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Efficacy of Nd: YAG and diode laser transscleral cyclophotocoagulation in the management of neovascular glaucoma associated with proliferative diabetic retinopathy

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Background: *Transscleral cyclophotocoagulation (TSCPC) is most commonly used in patients with neovascular glaucoma (NVG) associated with proliferative diabetic retinopathy (PDR) in whom maximal hypotensive medications have failed to reduce intraocular pressure (IOP) to the desired level, and glaucoma surgery cannot be carried out. Options for CPC can be performed using a neodymium:yttrium-aluminum-garnet (Nd:YAG) laser or diode laser.*
Purpose: *To compare the efficacy of TSCPC performed with the 1,064-nm Nd:YAG laser versus 810-nm diode laser in patients with painful NVG associated with PDR over a 12-month follow-up period.*
Material and Methods: *A prospective cohort study was carried out on 58 type 2 diabetics (58 eyes) who received a 1,064-nm Nd:YAG laser TSCPC or 810-nm diode laser TSCPC for painful NVG associated with PDR, with regular follow-up visits over 12 months and had no previous history of treatment with CPC. IOP between 6 and 21 mmHg (or a reduction in IOP of ≥ 30% from baseline IOP) and no ocular pain at 12 months was the primary outcome measure.*
Results: *The success rate at 12 months was 75% and 77% for eyes that received Nd:YAG laser TSCPC and diode laser TSCPC, respectively (p = 0.86). In the Nd:YAG laser TSCPC and diode laser TSCPC groups, the IOP reduced by 46% and 45%, respectively (p = 0.34) from baseline values of 38.0 mmHg and 36.0 mmHg, respectively (p = 0.96) at month 12 after TSCPC. At month 12 after CPC, the BCVA in patients with preserved pattern vision improved in both groups (p = 0.41). The rate of ocular complications was, however, higher in the diode laser TSCPC group (71% versus 33%, p = 0.004).*
Conclusion: *Nd:YAG laser TSCPC resulted in a reduction in IOP to ≤ 21 mmHg at month 12 in 75%, and diode laser TSCPC, in 77% of patients with NVG associated with PDR. The number of sessions required for treatment success was 3.2 times larger for Nd:YAG laser CPC than for diode laser CPC. Both these types of CPC are safe and can be repeatedly used to improve treatment efficacy.*

Keywords:
neovascular glaucoma, proliferative diabetic retinopathy, intraocular pressure, Nd:YAG laser, diode laser, cyclophotocoagulation

Introduction

The pathophysiology of proliferative diabetic retinopathy (PDR) includes retinal microvascular damage and ischemia resulting in neovascularization of the retina, iris and trabecular meshwork and proliferation of the fibrovascular tissue in the anterior chamber angle, which often occurs in the presence of changes in anterior chamber angle structures and the development of neovascular glaucoma (NVG) [1-3].

In NVG, current treatment options include topical or systemic medical therapy for controlling IOP; laser and antiangiogenic treatment for combating neovascularization; surgery for improving aqueous outflow and cyclophotocoagulation (CPC) for reducing aqueous production [4].

Transscleral CPC (TSCPC) has become the most common treatment option for painful NVG, and its benefits include non-invasiveness, having an analgesing effect with a reduction in IOP, and preservation of visual functions. During TSCPC, laser burns are applied to the ciliary epithelium, and the laser beam is absorbed by melanin in the ciliary processes, leading to selective thermal coagulation of ciliary body tissues, which results in a reduction in aqueous production and hence IOP [5]. Options for CPC can be performed using a neodymium:yttrium-aluminum-garnet (Nd:YAG) laser or diode laser [6, 7].

The diode laser emits light near the infrared spectrum at 810 nm, which is strongly absorbed by melanin in the ciliary body epithelium. TSCPC is typically performed using a continuous delivery of laser energy, which is effective for IOP reduction, but is associated with important complications such as a reduction in best-corrected visual acuity (BCVA), hypotony, chronic uveitis

and phthisis [8-10]. These complications are most likely due to the collateral damage of surrounding tissues via thermal spread [8].

The Nd:YAG laser emits light at 1064 nm, and its energy penetrates the sclera more effectively, but is less strongly absorbed by melanin [11], with similar hypotensive effect but less damage to the surrounding tissues and lower complication rates compared to the 810-nm laser.

The purpose of the study was to compare the efficacy of TSCPC performed with the 1,064-nm Nd:YAG laser versus 810-nm diode laser in patients with painful NVG associated with PDR over a 12-month follow-up period.

Material and Methods

Study design and participants

A prospective cohort study was carried out on 58 type 2 diabetics (58 eyes) who received inpatient and/or outpatient treatment for painful NVG associated with PDR at the Department of Laser Microsurgery of Eye Diseases, State Institution "The Filatov Institute of Eye Diseases and Tissue Therapy", during 2021 through 2023.

The study was conducted in accordance with the standards expressed in the Helsinki Declaration and was approved by the Filatov Institute ethics committee (Minutes no. 1 dated February 5, 2024).

Written informed consent was obtained from all study patients.

Inclusion criteria included neovascularization of the iris or angle documented in clinical notes, ocular pain and an IOP ≥ 30 mmHg despite maximal hypotensive medication.

Exclusion criteria were NVG secondary to other disorder; systemic disease prevent-ing TSCPC; no eye pain; history of CPC, or the presence of ocular inflammation.

