Efficacy of Selective Laser Trabeculoplasty in Phakic and Pseudophakic Eyes

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Purpose: To compare the efficacy of selective laser trabeculoplasty (SLT) in phakic and pseudophakic eyes in open-angle glaucoma and ocular hypertension.

Materials and Methods: Charts of 28 pseudophakic eyes and 60 phakic eyes that underwent 360-degree SLT were retrospectively reviewed. Patients were examined at 1, 3, 6, and 12 months. Treatment success was defined as $\geq 20\%$ intraocular pressure (IOP) reduction, with no additional medications, laser, or glaucoma surgery. Mean IOP change, mean percentage of IOP reduction, and success rates for phakic and pseudophakic eyes were compared.

Results: Mean percentage of IOP reduction post-SLT at 1-, 3-, 6-, and 12-month visits were 21.4%, 25.8%, 24.8%, and 23.7%, respectively, in the pseudophakic group and 22.8%, 25.0%, 25.7%, and 21.2%, respectively, in the phakic group. Success rates ranged between 60% and 64% in the pseudophakic group and between 58% and 73% in the phakic group. No statistically significant differences in IOP change, percentage of IOP reduction, and success rate were seen between the groups at any of the post-SLT visits ($P > 0.05$).

Conclusions: Application of 360-degree SLT seems to be an efficient and safe treatment option for the management of phakic and pseudophakic open-angle glaucoma and ocular hypertension.

Key Words: intraocular pressure, ocular hypertension, open-angle glaucoma, pseudophakic, selective laser trabeculoplasty

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Randomized clinical trials have shown that lowering of intraocular pressure (IOP) can prevent the progression of glaucoma-related structural and functional damage.[1–4] The traditional approach for open-angle glaucoma treatment involves a stepped approach of increasing medical treatment, followed by laser trabeculoplasty and surgery if the first 2 approaches fail to lower IOP. Laser trabeculoplasty is an effective and safe method for lowering IOP in various types of open-angle glaucoma. Argon laser trabeculoplasty (ALT) has been in use since 1979, after the landmark publication of Wise and Witter.[5] The advent of selective laser trabeculoplasty (SLT) has renewed interest in laser trabeculoplasty as a means of lowering IOP in eyes with glaucoma.[6]

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SLT uses a frequency-doubled Q-switched Nd:YAG laser with a treatment duration significantly shorter than the thermal relaxation time of the melanin pigment in the trabecular meshwork. SLT is capable of selectively targeting pigmented trabecular meshwork cells without collateral thermal damage to the adjacent nonpigmented trabecular meshwork cells and underlying trabecular beams.[7–9]

Numerous investigators have reported successful outcomes for SLT in lowering IOP in phakic eyes in the short and long term as initial and adjunctive treatment.[10–21] Application of 360-degree SLT was shown to be more effective than 180-degree SLT for intermediate term reduction in IOP.[15,22]

Cataract extraction is associated with a significant and sustained reduction in IOP in both normal subjects and patients with open-angle glaucoma by incompletely known mechanisms.[23–28] It is reasonable that cataract extraction and SLT may share a common pathway of IOP reduction such as inflammation, prostaglandin release, and interleukin-1α release. Shazly et al[29] hypothesized that the IOP response to SLT in pseudophakic eyes may be less than in phakic eyes due to partial or complete activation of pathways common to both SLT response and cataract extraction–mediated IOP-lowering effect.

To date, there are only a few studies reporting the results of 180-degree SLT in pseudophakic eyes in comparison with phakic eyes, where pseudophakic eyes responded similar to phakic eyes.[29,30] Whether 360-degree SLT would have a more robust effect in phakics compared to pseudophakics is yet unknown. The purpose of our study is to compare the efficiency of 360-degree SLT in phakic and pseudophakic eyes in open-angle glaucoma and ocular hypertension (OHT) patients.

