·Clinical Research·

Effects of primary selective laser trabeculoplasty on anterior segment parameters

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Received: 2014-04-02 Accepted: 2014-09-10

Abstract

• **AIM: To investigate the effects of selective laser trabeculoplasty (SLT) on the main numerical parameters of anterior segment with Pentacam rotating Scheimpflug camera in patients with ocular hypertension (OHT) and primary open angle glaucoma (POAG).**

• **METHODS: Pentacam measurements of 45 eyes of 25 (15 females and 10 males) patients (12 with OHT, 13 with POAG) before and after SLT were obtained. Measurements were taken before and 1 and 3mo after SLT. Pentacam parameters were compared between OHT and POAG patients, and age groups (60y and older, and younger than 60y).**

• **RESULTS: The mean age of the patients was 57.8±13.9 (range 20-77y). Twelve patients (48%) were younger than 60y, while 13 patients (52%) were 60y and older. Measurements of pre-SLT and post-SLT 1mo were significantly different for the parameters of central corneal thickness (CCT) and anterior chamber volume (ACV) (*P*<0.05). These parameters returned back to pre-SLT values at post-SLT 3mo. Decrease of ACV at post-SLT 1mo was significantly higher in younger than 60y group than 60y and older group. There was no statistically significant difference in Pentacam parameters between OHT and POAG patients at pre- and post-treatment measurements (*P*>0.05).**

• **CONCLUSION: SLT leads to significant increase in CCT and decrease in ACV at the 1st month of the procedure. Effects of SLT on these anterior segment parameters, especially for CCT that interferes IOP measurement, should be considered to ensure accurate clinical interpretation.**

• **KEYWORDS:** anterior segment; selective laser trabeculoplasty; Pentacam

DOI:10.3980/j.issn.2222-3959.2015.05.18

Guven Yilmaz S, Palamar M, Yusifov E, Ates H, Egrilmez S, Yagci A. Effects of primary selective laser trabeculoplasty on anterior segment parameters. *Int J Ophthalmol* 2015;8(5):954-959

INTRODUCTION

Selective laser trabeculoplasty (SLT) is a safe and effective technique to lower intraocular pressure (IOP) in primary open angle glaucoma (POAG) and ocular hypertension (OHT) patients[1,2]. This procedure can be used as a primary or supplemental treatment for these patients[3,4]. SLT selectively targets the pigmented trabecular cells without damaging the adjacent nonpigmented meshwork structure[5]. It has been suggested that SLT reduces IOP by initiating a series of biological events that facilitate trabecular outflow, but the exact mechanism of action remains unclear[5-8].

Pentacam rotating Scheimpflug camera (Oculus Optikgerate GmbH, Wetzlar, Germany) promises quantitative information and qualitative imaging of the anterior and posterior surfaces of the cornea, anterior chamber depth (ACD), anterior chamber angle (ACA), iris, and lens[9]. The assessment of the changes in anterior segment parameters may enable important information about the effects of SLT on aqueous humour dynamics and mechanism of action of IOP reduction.

In this prospective study, we aimed to investigate the influences of SLT on various parameters of anterior segment as measured with pentacam [ACD, anterior chamber volume (ACV), ACA width, central corneal thickness (CCT), mean astigmatism and keratometry] which could be affected by the procedure in patients with POAG and OHT. Some changes in anterior segment such as endothelial cell count, CCT, and refractive error after SLT were previously reported[10,11]. Effects of SLT on anterior segment parameters, especially on CCT-that interferes IOP measurements-should be considered to ensure accurate clinical interpretation. To the best of our knowledge, the alterations in anterior segment parameters (ACD, ACV, ACA, CCT) as measured with Pentacam after SLT have not previously been reported.

SUBJECTS AND METHODS

Subjects Forty-five eyes with newly diagnosed and previously untreated POAG or OHT from 25 patients with IOP higher than 21 mm Hg were enrolled. Glaucoma and OHT diagnosis were established following European Glaucoma Society (EGS) Guidelines [12] in all patients by a glaucoma specialist. POAG diagnose was based on abnormal visual field testing and corresponding disc changes with open angles on gonioscopy. OHT was defined as an IOP of 22 mm Hg or higher with normal optic discs and minimum two normal visual field tests. Normal visual field is defined as visual field within the normal range of visual field indices [MD: 0 dB to -2 dB and pattern standard deviation (PSD): P>0.05][12]. In this study SLT was performed as the primary treatment in patients either with high-risk OHT or mild to moderate POAG. Patients with any refractive errors higher than 0.50 D, secondary glaucoma, normotensive glaucoma, primary angle closure, history of intraocular inflammation, trauma and surgery, advanced glaucoma (cup/disc ratio 0.9 or higher and visual field defect within 10° of fixation) were excluded. Ethics approval for this prospective study was obtained from the Ege University Local Research Ethics Committee. Written informed consent for laser treatment and for participation in the study were obtained from each patient.