Data collection

IOP, BCVA, and the number of antihypertensive medications used were documented at presentation and at 1 month and 3, 6 and 12 months after CPC. IOP was assessed by Goldmann applanation tonometry. Repeat CPC or other treatment was used in case of lack of response to IOP lowering or loss of the intraocular hypotensive effect. After treatment, eyes were dichotomized into three groups based on whether their BCVA improved, did not change or worsened postoperatively.

TSCPC procedures, study groups and post-procedural follow-up

Epibulbar anesthesia with ophthalmic propacaine hydrochloride 0.5% and either peribulbar or retrobulbar anesthesia with lidocaine hydrochloride 2.0% were administered before the onset of the TSCPC.

Patients were randomly divided into two groups based on the method of TSCPC and the type of laser employed.

Group 1 (controls) included 30 patients (30 eyes) who received standard TSCPC with a 1064-nm Nd:YAG laser and group 2 (the study group) included 28 patients (28 eyes) who received modified TSCPC with a 810-nm diode laser.

In group 1, a 1064-nm Nd:YAG laser was used to perform TSCPC with an exposure duration of 5 s (corresponding to 1.0 J/pulse), and a 600-μm fused-silica fiber optic tip of the laser, for dosed scleral compression ($2.4\text{-}4 \bullet 10^4$ Pa) [12].

In group 2, an 810-nm diode laser TSCPC was applied using a fiber optic G-probe connected to the Vitra 810 (Quantel Medical Instruments, Cournon d'Auvergne Cedex, France), and was performed with a laser power of 1,000 mW and exposure duration of 1.5 s (corresponding to 1.5 J/pulse). The footplate of the G-probe was held parallel to the visual axis with the shorter edge of the footplate firmly between the anterior border and the middle of the limbus which placed the laser fiberoptic over the pars plicata.The CPC procedure was performed only once.

In both groups, TSCPC was performed concentrically in a circular fashion. The number of laser spots applied to one eye was larger in eyes treated with 1064-nm Nd:YAG laser TSCPC, since in this group the laser spots were placed in two rows. In our previous study [13], the pars plicata were visualized with infrared diaphanoscopy, and found to have a mean width of about 2.0 mm. Given these findings, in the current study, laser energy was delivered 1.5-2.0 mm posteriorly to the surgical limbus, with care taken to avoid the 3- and 9-o'clock positions (to prevent damage to the long ciliary nerves), areas of sclera thinning and sites of failed filtering blebs and glaucoma drainage devices.

Impulse laser energy of 2.5-4.5 J has been reported to be necessary for effective laser CPC. However, based on the findings of our previous study [14], we used laser energy of 1.5 J in diode laser TSCPC, and 1.0 J in Nd:YAG laser TSCPC, for effective laser TSCPC and reducing the rate of complications. The total energy per CPC session was calculated using the following equation:

TE = LP x EXP x LSN,

where TE is total energy (in joules), LP is laser power (in watts), EXP is exposure (in seconds), and LSN is number of laser spots.

The mean sum of the number of laser spots per session was 40 (38-40) for group 1 and 30 (30-30) for group 2 ($p = 0.000$). The mean total energy per session was 40 (38-40) J for group 1 and 45 (44.9-45) J for group 2 ($p = 0.000$).

Ophthalmic dexamethasone 1 drop (1 mg/1 ml, three times daily) was administered over two weeks after CPC to prevent inflammation [15]. Postoperative treatment included ophthalmic dexamethasone 1 drop (1 mg/1 ml, three times daily) over two weeks to prevent inflammation and a course of non-steroidal anti-inflammatory drug (bromfenac ophthalmic solution 0.09%) over a month to reduce cyclooxygenase activity and inhibit prostaglandin synthesis [16].

Postoperatively, patients were recommended to continue taking glaucoma medications (the fixed combination of dorzolamide and timolol twice daily, bromonidine twice daily) and acetazolamide orally.

Gradual tapering of medical hypotensive therapy was considered at each follow-up visit in each patient.

Measures of success and failure

IOP between 6 and 21 mmHg (or a reduction in IOP of ≥ 30% from baseline IOP) as well as no ocular pain at 12 months was the primary outcome measure.

Secondary outcomes included postoperative BCVA, number of glaucoma medications, the need for oral acetazolamide, and the need for repeat CPC treatment.

Failure was defined as IOP of ≥ 22 mmHg despite maximal hypotensive medication, the development of serious complications (exudative fibtosis or phthisis) or the need for glaucoma surgery.

The decision to perform repeat CPC was made not earlier than one month after previous CPC. If the effect of hypotensive medications and laser therapy was not enough for long-term control of the patient's IOP, the decision on the need for surgical treatment was made by the surgeon and was individualized according to the needs of the patient, which is in agreement with reports by others [17].

Statistical analyses

Statistical analyses were conducted using Statistica 10.0 (StatSoft, Tulsa, OK, USA) software. Qualitative data are presented as numbers and percentages. Quantitative data were evaluated for normality using the Shapiro-Wilk test. Parametric data are presented as mean ± standard deviation and 95% confidence intervals (CI), and non-parametric data, as median (Me) and interquartile range (IQR). The paired t test was used for the comparison of two parametric variables. The number of postoperative complications, number of medications compared to baseline, and number of follow-up months were recorded for each patient. The Mann-Whitney U-test was used for comparison between groups for these non-parametric data. Chi-square test was used for categorical data. Post hoc analysis for Friedman's test of repeated measures (χ2F) was used within the groups to determine which conditions differ significantly from each other based on average rank of these groups. Spearman correlation coefficients (rs) were calculated. The level of significance $p \leq 0.05$ was assumed.