MATERIALS AND METHODS

This was a retrospective chart review study, which included patients who had SLT performed by the senior author (E.B.) between January 2008 and January 2010. The study protocol was approved by the Ethics Committee of our institution and informed consent was obtained from all patients before the procedure. The study also adhered to the tenets of the Declaration of Helsinki.

Inclusion criteria were age older than 18 years, open-angle glaucoma (primary open angle or pseudoexfoliation glaucoma) patients and a diagnosis of OHT, adequate visualization of the angle (ie, clear media and cooperative patient), on no systemic medications known to increase IOP (corticosteroids), and who had been given 360-degree SLT treatment.

Exclusion criteria were evidence of ocular disease other than glaucoma or OHT which might affect IOP measurements, proliferative diabetic retinopathy, patients who had any type of ophthalmic laser or had refractive

surgery, current or expected use of systemic steroids, and if the patients were pregnant or planning to be pregnant within the next year.

Patients with history of cataract surgery within 6 months, complicated cataract surgery, or prior laser trabeculoplasty were excluded. All pseudophakic patients underwent uncomplicated phacoemulsification with implantation of a foldable posterior chamber intraocular lens in the capsular bag.

Laser treatment was performed using the SLT Solo laser (Ellex, Adelaide, Australia) which is a frequency-doubled, Q-switched, 532 nm Nd:YAG laser. The laser procedure was performed by using a Latina goniolens in a standard fashion in all cases. An initial power setting between 0.6 and 0.8 mJ was selected. The energy was increased or decreased until small bubble formation appeared and then decreased by 0.1 mJ for the remainder of the treatment. The procedure was then completed for 360 degrees. A drop of brimonidine 0.2% was administered after laser therapy. All patients were examined at 1 hour after treatment. Patients who experienced a postoperative elevation of ≥ 5 mm Hg received oral carbonic anhydrase inhibitors and the patient was monitored until IOP normalized to preoperative levels. Any significant IOP elevations and treatment were recorded.

Patients did not receive any topical steroids or nonsteroidal anti-inflammatory medications after the procedure. The same preoperative medical treatment was maintained during follow-up. The patients were seen in follow-up at 1, 3, 6, and 12 months. If a patient was referred back to the primary ophthalmologist, IOP information was updated from the referring ophthalmologist.

Data were recorded from each patient including age, sex, type of glaucoma, phakic status, other prior surgeries, glaucoma medications, and the SLT protocol (number of spots and laser power settings). Combination drops (ie, timolol-brimonidine combination drops) were counted as 2 medications. Preoperative IOP was determined by the average of all IOP measurements within 1 month before SLT, with the Goldmann applanation tonometer. Postoperative IOP data were collected at postoperative visits at 1, 3, 6, and 12 months, with the Goldmann applanation tonometer.

Mean IOP change (mm Hg) and mean percentage decrease in IOP from baseline at 1-, 3-, 6-, and 12-month postoperative visits were determined. Success was defined as an IOP reduction of $\geq 20\%$, without additional medications, repeat laser trabeculoplasty, or glaucoma surgery. As an additional analysis, number of patients who had ≥ 3 mm Hg IOP reduction at 6 months was also determined.

Patients were categorized as phakics and pseudophakics. When 2 eyes of the same patient were treated, 1 eye was chosen at random for analysis by flipping a coin. Age, diagnosis, mean number of medications, mean SLT energy, mean number of shots, baseline IOP, and IOP at postoperative visits were compared between the phakic and pseudophakic groups. In addition, the mean change in IOP, the mean percentage decrease of IOP, and the success rates at each follow-up visit were compared between the 2 groups.

Statistical analysis was performed using the Statistical Program for the Social Sciences (version 15.0; SPSS Inc., Chicago, IL). Normal distribution of data in the phakic and the pseudophakic groups were tested by Kolmogorov-Smirnov test. Since numerical variables showed normal distribution for both groups, difference between the means in both groups were tested using the Student t test. χ^2 testing was performed to compare the distribution of baseline characteristics (age, sex, diagnosis, number of medications, type of medications) between the 2 study groups. Comparison of the success rates in the phakic and pseudophakic groups at each follow-up visit were also analyzed by χ^2 test. Significance was set at $P < 0.05$.