Methods All participants underwent a complete ophthalmic examination, including best corrected visual acuity (BCVA) measurement using a logarithm of minimum-angle-of-resolution chart (logMAR chart, Lighthouse Inc., Long Island, NY, USA), auto-refraction (Topcon RM-8000B, Topcon Corporation, Tokyo, Japan), IOP measurement using Goldmann applanation tonometry (Haag-Streit, Koniz, Switzerland), and visual field testing with 24-4 SITA protocol (Humphrey Visual Field Analyzer, Carl Zeiss Meditec AG, Berlin, Germany). All patients were treated with 360-degree SLT after a baseline measurement of IOP and Pentacam. All Pentacam measurements were obtained under dark light conditions approximately 1 lx using a digital light meter (Extech 401027 Pocket Digital Light Meter, Extech Instruments, Waltham, MA, USA). SLT treatment was performed by the same ophthalmologist (Yusifov E) using the Q-switched, Nd-YAG laser machine Ellex Tango (Ellex Lasers, Adelaide, Australia) 5min after instillation of one drop of proparacaine hydrochloride (Alcaine; Alcon Laboratories UK Ltd., Texas, USA). The starting energy level was 0.6 mJ which was increased or decreased until a bubble formation appeared. After bubble formation the energy level was decreased by 0.1 mJ for the remainder of the treatment. A total of 90 to 100 laser burns with a spot size of 400 μm and pulse duration 3 nanoseconds were given using the Latina SLT Gonio Laser gonioscopy lens (Ocular Instruments, USA) to visualize the trabecular meshwork. The IOP of the treated eye was measured to detect any possible IOP spike 1h after treatment. Patients received topical ketorolac tromethamine 0.5% (Acular, Allergan Inc., USA) four times daily for 5d after the procedure. Antiglaucomatous drugs were initiated whenever target IOP (20% or more reduction from baseline IOP, and IOP below or equal to 21 mm Hg) was not achieved.

Measurements After baseline measurements which were obtained immediately before SLT, patients were followed at the first and the third months after SLT treatment to repeat IOP and Pentacam measurements.

Pentacam system is based on a 180° rotating Scheimpflug camera that can take 12-50 single images to reconstruct the anterior chamber. After completing a scan, Pentacam software constructs the 3-dimensional image of the anterior segment and calculates the anterior chamber parameters. This imaging provides measurements of ACD, ACV, ACA width, CCT, pupil size and keratometry.

Statistical Analysis Statistical analysis was performed with SPSS for Windows Version 12.0 (SPSS Inc., Chicago, IL, USA). All data were reported as averages ±standard deviations (SD). For the comparison of the mean IOP reduction between pre- and post-SLT in the same eye a paired t-test was used. Independent sample t-test was performed to compare the mean percentage of IOP reduction in patients <60y versus ≥60 years of age. Wilcoxon and Mann-Whitney U non-parametric tests were used to compare variables between the pre- and post-SLT Pentacam parameters of all 45 eyes in which data were not normally distributed. Spearman correlation test was used to calculate the correlation between IOP and anterior segment parameters. P value of 0.05 or less was considered statistically significant. Repeatability analysis of study parameters measured with Pentacam was evaluated with coefficient of variation (Cv). Cv is defined as the ratio of the standard deviation to the mean: $c_v = \frac{\sigma}{\mu}$

For Cv calculation of study parameters measured by Pentacam, 10 consequential measurements were performed by same operator to the same adult volunteer's same eye with a period of 2min [13].

RESULTS

Baseline and post-treatment IOP and Pentacam data of 45 eyes of 25 consecutive patients with OHT or POAG treated with 360-degree SLT were evaluated. The mean age of the patients was 57.8±13.9 (range 20-77y) and 48% of cases were <60 years of eye. OHT was diagnosed in 24 eyes of 12 patients, and POAG in 21 eyes of 13 patients (Table 1).

Initial IOP (25.9±4.4 mm Hg; range 21.0 to 36.0) decreased significantly to 18.4±3.5 (range 10.0 to 26.0) mm Hg with 29% IOP reduction at the 1st month and 17.4±3.5 (range 13.0 to 34.0) mm Hg with 33.8% IOP reduction at the 3rd month following SLT (P<0.01 and P<0.01, respectively; paired t-test). Antiglaucomatous drugs (0.005% latanoprost) were prescribed in 9 eyes (20%) of 6 patients due to inadequate IOP reduction (20% or more reduction from baseline IOP, and IOP below or equal to 21 mm Hg) at post-SLT 1st month. Four of these 6 patients were ≥60 years of age. Measurements of pre- and post-SLT 1mo disclosed that only

Table 1 Demographic and clinical characteristics of the patients *n* (%)