ANOVA test followed by Post-hoc analysis was used within the groups to find out the statistical significance

Results

Baseline demographic and clinical data

Fifty-eight eyes of 58 patients with a median age of 66 (IQR, 62-68) years were included in the study. Of these, 20 eyes (34%) had no pattern vision. At baseline, the median BCVA was 0.02 (IQR, 0.01-0.03) for 38 eyes (66%), and the mean number plus or minus SD of BCVA for the fellow eyes, 0.23 ± 0.29 (Table 1).

Changes in IOP over the follow-up period

Ocular pain relieved in all patients following CPC. At 1 month (V1), the IOP decreased by 24% and 33% from baseline in group 1 and group 2, respectively ($p < 0.05$) (Table 2). At 6 months (V6), the median IOP decreased to 22 mmHg (IQR, 18-30 mmHg) in group 1, with 47% of eyes having an IOP of less than 21 mmHg. In addition, at this time point, 71% of eyes in group 2 had an IOP of less than 21 mmHg. At 12 months, in group 1 and group 2, the median IOP was 29 mmHg (IQR, 18-22.5 mmHg) and 21 mmHg (IQR, 20-21 mmHg), respectively, and the IOP success rate was 75% and 77%, respectively. The median number of laser interventions per eye for group 1 and group 2 was 4.5 (IQR, 3-9), and 1 (IQR, 1-2.5), respectively ($p = 0.000$), with the average number of laser interventions per eye over 12 months in group 1 being 3.2 times larger than in group 2.

Changes in BCVA over the follow-up period

At the first follow-up visit, the median BCVA changed to 0.02 (IQR, 0.01-0.02) and 0.03 (IQR, 0.02-0.06) in groups 1 and 2, respectively. At months 3 and 6, the median BCVA improved to 0.05 (IQR, 0.01-0.02) and 0.06 (IQR, 0.05-0.08) in groups 1 and 2, respectively. At month 12, BCVA stabilized in group 1 (χ2F = 41.9, $p = 0.000$) and group 2 (χ2F = 35.9, $p = 0.000$). In addition, at month 12, BCVA improved in 16/30 eyes (53%) and 13/28 eyes (46%) in groups 1 and 2, respectively. No significant deterioration in BCVA was noted at any follow-up visit in any of the treated eyes in either group.

Glaucoma medications

At baseline, the mean number plus or minus SD of glaucoma medications was 2.87 ± 0.78 and 3.4 ± 0.79 in groups 1 and 2, respectively. In group 1, 11/30 patients (37%), 12/30 patients (40%), and 7/30 patients (23%) were taking two types, three types and four types of medications, respectively. In group 2, 1/28 patients (3%), 2/28 patients (7%), 10/28 patients (36%) and 15/28 patients (54%) were taking one type, two types, three types and four types of medications, respectively.

At each time point, there was a reduction in the number of topical medications taken. At month 12, the numbers (percentages) of patients not taking any glaucoma medications, and taking one type, two types, and three types of medications, were 1/30 (4%), 13/30 (54%), 9/30 (38%) and 1/30 (4%), respectively, for group 1 versus 1/28 (4.5%), 10/28 (45.5%), 10/28 (45.5%) and 1/28 (4%), respectively, for group 2. In addition, at month 12, the mean number plus or minus SD of glaucoma medications was 1.4 ± 0.65 (χ2F = 62.8, p=0.000) and 1.5 ± 0.67 (χ2F = 64.4, p=0.000) for groups 1 and 2, respectively. The median (IQR) values of the numbers of glaucoma medications at various time points after CPC are presented in Fig. 2.

In groups 1 and 2, the numbers (percentages) of patients taking oral acetazolamide decreased from 26/30 (87%) and 27/28 (96%), respectively, at baseline, to 6/30 (25%) and 4/28 (18%), respectively, at month 12, with no significant difference between groups at either of these points (pV0=0.19; pV12=0.86).

Complications

Long-term inflammation was the most common complication over the follow-up period (43% of patients

Table 1. Demographic and clinical characteristics of groups of patients with neovascular glaucoma (NVG) associated with proliferative diabetic retinipathy (PDR)

Baseline characteristics	Group 1, n = 30 eyes	Group 2, n = 28 eyes	p
Age, years	67 (62-69)	65.5 (62.5-68)	p=0.9 [a]
Males / Females	14 (47%)/16 (53%)	11 (39%)/17 (61%)	p=0.64[B]
Axial length of the eye, mm	22.8 (22.4-23.4)	22.7 (22.3 - 23.4)	p=0.93 [a]
IOP V0, mmHg	38.0 (33-40)	36.0 (33-41)	p=0.96 [a]
Number of topical glaucoma medications	2.87±0.78 (2-4)	3.4±0.79 (1-4)	p=0.01 [c]
Oral acetazolamide	26 (87%)	27 (96%)	p=0.53[B]
Glaucoma surgeries	11 (37%)	10 (36%)	p=0.94[B]
Cataract/ Pseudophakia	21 (70%) /9 (30%)	15 (54%)/13 (46%)	p=0.29[B]
BCVA V0,	0.02 (0.01-0.02)	0.02 (0.02-0.06)	
0 (zero)	11 (37%)	9 (32%)	p=0.07 [a]
0.01-0.1	19 (63%)	19 (68%)	
Panretinal laser photocoagulation, yes/no	6 (20%)/24 (80%)	11 (39%)/17 (61%)	p=0.21[B]
Anti-VEGF therapy, yes/ no	7 (23%)/23 (77%)	6 (21%) / 22 (79%)	p=0.9[B]
Ophthalmoscopic evidence of:	14 (47%)	13 (46%)	
Corneal bullous dystrophy	3 (10%)	2 (7%)	
Corneal edema	4 (13%)	3 (11%)	p=0.01[B]
Posterior hyaloid detachment	2 (7%)	3 (11%)	
Epiretinal membrane	3 (10%)	4 (14%)	
Hyphema/ Vitreous hemorrhage	2 (7%) /1 (3%)	1 (4%)/1 (4%)	
Diabetes duration, years	12 (7-14)	8 (6-11.5)	p=0.88[a]
HbA1c, %	7.0 (7.0-7.3)	7.0 (7.0-7.3)	p=0.549[a]
Presence of cardiovascular pathology	27 (90%)	15 (54%)	
Nephropathy	5 (17%)	6 (21%)	p=0.002[B]
Neuropathy	4 (13%)	3 (11%)	
Smoking	9 (30%)	11 (39%)	p=0.55[B]

