treatment of monkeys with ALT has shown that the region of the TM becomes scarred and impermeable to aqueous humor flow, with shift of flow to adjacent untreated regions.[7] Moreover, excessive scarring of the TM can lead to an increase in IOP and worsening of glaucoma in animals and humans.[17,18] In contrast, with SLT the pulse duration is 3 nanoseconds, so there is no coagulation damage to adjacent cells other than the pigmented TM cells, and thus SLT may be associated with fewer IOP spikes or spikes that are less severe.[19,20] Latina and Park[19] have shown that Q-switched, 532-nm, Nd:YAG laser selectively lyses intracellular melanosomes, killing pigmented cells while leaving cellular membranes and neighboring nonpigmented cells intact. Hollo[21] examined morphologic changes in human TM after ALT and showed the formation of a membrane by migrating endothelial cells. This membrane covers the meshwork between the laser spots and is responsible for the late IOP rise after ALT; it does not exist after Nd:YAG laser trabeculoplasty.

Kramer and Noecker[22] treated 8 human autopsy eyes with SLT and ALT (one half of each TM underwent SLT and the other half ALT) and evaluated the specimens with scanning and transmission electron microscopy. The ALT-treated TM showed coagulative damage with disruption of collagen beams, fibrinous exudates, lysis of endothelial cells, and nuclear and cytoplasmic debris. The SLT-treated TM showed no evidence of coagulative damage or disruption of trabecular beam structure. The only ultrastructural evidence of laser tissue interaction was cracking of intracytoplasmic pigment granules and disruption of trabecular endothelial cells.

These findings may also imply that retreatment with SLT can be carried out with less fear of TM damage or IOP elevation. Moreover, as shown by previous studies, SLT can further decrease IOP in patients with previous ALT who became nonresponders. These patients may require filtration surgery to further decrease their IOP, and SLT may be their last resort before an invasive surgical intervention.[14]

Other investigators have described an average IOP reduction of 18.7% to 40%.[10-15] In all of those studies, the eyes treated had either maximal medical therapy or previous ALT.

Selective laser trabeculoplasty appears to be equivalent to ALT in lowering IOP during the first 6 months

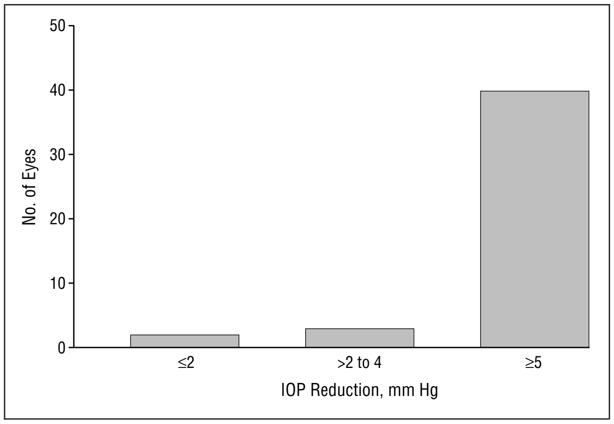

Figure 3. Absolute reduction in intraocular pressure (IOP).

after treatment. Patients who may benefit the most are those with previous failed ALT; they had a significantly greater drop in IOP when treated with SLT as compared with ALT.[14] In a retrospective study conducted by Pirnazar et al,[15] there was no difference in the decrease in IOP 1, 6, and 12 months after treatment when ALT (27 eyes) was compared with SLT (30 eyes).

In contrast, our patients had newly diagnosed untreated glaucoma or eyes with a history of a single topical medication only. This may explain the relatively high rate of success (30% IOP reduction) and also the relatively low incidence and low level of IOP spikes (incidence of IOP spikes, 17.8%) 1 hour after treatment.

At the end of the follow-up period, visual acuity and visual fields had not changed and gonioscopy did not detect any scarring or formation of peripheral anterior synechiae. This confirms the strong safety profile of SLT.

Interestingly, we detected IOP reduction of more than 5 mm Hg within the first hour after SLT in 33% of the eyes. One of the explanations for such early IOP reduction may be a mechanical effect of photodisruption or very early recruitment of inflammatory mediators. An increased level of lipid peroxidase in aqueous humor of rabbit eyes treated with SLT suggests that free oxygen radicals are formed in the pigmented TM due to photodisruption, and may be responsible for the inflammation associated with this procedure.[23]

In conclusion, this study shows that SLT is a safe and effective method of lowering IOP in open-angle glaucomas even when used as a primary procedure. To our knowledge, this is the first report of the safety and efficacy of SLT as a primary treatment for open-angle glaucoma.

The fibrosis and scarring that result after ALT do not occur after SLT because of the limited structural damage to the TM; thus, SLT may theoretically be repeated and result in additional reduction in IOP greater than that with ALT.[22] The Glaucoma Laser Trial[24] recently showed the efficacy of ALT as a primary treatment for primary open-angle glaucoma to be similar to that of topical medications. Although it was not examined in the current study, our results suggest that SLT may be a safe, noninvasive, and effective treatment modality in open-angle glaucoma as a primary treatment instead of topical medications or ALT. Also, the recent report of the Ocular Hypertension Treatment Study Group[25] recommended early medical treatment in certain cases of ocular hypertension. As there were very minor and temporary complications of SLT in our patients, this treatment modality may be a good alternative to long-term medical therapy even in the ocular hypertension group. Only a randomized, multicenter study comparing SLT with medical therapy as primary treatment in glaucoma will provide a more definite role of SLT in such patients.

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