Features	Values
Age±SD (a)	57.8±13.9
<60 years old patients	12 (48)
≥ 60 years old patients	13 (52)
Sex (M/F)	10/15
Patients (*n*)	25
Unilateral	5
Bilateral	20
BCVA (logMAR units)	0.2±0.1
Spherical equivalent (diopters)	-0.3±0.2
Pre-SLT IOP (mm Hg)	25.9±4.4
VF index (dB)	
MSD	5.1±1.9
PSD	3.1±0.8
Diagnosis	
POAG	13 (52)
OHT	12 (48)

SD: Standard deviation; BCVA: Best corrected visual acuity; SLT: Selective laser trabeculoplasty; IOP: Intraocular pressure; VF: Visual field; MSD: Mean standard deviation; PSD: Pattern standard deviation; POAG: Primary open angle glaucoma; OHT: Ocular hypertension

IOP (from 25.1±3.1 to 22.1±0.6 mm Hg) value was significantly different in antiglaucomatous initiated 9 eyes (*P* = 0.03; paired *t*-test).

Regarding all eyes, mean CCT measurement was 573.5±25.8 (range 518.0 to 625.0) μm pre-SLT and showed significant increase to 591.7 ±36.1 (range 526.0 to 662.0) μm at post-SLT 1mo (*P*<0.01; Wilcoxon signed-rank tests). Mean CCT value significantly decreased and returned back to pre-SLT value (565.5±30.6) μm at post-SLT 3rd month (*P*< 0.01; Wilcoxon signed-rank tests).

Mean ACV measurement was 146.8±47.4 (range 88.0-294.0) mm^3 pre-SLT and changed to 143.1 ±46.7 (range 83.0-285.0) mm^3 and 145.3±46.0 (range 88.0-283.0) mm^3 at post-SLT 1 and 3mo, respectively. The ACV difference between pre- and post-SLT 1mo was statistically significant, whereas not significant difference was detected between pre-SLT and post-SLT 3mo (*P* =0.001 and *P* =0.195, respectively; Wilcoxon signed-rank test).

No correlation between IOP change and CCT and ACV change was detected at post-SLT 1 and 3mo compared to baseline values (Table 2) (*P*>0.05; Spearman correlation analysis).

No statistically significant difference in the means of K_1, K_2, ACD, ACA, pupil diameter (PD) parameters between pre-SLT and post- SLT 1 was detected (*P*>0.05; Wilcoxon signed-rank test) (Table 3).

Considering age, there was no statistically significant difference between pre-SLT and post-SLT 1 and 3mo values in the means of IOP, CCT, K_1, K_2, ACD, ACA, PD (*P*>0.05).

Table 2 Correlation between changes of IOP and CCT, ACV parameters at post-SLT 1mo compared to baseline values

Parameters	Correlation coefficient	*P*
IOP versus CCT change at post-SLT 1mo	-0.017	0.91
IOP versus ACV change at post-SLT 1mo	0.028	0.86
IOP versus CCT change at post-SLT 3mo	-0.052	0.73
IOP versus ACV change at post-SLT 3mo	0.095	0.54

SLT: Selective laser trabeculoplasty; CCT: Central corneal thickness (μm); ACV: Anterior chamber volume (mm^3).

However, decrease of ACV value at post-SLT 1mo was significantly higher in patients <60 years old than those who were ≥60 years of age (*P*=0.01; Mann-Whitney *U* test) (Table 4).

There was no statistically significant difference in terms of IOP and Pentacam parameters between OHT and POAG patients (*P*>0.05; Mann-Whitney *U* test).

Repeability analysis of study parameteres measured with Pentacam was calculated. The Cv of K_1, K_2, ACD, CCT, ACV, PD and ACA were 0.11%, 0.20%, 0.72%, 1.63%, 2.73%, 5.95%, 6.11%, respectively. The least reliable parameters were ACA and pupil size[12].

DISCUSSION

A number of publications demonstrated the efficacy of SLT as an IOP-lowering procedure in patients with OHT and POAG [1,14-16]. In accordance to these reports, significant decrease of IOP was achieved in all eyes of our patients at the post-SLT 1 and 3mo. Despite the significant decrease of IOP, antiglaucomatous drugs were prescribed in 9 eyes (20%) of 6 patients due to inadequate IOP reduction (less than 20%) at post-SLT 1st month. Ayala and Chen[16] reported a significant negative correlation between successful SLT and age (*P*=0.015). Similarly 4 of 6 patients that displayed inadequate reponse to SLT were over 60 years of age. It was concluded that autochemical factors (prostaglandins and other inflammatory cytokines) are reduced due to increased age which leads to decreased response to SLT in elder patients [17]. In contrast, Hodge *et al* [18], and Mao *et al*[19] reported that they did not find any significant correlation between SLT success and age in their studies.