Note: p, significance of difference by (a) Mann-Whitney test, (median, interquartile range), (b) Student t-test, mean value ± significant difference (95% confidence interval), (c) Chi-square test, n (%); BCVA, best-corrcted visual acuity; HbA1c, glycated hemoglobin; IOP, intraocular pressure

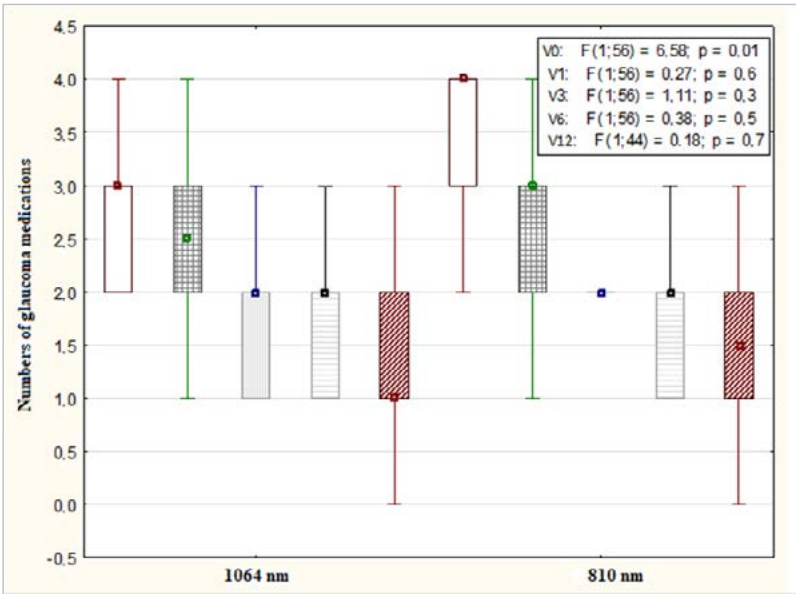

Fig. 2. Boxplots showing median and interquartal ranges for numbers of topical glaucoma medications used by patients of group 1 (treated with the 1064-nm laser) and group 2 (treated with the 810-nm laser) for neovascular glaucoma associated with proliferative diabetic retinopathy at baseline (V0) and various time points (V1, V3, V6 and V12) after cyclophotocoagulation

Table 2. Numbers (percentage) of patients with IOP ≤ 21 mmHg and IOP ≥ 22 mmHg in groups 1 and 2 at time points

Visit	Group 1, number of eyes (percentage)		Group 2, number of eyes (percentage)	
	IOP ≤ 21 mmHg	IOP ≥ 22 mmHg	IOP ≤ 21 mmHg	IOP ≥ 22 mmHg
	n = 30		n = 28	
V0	0	30 (100%)	0	28 (100%)
P_{V0}	$P_{V0(I-II)}$>0.05			
V1	10 (33%)	20 (67%)	8 (29%)	20 (71%)
P_{V1}	χ^2=0.15; $P_{V1(I-II)}$=0.7			
Repeat (II) course of CPC		15 (50%)	-	9 (32%)
		χ^2=1.9; P=0.17		
V3	10 (33%)	20 (67%)	12 (43%)	16 (57%)
P_{V3}	χ^2=0.56; $P_{V3(I-II)}$=0.46			
Repeat (III) course of CPC		8 (27%)	-	7 (25%)
		χ^2=0.02; P=0.89		
V6	14 (47%)	16 (53%)	20 (71%)	8 (29%)
P_{V6}	χ^2=3.66; $P_{V6(I-II)}$=0.056			
Repeat (IV) cource of CPC		6 (20%)	-	4 (14%)
		χ^2=0,33; P=0,57		
V12	n =24		n = 22	
	18 (75%)	6 (25%)	17 (77%)	5 (23%)
P_{V12}	χ^2=0.03; $P_{V12(I-II)}$=0.86			

Note: CPC, cyclophotocoagulation; IOP, intraocular pressure; V, time points at months 1, 3, 6 and 12; p, significance of difference

treated with the diode laser and 20% of patients treated with the Nd:YAG laser, p = 0.03), followed by corneal edema (18% and 10%, p = 0.62) and hyphema (7% and 3%, p = 0.51) (Table 3).

The complications noted in the first month after TSCPC were those seen in eyes with either low vision or no pattern vision. Although hyphema was observed in eyes with a BCVA of 0.1 (group 1), and 0.06 and 0.08 (group 2) at the immediate examination (V0) after CPC, its resolution was observed by the first follow-up visit, which had no impact on the BCVA.