A 1 mm Hg of difference between groups was chosen as a clinically significant IOP difference. Power calculation revealed that to detect a difference of 1 mm Hg with 80% power at the $P \leq 0.05$ level required a minimum of 26 eyes in each arm.

RESULTS

We analyzed the results of SLT in 88 eyes of 88 patients diagnosed with open-angle glaucoma or OHT. The pseudophakic group consisted of 28 eyes whereas phakic group consisted of 60 eyes. Forty-three right eyes and 45 left eyes were treated. The mean age of the total group was 60.6 ± 11.6 years (range, 25 to 86 y). The average age was 67.9 ± 9.9 years in pseudophakic and 57.3 ± 10.9 years in phakic group ($P = 0.001$). All patients were exclusively Caucasians. Patient demographics at baseline are shown in Table 1.

Primary open-angle glaucoma composed the primary indication (72%) for the procedure, whereas pseudoexfoliation glaucoma represented 10%, and OHT represented 18% of the patients undergoing SLT (Table 1). The 2 study groups were comparable with respect to diagnosis ($P = 0.1$).

SLT was mainly performed as adjunctive therapy in this study. Patients who could not tolerate any topical antiglaucoma medications or who were noncompliant with medical therapy were offered primary SLT. The 2 groups were comparable with respect to number of antiglaucoma medications used before SLT ($P = 0.2$). Percentage of

TABLE 1. Patient Demographics at Baseline

Characteristics	Phakic	Pseudophakic
Age (y, mean ± SD)	57.3 ± 10.9	67.9 ± 9.6
Sex (%)		
Male	51.6	53.6
Female	48.4	46.4
Eye (%)		
Right	53.3	39.3
Left	46.7	60.7
Diagnosis (%)		
POAG	66.7	82.1
PXG	11.7	7.1
OHT	21.6	10.8
No. medications (%)		
0	28.3	14.3
1	8.3	3.6
2	10.0	7.1
3	25.0	25.0
4	28.4	50.0
Type of medication (%)		
Prostaglandin analogue	58.3	64.3
β-blocker	65.0	85.7
Carbonic anhydrase inhibitor	60.1	82.1
α-2 adrenergic agonist	35.0	64.3

OHT indicates ocular hypertension; POAG, primary open-angle glaucoma; PXG, pseudoexfoliative glaucoma.

patients using prostaglandin analogues were similar between the groups ($P = 0.595$). Percentage of patients using β-blockers and carbonic anhydrase inhibitors were marginally significantly higher in the pseudophakic group ($P = 0.045$ and 0.040, respectively). The percentage of patients using α-2 adrenergic agonists were significantly higher in the pseudophakic group ($P = 0.010$).

Average number of laser pulses were 114 ± 19 and 110 ± 22 in the phakic and pseudophakic eyes, respectively ($P = 0.3$). Average total laser energy used was 104 ± 29 and 95 ± 23 mJ in the phakic and pseudophakic eyes, respectively ($P = 0.1$).

The mean baseline IOP of the total number of subjects was 22.42 ± 4.37 mm Hg (range, 14 to 38 mm Hg). The mean baseline IOP for the phakic group was 22.5 ± 3.9 mm Hg (range, 15 to 30 mm Hg), whereas the baseline IOP for the pseudophakic group was 22.2 ± 5.2 mm Hg (range, 14 to 38 mm Hg). Baseline IOP was not significantly different between the 2 study groups ($P = 0.7$).

Mean post-SLT IOP values at 1, 3, 6, and 12 months were 17.3, 16.3, 16.2, and 16.9 mm Hg, respectively, in the pseudophakic group. The respective values were 17.2, 16.7, 16.5, and 17.5 mm Hg in the phakic group (Fig. 1). There was no statistically significant difference between the groups at any time point ($P > 0.05$). None of the patients in both study groups received additional medications, had repeat laser trabeculoplasty, or glaucoma surgery during the follow-up. SLT treatment provided significant decrease in IOP from baseline at each time point in both study groups ($P < 0.05$).