The mean number plus or minus SD of complications over the 12-month follow-up was 0.33 ± 0.44 for group 1 and 0.71 ± 0.46 for group 2, with a relative risk (RR) of 0.47 ± 0.29 [95%CI, 0.27-0.82]) (χ2 = 8.42, p = 0.004).

Treatment success correlated strongly, negatively and significantly with IOP reduction (rs = -0.74, p < 0.05), weakly, negatively and significantly with complication development (rs = -0.31, p < 0.05) and history of smoking (rs = -0.37, p < 0.05), and weakly, positively and significantly with repeat CPC (rs = 0.33, p < 0.05). In addition, complication development showed a mild positive but significant (p < 0.05) correlation with diabetes duration (rs = 0.3), laser wavelength (rs = 0.38), and repeat CPC (rs = 0.32).

Table 4 shows within-group mean changes from baseline to month 12 after CPC in IOP, BCVA, and number of topical and systemic glaucoma medications, as well as percentages of eyes with complications at month 12 for groups 1 and 2.

Discussion

NVG often manifests as a terminal-stage disease with chronic eye pain and elevated IOP, which can lead to blindness and loss of the eye. At this stage of the disease,

Table 3. Numbers (percentage) of different complications in groups over the period from baseline to month 12

Complication	Group 1, number (percentage) of eyes	Group 1, number (percentage) of eyes	χ^2; p
Long-term inflammation	6 (20%)	12 (43%)	χ^2=4.59; p=0.03
Hyphema	1 (3%)	2 (7%)	χ^2=0.43; p=0.51
Corneal edema	3 (10%)	5 (18%)	χ^2=0.25; p=0.62
Vitreous hemorrhage	-	1 (3%)	χ^2=1.09; p=0.3

Note: Chi-square test was used for categorical data; p, significance of difference between groups

Table 4. Summary of results for outcome measures for patients in groups 1 and 2

Outcome measure (V0-V12)	Group 1, n =30 eyes	Group 2, n= 28 eyes	p
Change in IOP, mmHg	18 (14.5-21)	15.5 (15-18)	p=0.35[a]
Change in BCVA	0.03 (0.01-0.05)	0.03 (0-0.04)	p=0.41[a]
Change in the number of glaucoma medications	2 (1-2)	2 (1-3)	p=0.47[a]
Percentage of patients with complications	33%	71%	p=0.004[в]

Note: p, significance of difference by (a) Mann-Whitney test, (median, interquartile range), (b) Chi-square test, n (%)

the treatment aims at reducing IOP, alleviating pain and saving the eye, and preserving pattern vision (if present).

The management of patients with glaucoma associated with diabetic complications is a challenge for ophthalmologist. The European Glaucoma Society Terminology and Guidelines for Glaucoma (5th edition) state that cyclodestructive procedures are indicated when filtration surgery or glaucoma drainage devices are likely to fail, have failed or are not feasible [18].

Transscleral ciliary body ablation utilizing the Nd:YAG laser at 1064 nm wavelength has the theoretical advantage of better scleral penetration (60% to 75%) with less back scatter than the shorter 810-nm wavelength of the diode laser. A semiconductor solid state diode laser system with an 810 mm wavelength exhibits less scleral transmission (about 35%) but considerably greater absorption by melanin of the ciliary pigment epithelium than the 1064 Nd:YAG wavelength [19-21]. This advantage allows the diode laser to use less energy to produce comparable lesions while using a contact, transscleral approach to CPC. Dosed scleral compression additionally increases scleral penetration by laser and enables reducing the energy of laser exposure [11, 22].

A major advantage of CPC is that it can be repeated if the first treatment does not yield the desired result. Some surgeons advocate using a lower amount or laser energy over a longer duration of time, whereas others advocate increasing the power in eyes with severe IOP elevation and poor vision [23, 24].

In the current study, we used a 1064-nm laser system and an 810-nm laser system, and employed low energy settings with the former system (1.0 J/pulse, with 41 applications for a total energy of 41 J per session) and the latter system (1.5 J/pulse, with 30 applications for a total energy of 45 J per session). However, with the Nd:YAG laser system, we performed three CPC sessions every other day for each eye, and taking into account repeat treatments, the number of sessions over 12 months was 3.2 times larger for Nd:YAG laser CPC than for diode laser CPC (p=0,000).

Aquino and colleagues [5] used higher energy levels with the diode laser (the laser settings used were 1.5-2 W, 2 s exposure time, 20-28 burns per eye delivering 60-112 J per treatment). In a study by other researchers [25], typically, the number of applications ranged from 10 to 40, the starting power was set at 1500 mW for 1500 ms and gradually increased until soft "pops" were heard during treatment, and the success rate was 51%.

Alzuhairy and colleagues [26] compared outcomes of transscleral diode CPC using short duration (1.5 s with variable power ≤ 2 W) versus longer duration treatment (4 s with variable power ≤ 1 W), and found no significant difference in terms of IOP reduction and the number of IOP lowering medications. However, longer duration treatment appeared to result in a decrease in visual acuity and greater postoperative inflammation [26].

Duerr and colleagues [23] compared the outcomes of standard pop-titrated TSCPC (a starting power of 1.75 W and 2.0-second duration) and slow-coagulation TSCPC (1.25 W and 4.0 to 4.5-second duration for dark or light brown irises, and 1.5 W and 3.5 to 4.0-second duration for other iris pigmentation). They concluded that the former technique and the latter technique resulted in similar VA and IOP outcomes and comparable complication profiles, although the former technique had a higher incidence of prolonged inflammation postoperatively.

That is why, based on the findings of previous studies [14] and clinical experience, we decided not to use high laser energy levels and to assess the outcomes of TSCPC treatment for diabetic neovascular glaucoma and minimize complications in a study with a 12-month follow-up.

In the current study, we demonstrated that the primary outcome measure (an IOP ≤ 21 mmHg or a reduction in IOP of ≥ 30% from baseline IOP at 12 months) was achieved in 35/46 eyes (76%). Particularly, the success rate at 12 months was 75% and 77% for eyes that received Nd:YAG laser TSCPC and diode laser TSCPC, respectively (p = 0.86). We found no significant difference between the groups in the IOP reduction from baseline at month 12 (p = 0.35). In the Nd:YAG laser TSCPC and diode laser TSCPC groups, the IOP reduced by 46% and 45%, respectively (p = 0.34) from baseline values of 38.0 mmHg and 36.0 mmHg, respectively (p = 0.96) at day 358 and day 362.5 after TSCPC, respectively (p = 0.01). At 12 months, the mean IOP in group 1 was 17.9 mmHg, and in group 2, 16.8 mmHg, with a between-group difference of 1.1 [95% CI, 0.89; 1.42] mmHg.

Youn and colleagues [20] compared the efficacy of TSCPC using a Nd:YAG or diode laser in controlling IOP in patients with refractory glaucoma. They reported no significant difference in IOP between groups at 6 months and 12 months postoperatively (p = 0.97 and p = 0.54, respectively).

In the current study, the frequency of repeat CPC took into account the 2nd course of treatment in 50% of eyes treated with Nd:YAG laser TSCPC and 32% of eyes treated with diode laser TSCPC (p = 0.17), the 3rd course of treatment in 27% of eyes treated with Nd:YAG laser TSCPC and 25% of eyes treated with diode laser TSCPC (p = 0.89), and the 4th course of treatment in 20% of eyes treated with Nd:YAG laser TSCPC and 16% of eyes treated with diode laser TSCPC (p = 0.57). Therefore, the average number of laser interventions per eye in group 1 was 3.2 times larger than in group 2. At month 12 after CPC, the BCVA in patients with preserved pattern vision improved in both groups (p = 0.41).

Some studies reported a reduction in BCVA by 2 or more lines in the Early Treatment of Diabetic Retinopathy Study (ETDRS) chart in eyes at month 12 after CPC for refractive NVG. Aquino and colleagues [5] did not report on the mean change in visual acuity, but observed a reduction in vision in two subjects in the continuous wave CPC group (n = 23) and one in the micropulse CPC group (n = 23). Duerr and colleagues [23] noted a reduction in visual acuity (a change ≥ 0.2 LogMAR) in 57.9% and 65.0% of patients of slow-coagulation TSCPC and standard pop-titrated TSCPC groups.

In the current study, there was no significant difference in the number of anti-glarcoma medications at month 12 after CPC (p = 0.47). Particularly, the numbers of IOP-lowering medications were reduced to 1.54 after Nd:YAG laser TSCPC and to 1.82 after diode laser TSCPC (p = 0.47), which is similar to findings of other studies.

Aquino and colleagues [5] did not assess the number of glaucoma medications required at month 12 after CPC. They, however, noted that the numbers of IOP-lowering medications were reduced from two to one 18 months after micropulse CPC and two to one after continuous wave CPC. Chan and colleagues [24] compared the efficacy and safety of diode TSCPC using either the long duration or short duration. They concluded that the long duration protocol, using less laser power, appeared better in reducing medication requirement by 6 months.

In the current study, the numbers of patients requiring oral acetazolamide were reduced after CPC by 67% in the Nd:YAG laser treatment group and by 71% in the diode laser treatment group (p = 0.86).

Aquino and colleagues [5] also reported on the reduction in the need for oral acetazolamide after CPC, which is in agreement with our findings.

Although CPC has been used to treat refractory glaucoma successfully, significant postoperative complications (i.e. visual loss, phthisis, loss of light perception) and discomfort have been reported by people undergoing this procedure [6].

In the current study, the rate of complications was higher for eyes treated with diode laser TSCPC than for those treated with Nd:YAG laser TSCPC (71% versus 33%, p = 0.004). Inflammation was the most common complication in both groups, but was significantly less common in eyes treated with Nd:YAG laser TSCPC than in those treated with diode laser TSCPC (20% versus 46%, p = 0.03). Corneal edema was the second most common complication (10% versus 14%, respectively, p = 0.62). Post-procedural hyphema was also less common in group 1 than in group 2 (3% versus 7%, p = 0.51). In addition, intravitreal hemorrhage was noted only in one eye (3%) treated with the diode laser. No eye in the current study exhibited postprocedural hypotony.

In a study by Duerr and colleagues [23], inflammation was the most common complication in both groups but occurred at a significantly lower frequency in the slow coagulation CPC group (34%) than in the standard pop-titrated CPC group (73%).

Post-procedural eye pain was less common in the slow coagulation CPC group (15%) than in the standard pop-titrated CPC group (35%) in a study by Duerr and colleagues [23]. However, in the current study, all patients reported on the disappearance of eye pain after CPC. In addition, the complications (cataract progression, lens subluxation, necrotizing scleritis, phthisis bulbi, and sympathetic ophthalmia) reported by others [27] were not observed in our study.