The mean reduction of IOP at 1, 3, 6, and 12 months were 4.8, 5.8, 5.6, and 5.5 mm Hg, respectively, in the pseudophakic group. The respective values for the phakic group were as follows: 5.2, 5.7, 5.9, and 4.9 mm Hg (Table 2). There was no statistically significant difference between the groups at any time point ($P > 0.05$).

The mean percentage reduction of IOP post-SLT at 1-, 3-, 6-, and 12-month visits were 21.4%, 25.8%, 24.8%, and 23.7%, respectively, in the pseudophakic group. The mean percentage reduction of IOP at the same periods were 22.8%, 25.0%, 25.7%, and 21.2% in the phakic group, respectively (Fig. 2). There were no statistically significant differences between phakic and pseudophakic groups at any of the post-SLT visits ($P > 0.05$).

TABLE 2. Change From Baseline Intraocular Pressure (mm Hg) After Selective Laser Trabeculoplasty

Time (mo)	Pseudophakic†	Phakic†	P*
1	4.8 ± 3.4	5.2 ± 3.0	0.6
3	5.8 ± 3.9	5.7 ± 3.2	0.8
6	5.6 ± 4.1	5.9 ± 3.2	0.6
12	5.5 ± 3.8	4.9 ± 3.1	0.4

*Student *t* test.
†Values shown are mean ± SD in mm Hg.

The success rate (≥ 20% IOP reduction) for each group is shown in Figure 3. The success rates varied for different time points for both the phakic and pseudophakic groups. Over the course of the study, 58% to 73% of phakic eyes and 60% to 64% of pseudophakic eyes were defined as successful using our criteria. The success rates between the groups did not differ at any time point ($P > 0.05$).

At the 6-month visit 23 (82%) pseudophakic eyes and 51 (85%) phakic eyes had IOP reductions of ≥ 3 mm Hg. A total of 14 eyes (5 pseudophakic and 9 phakic eyes) had IOP reductions of ≤ 3 mm Hg after SLT.

Eight phakic eyes (13%) and 3 pseudophakic eyes (11%) developed an IOP elevation between 2 and 5 mm Hg within 1 hour after SLT. IOP elevation over 5 mm Hg was observed in 1 pseudophakic eye (3.5%) and in 3 phakic eyes (5%). None of the pseudophakic eyes experienced IOP elevation of ≥ 10 mm Hg, whereas 2 (3%) phakic eyes with pseudoexfoliation glaucoma had 10 mm Hg IOP elevation within 1 hour of SLT. All significant early IOP elevations were treated with oral carbonic anhydrase inhibitors. No permanent adverse effects of SLT were noted in any of the patients.

DISCUSSION

Laser trabeculoplasty has been reported to lower IOP by enhancement of aqueous outflow facility. ALT was the gold standard in laser trabeculoplasty for over 20 years, until the introduction and wide acceptance of SLT, which has comparable efficiency and safety profile, with considerably less thermal damage to the trabecular meshwork.[8,12,14] SLT