Conclusion

This study with a follow-up of 12 month demonstrated that TSCPC utilizing a 1064-nm Nd:YAG laser is as effective for NVG associated with PDR as that utilizing a 810-nm diode laser. Nd:YAG laser TSCPC resulted in a reduction in IOP to ≤ 21 mmHg at month 12 in 75%, and diode laser TSCPC, in 77% of patients with diabetic NVG. The number of CPC sessions per eye required for treatment success with the Nd:YAG laser was 3.2 times larger than that required with the diode laser. However, the relative risk of complications after diode laser TSCPC was by 53% higher than that after Nd:YAG laser TSCPC. Both these types of CPC are safe and can be repeatedly used to improve treatment efficacy.

References

1. Tang Y, Shi Y, Fan Z. The mechanism and therapeutic strategies for neovascular glaucoma secondary to diabetic retinopathy. Front Endocrinol (Lausanne). 2023;14:1102361. doi:10.3389/fendo.2023.1102361.
2. Havens SJ, Gulati V. Neovascular Glaucoma. Dev Ophthalmol. 2016;55:196-204.
3. Garkava NA, Fedirko PA, Babenko TF, Dorichevska RY. Radiation induced violations of blood circulation in the ciliary body and changes of the anterior chamber angle in the pathogenesis of glaucoma in clean-up workers of the Chornobyl NPP accident and residents of contaminated areas. Probl Radiac Med Radiobiol. 2017;22:332–338.
4. Guzun O, Zadorozhnyy O, Wael C. Current Strategy of Treatment for Neovascular Glaucoma Secondary to Retinal Ischemic Lesions. J Ophthalmol (Ukraine). 2024;2:32–39. https://doi.org/10.31288/oftalmolzh202423239.
5. Aquino MC, Barton K, Tan AM, Sng C, Li X, Loon SC, Chew PT. Micropulse versus continuous wave transscleral diode cyclophotocoagulation in refractory glaucoma:

A randomized exploratory study. Clin Exp Ophthalmol. 2015;43:40–46.
6. Lin P, Wollstein G, Glavas IP, Schuman JS. Contact transscleral neodymium:yttrium-aluminum-garnet laser cyclophotocoagulation. Long-term outcome. Ophthalmology. 2004;111(11):2137-43.
7. Martin KR, Broadway DC. Cyclodiode laser therapy for painful, blind glaucomatous eyes. Br J Ophthalmol. 2001;85(4):474-476.
8. Ma A, Yu SWY, Wong JKW. Micropulse laser for the treatment of glaucoma: A literature review. Surv Ophthalmol. 2019;64:486–497.
9. Pastor SA, Singh K, Lee DA, Juzych MS, Lin SC, Netland PA, Nguyen NT. Cyclophotocoagulation: A report by the American Academy of Ophthalmology. Ophthalmology. 2001;108:2130–2138.
10. Schlote T, Derse M, Rassmann K, Nicaeus T, Dietz K, Thiel HJ. Efficacy and safety of contact transscleral diode laser cyclophotocoagulation for advanced glaucoma. J Glaucoma. 2001;10:294–301.
11. Vogel A, Dlugos C, Nuffer R, et al. Optical properties of human sclera and their significance for trans-scleral laser use. Fortschr Ophthalmol. 1991;88(6):754-761.
12. Chechin P, Guzun O, Khramenko N, Peretyagin O. Efficacy of transscleral Nd:YAG laser cyclophotocoagulation and changes in blood circulation in the eye of patients with absolute glaucoma. J Ophthalmol (Ukraine). 2018;2:34–39. https://doi.org/10.31288/oftalmolzh/2018/2/34-39.
13. Zadorozhnyy O, Guzun O, Kustryn T, Nasinnyk I, Chechin P, Korol A. Targeted transscleral laser photocoagulation of the ciliary body in patients with neovascular glaucoma. J Ophthalmol (Ukraine). 2019;4:3–7. http://doi.org/10.31288/oftalmolzh2019437.
14. Guzun O, Zadorozhnyy O, Artyomov A, Elagina V. Histological Changes in the Intraocular Structures of an Enucleated Eye with Uveal Melanoma and Secondary Painful Neovascular Glaucoma after Palliative Diode Transscleral Cyclophotocoagulation (Clinical Case). Oftalmologija. Vostochnaja Evropa. 2021;3(11):368-377.
15. Bernardi E, Töteberg-Harms M. MicroPulse Transscleral Laser Therapy Demonstrates Similar Efficacy with a Superior and More Favorable Safety Profile Compared to Continuous-Wave Transscleral Cyclophotocoagulation. J Ophthalmol. 2022 Feb 8;2022:8566044. doi: 10.1155/2022/8566044
16. Guzun OV, Velichko LN, Bogdanova AV, Zadorozhnyy OS, Korol AR. Dynamics of the molecular marker of intercellular adhesion (ICAM-1) in patients with neovascular glaucoma after transscleral laser cyclocoagulation. 10-th World glaucoma congress. June 28-July 1, 2023, Rome, Italy. Abstract book. PLB-013 - P.431.
17. Prum BE Jr, Rosenberg LF, Gedde SJ, Mansberger SL, Stein JD, Moroi SE, et al. Primary Open-Angle Glaucoma Preferred Practice Pattern Guidelines (2015). Ophthalmology. 2016;123(1):P41-111.
18. European Glaucoma Society Terminology and Guidelines for Glaucoma, 5th Edition. Br J Ophthalmol. 2021;105(Suppl 1):1-169. doi: 10.1136/bjophthalmol-2021-egsguidelines. PMID: 34675001.
19. Pastor SA, Singh K, Lee DA, et al. Cyclophotocoagulation: a report by the American Academy of Ophthalmology. Ophthalmology. 2001;108:2130–8.
20. Youn J, Cox TA, Herndon LW, Allingham RR, Shields MB. A clinical comparison of transscleral cyclophotocoagulation with neodymium: YAG and semiconductor diode lasers. Am J Ophthalmol. 1998;126(5):640-647.
21. Chen TC, Pasquale LR, Walton DS, Grosskreutz CL. Diode laser transscleral cyclophotocoagulation. Int Ophthalmol Clin. 1999;39:169–76.
22. Linnik LA, Privalov AP, Chechin PP, Zheltov GI, Tverskoĭ IuL. [Laser transscleral contact-compression coagulation of the fundus oculi tissues]. Oftalmol Zh. 1989;(6):362-364.
23. Duerr ER, Sayed MS, Moster S, Holley T, Peiyao J, Vanner EA, Lee RK. Transscleral Diode Laser Cyclophotocoagulation: A Comparison of Slow Coagulation and Standard Coagulation Techniques. Ophthalmol Glaucoma. 2018;1(2):115-122. doi: 10.1016/j.ogla.2018.08.007.
24. Chan JC, Chow SC, Lai JS. Effectiveness and Safety of Long Duration versus Short Duration Diode Laser Transscleral Cyclophotocoagulation. Clin Ophthalmol. 2020;14:197-204. doi: 10.2147/OPTH.S228910.
25. Alabduljabbar K, Bamefleh DA, Alzaben KA, Al Owaifeer AM, Malik R. Cyclophotocoagulation versus Ahmed Glaucoma Implant in Neovascular Glaucoma with Poor Vision at Presentation. Clin Ophthalmol. 2024;18:163-171. doi: 10.2147/OPTH.S424321.
26. Alzuhairy S, Albahlal A, Aljadaan I, Owaidhah O, Al Shahwan S, Craven ER, Mousa A, Edward DP. Intraocular Pressure Outcomes Following Transscleral Diode Cyclophotocoagulation Using Long and Short Duration Burns. J Glaucoma. 2016;25(9):e782-6. doi: 10.1097/IJG.0000000000000503.
27. Ishida K. Update on results and complications of cyclophotocoagulation. Curr Opin Ophthalmol. 2013;24(2):102-10. doi: 10.1097/ICU.0b013e32835d9335.