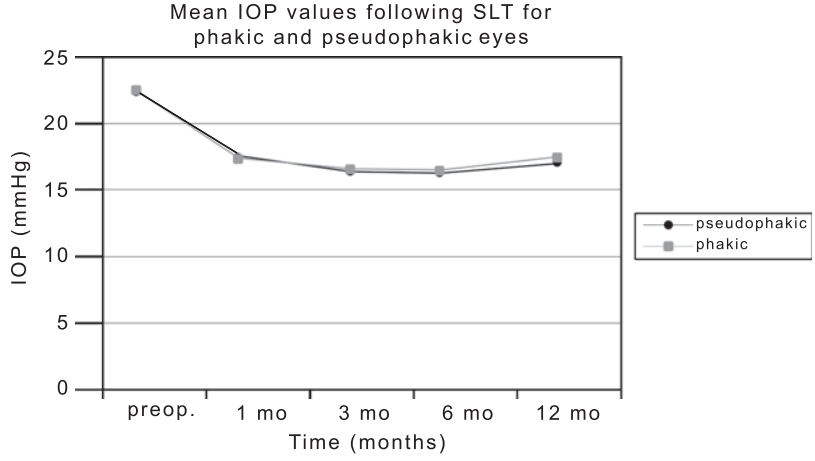

FIGURE 1. Mean IOP after selective laser trabeculoplasty for phakic and pseudophakic eyes. IOP indicates intraocular pressure; SLT, selective laser trabeculoplasty.

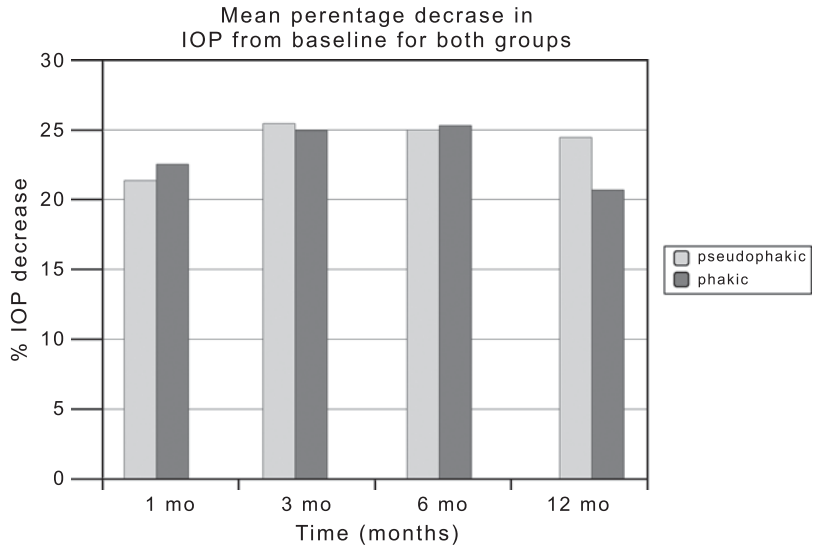

FIGURE 2. Mean percentage decrease in IOP from baseline for pseudophakic and phakic eyes. IOP indicates intraocular pressure.

can be performed as primary or as an adjuvant treatment for patients with primary open-angle glaucoma, pseudoexfoliation glaucoma, and OHT.[8,11–13,16,20,31,32] Recent studies have found it to have potential for repeated treatments after prior ALT or SLT.[33–35]

SLT has been shown to be effective in both short and long term in phakic eyes.[10,12,14,17,19,21,31,36] However, there are very limited numbers of studies in the literature dealing with the efficacy of SLT in pseudophakic eyes compared with phakic eyes.[29,30]

A number of studies have investigated into factors that might influence SLT outcomes.[13,14,21,37–40] These studies have shown that the main predictor of SLT success was baseline IOP. Age, sex, pigmentation of the anterior chamber angle, previous ALT, number of medications used, and diagnosis do not seem to affect success rates. A recent study by Tzimis et al[38] reported that pseudophakic status had no significant effect. Similarly, Martow et al[37] found that pseudophakia was not associated with SLT treatment efficacy in patients undergoing SLT as an adjunctive treatment.

In this study we compared the efficiency of SLT as initial and adjunctive treatment in pseudophakic and phakic patients. All of our patients had 360-degree SLT performed by a single surgeon, using a standard treatment and follow-up protocol. The pseudophakic eyes were less numerous, a finding not surprising in consecutive series of patients, as this was a retrospective chart review.

The mean baseline IOP values, diagnosis, number of medications, total laser energy, and number of spots were comparable between pseudophakics and phakics. There was a significant difference between the mean age of groups; pseudophakic patients were significantly older than phakic patients. This was not unusual, as cataract surgery is required more often in later years of life. Since age has not been shown to be a factor for successful SLT, we do not think the age difference in our study might affect the results.[39,41,42]

In this study SLT was mainly performed as adjunctive therapy. Patients who could not tolerate topical medications or who were noncompliant with medical therapy were offered primary SLT. Phakic and pseudophakic groups were comparable with respect to number of medications ($P = 0.2$).

When analyzed for the type of medications, there was no difference between the study groups regarding prostaglandin use. However, the pseudophakic group had slightly higher use of β-blockers and carbonic anhydrase inhibitors, and significantly higher use of α-2 adrenergic agonists. The effect of medications on SLT is still controversial. Some retrospective case series have addressed the question with inconsistent findings. Scherer[43] reported a greater IOP

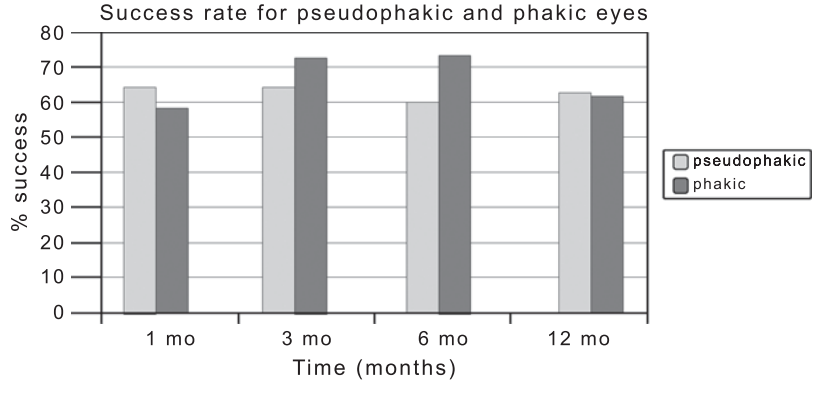

FIGURE 3. Success rate (≥ 20% intraocular pressure decrease) for phakic and pseudophakic eyes.

decrease after SLT in patients on concomitant prostaglandin analogue therapy, whereas Singh et al[42] did not find any relationship, and Kara et al[44] showed a decreased response to SLT in patients on prostaglandin analogue versus timolol and dorzolamide therapy. Recently Martow et al[37] reported that topical medications do not adversely, nor favorably, affect SLT success. The effect of medications on SLT outcome was not specifically sought in our study. Pseudophakic eyes had higher use of β-blockers, carbonic anhydrase inhibitors, and α-2 adrenergic agonists. Since SLT showed similar efficacy in pseudophakics and phakics, our results seem to agree with those of Martow and colleagues. Nevertheless, strict conclusions about effect of medications cannot be made from our study with a relatively limited sample size.

Our study shows that SLT is effective in decreasing IOP in both phakic and pseudophakic eyes. The mean decrease in IOP varied from 4.9 to 5.9 mm Hg in the phakic group and 4.8 to 5.8 mm Hg in the pseudophakic group throughout the follow-up period. In a recent study, Werner et al[30] reported the results of SLT performed primarily or as an adjuvant treatment in pseudophakic and phakic eyes. They found that average decrease in IOP varied from 2.6 to 3.4 mm Hg in the phakic group and 3.0 to 3.6 mm Hg in the pseudophakic group. The mean decrease in IOP are of higher magnitude in our study. This may be largely attributed to the higher baseline IOP of our patients compared with baseline IOP values in their study (18.1 and 18.3 mm Hg for phakic and pseudophakic groups, respectively). In addition, we used 360-degree SLT, whereas Werner et al[30] had performed 180-degree SLT. Nagar et al[15] reported higher success with 360-degree SLT compared to 90-degree and 180-degree SLT.