Disclosures

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Abbreviations: *BCVA, best corrected visual acuity; CPC, cyclophotocoagulation; DM, diabetes mellitus; DR, diabetic retinopathy; IOP, intraocular pressure; Nd:YAG, Neodymium:yttrium-aluminum-garnet; NVG, neovascular glaucoma; PDR, proliferative diabetic retinopathy; TSCPC, transscleral cyclophotocoagulation*

Figures to article Guzun O.V. et al. «Efficacy of Nd:YAG and diode laser transscleral cyclophotocoagulation in the management of neovascular glaucoma associated with proliferative diabetic retinopathy»

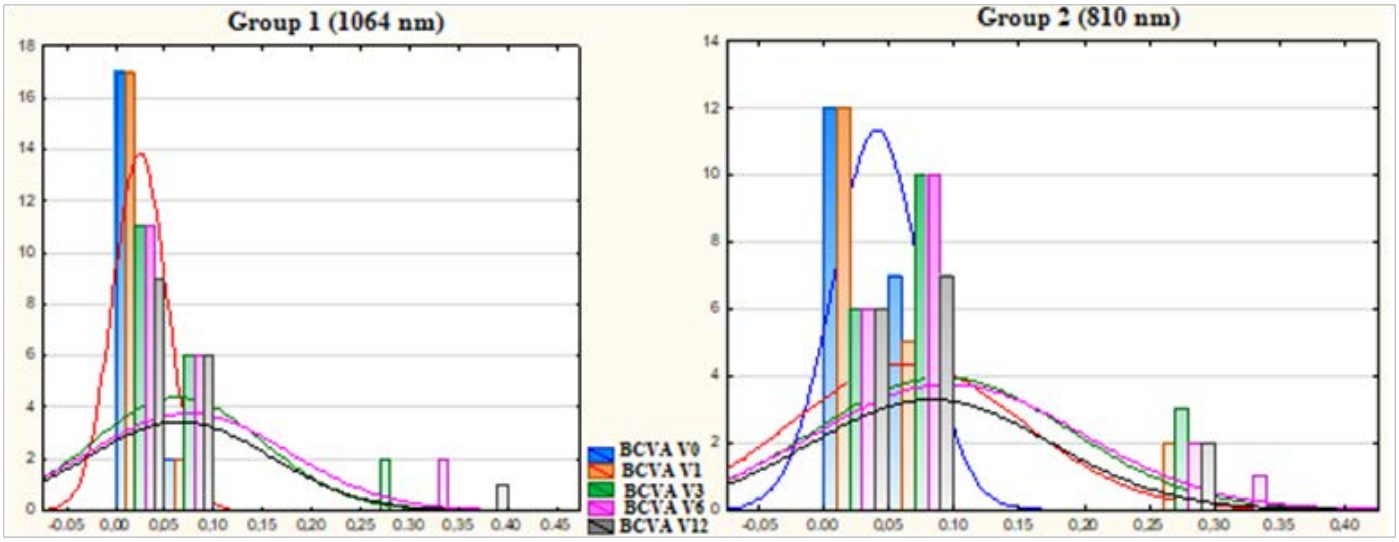

Fig. 1. Histograms of best-corrected visual acuity (BCVA) distributions in eyes of patients of group 1 (treated with the 1064-nm laser) and group 2 (treated with the 810-nm laser) at baseline (V0) and various time points (V1, V3, V6 and V12). The abscissa displays BCVA, and the ordinate represents number of patients.