To be comparable with other studies, we chose the definition of success as reduction of $\geq 20\%$. Our success rates ranged from 58% to 73%. Success rates in our study appear to be comparable with those of prior studies, suggesting that SLT may be an effective treatment option for both phakic and pseudophakic eyes.[10,12,13,18,31]

In this study none of our patients received additional medications, had repeat laser trabeculoplasty, or glaucoma surgery during the follow-up. Most of our patients who did not have $\geq 20\%$ IOP reductions still had some benefit from SLT (ie, ≥ 3 mm Hg IOP reduction): At the 6-month visit 23 (82%) pseudophakic eyes and 51 (85%) phakic eyes had IOP reductions ≥ 3 mm Hg. Therefore a total of 14 eyes (5 pseudophakic and 9 phakic eyes) had IOP reductions ≤ 3 mm Hg after SLT. The aim of SLT in 11 of these was to decrease the number of medications for better quality of life; when this goal was not achieved, these patients continued to use the same medications. The remaining 3 patients were already on maximal medical therapy and were offered surgery; 2 patients refused surgery because of advanced age and fear of incisional surgery, and 1 patient was considered ineligible for surgery by Anesthesiology Department.

In this study medical therapy was not reduced in those patients who exhibited good IOP response to SLT. We performed SLT mainly as adjunctive therapy, aiming to reach lower target IOP values. Since most of our patients had moderate to advanced glaucoma, current medications were not reduced despite successful SLT.

In this study, there was no significant difference in the average percentage decrease in IOP between the 2 groups at any time point. The results of this study concurs with a prior study by Shazly et al[29] showing 27.4% decrease in mean IOP in the phakic group and 22.5% decrease in mean IOP in the pseudophakic group at 12 months compared with 21.2% decrease in phakics and 23.7% decrease in pseudophakics in our study. As in our study, they also found no significant difference between phakic and pseudophakic eyes in terms of IOP decrease and success rate at all time points except at 2 weeks after SLT. The authors commented that IOP-lowering effect of SLT may not be completely achieved at 2 weeks and that the 3-month IOP should be used. Our study did not look at the 2-week response. Our earliest follow-up period was 1 month, where both groups had similar outcomes. Thus our study shows that pseudophakic eyes respond similarly at 1 month after SLT and that we do not have to wait until the 3-month examination.

Recently, Hirn et al[45] examined the IOP-lowering effect of SLT, especially with regard to potential influence of pseudophakia. They reported that phakic patients had a significantly greater IOP reduction compared to pseudophakic patients after 360-degree SLT. However, they compared only 5 pseudophakic eyes with 25 phakic eyes. Our study included 28 pseudophakic eyes and found that pseudophakics responded similarly as phakic eyes.

Nagar et al[46] recently reported the efficacy and safety of SLT in pseudophakic secondary glaucoma in 3 patients. Their patients had developed secondary glaucoma due to complicated cataract surgeries. All 3 patients were successfully treated with 180-degree SLT, either along with reduction of antiglaucoma medications or as an adjunct to medical therapy to maintain target IOP. We cannot compare our results with those of Nagar and colleagues as our pseudophakic patients had uncomplicated surgery and did not have secondary glaucoma due to trabecular damage or prolonged steroid use.

Early post-SLT IOP elevations have been described in previous published series.[10,11,14,18,21,31] In our study, post-SLT transient IOP elevations were similar in the pseudophakic and phakic eyes. Three pseudophakic eyes (11%) developed mild IOP elevation; elevation of > 5 mm Hg was observed in only 1 pseudophakic eye.

In conclusion, our study demonstrates no negative effect of prior uncomplicated cataract surgery on the outcome of SLT in patients with OHT, primary open-angle glaucoma, and pseudoexfoliation glaucoma. The limitations of our study are the relatively small number of pseudophakic eyes, retrospective design, and inclusion of both primary SLT and SLT as an adjunctive treatment. Another limitation was our method of randomization when 2 eyes of the same patient were treated. We recognize that such simple randomization can be problematic in relatively small-sized clinical trials. Nonetheless, results from our study suggest that clinicians may choose to treat pseudophakic eyes with open-angle glaucoma and OHT with the expectation of similar efficacy as in phakic eyes. Further studies with larger number of patients and longer follow-up are needed to further establish the role of SLT in pseudophakic eyes.

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