Due to good safety profile, SLT is a commonly performed laser procedure for the treatment of both OHT and POAG. Less common side effects of the procedure include mild and transient inflammation, ocular pain, and a small risk of moderate IOP elevation after the procedure [1]. Ocular discomfort and blurry vision after SLT might be related to corneal edema due to transient corneal endothelial dysfunction. White *et al* [10] reported acute transient corneal endothelial change such as endothelial spots, slight increase in intracellular spacing and dysmorphism after SLT without any impact on cell count or visual acuity. Whitish spots in the corneal endothelium are also reported to be noted after

Table 3 The measured values of IOP and Pentacam parameters

Parameters	Pre-SLT±SD	Post-SLT±SD (1st month)	Post-SLT±SD (3rd month)	P^1	P^2	P^3
IOP	25.9±4.4	18.4±3.5	17.4±3.5	<0.01[a]	<0.01[a]	0.055
K_1	43.0±1.7	42.9±1.7	42.9±1.6	0.438	0.504	0.836
K_2	43.9±1.8	43.8±1.8	43.9±1.8	0.837	0.824	0.656
CCT	573.5±25.8	591.7±36.1	565.5±30.6	<0.01[a]	0.033	<0.01[a]
ACD	2.8±0.4	2.8±0.4	2.8±0.4	0.435	0.263	0.643
ACV	146.8±47.4	143.1±46.7	145.3±46.0	0.001[a]	0.195	0.368
ACA	33.3±6.2	33.7±4.6	33.4±5.2	0.243	0.986	0.277
PD	3.4±1.0	3.3±0.7	3.3±0.7	0.986	0.633	0.828

SD: Standard deviation; IOP: Intraocular pressure (mm Hg); K_1: Horizontal keratometry (mm); K_2: Vertical keratometry (mm); CCT: Central corneal thickness (μm); ACD: Anterior chamber depth (mm); ACV: Anterior chamber volume (mm^3); ACA: Anterior chamber angle (degree); PD: Pupil diameter (mm). [a]$P<0.05$ (paired *t*-test for IOP and Wilcoxon signed-ranks test for K_1, K_2, CCT, ACD, ACV, ACA, and PD). [1]Comparison pre-SLT and post-SLT (1st month); [2] Comparison pre-SLT and post-SLT (3rd month); [3]Comparison post-SLT (1st month) and post-SLT (3rd month).

Table 4 The measured values of patients ≥60 and <60 years of age

Parameters	Differences between pre- and post-SLT 1st month	Differences between pre- and post-SLT 3rd month	Differences between post-SLT 1st and 3rd months
IOP			
<60a	-8.6±4.6	-10.0±5.5	-1.4±3.5
≥60a	-6.4±3.7	-7.1±5.4	-0.7±4.3
[b]*P*	0.108	0.379	0.672
K_1			
<60a	-0.1±0.5	-0.1±0.6	0.0±0.3
≥60a	0.0±0.5	0.0±0.7	-0.1±0.6
[c]*P*	0.624	0.618	0.859
K_2			
<60a	0.1±0.4	0.1±0.3	0.0±0.4
≥60a	-0.1±0.5	0.0±0.4	0.1±0.5
[c]*P*	0.306	0.320	0.758
CCT			
<60a	25.7±28.3	-2.6±11.7	-28.3±29.1
≥60a	11.0±23.8	-13.2±25.9	-24.2±19.5
[c]*P*	0.078	0.251	0.856
ACD			
<60a	0.0±0.1	0.0±0.5	0.0±0.1
≥60a	0.0±0.7	0.4±0.2	0.0±0.2
[c]*P*	0.690	0.344	0.499
ACV			
<60a	-6.6±7.3	-2.6±12.1	4.7±11.1
≥60a	-0.1±5.6	-0.4±12.8	0.5±14.2
P	[a]0.014	[c]0.955	[c]0.162
ACA			
<60a	0.7±4.1	0.9±3.6	1.3±3.8
≥60a	-1.8±4.1	-1.7±3.2	0.1±4.2
[c]*P*	0.095	0.186	0.633
PD			
<60a	-0.4±1.1	-0.3±1.0	0.1±0.5
≥60a	0.2±0.5	0.1±0.4	-0.1±0.4
[c]*P*	0.064	0.488	0.340

SD: Standard deviation; IOP: Intraocular pressure (mm Hg); K_1: Horizontal keratometry (mm); K_2: Vertical keratometry (mm); CCT: Central corneal thickness (μm); ACD: Anterior chamber depth (mm); ACV: Anterior chamber volume (mm^3); ACA: Anterior chamber angle (degree); PD: Pupil diameter (mm). [a]$P<0.05$ (Mann-Whitney *U* test); [b]$P>0.05$ (Independent *t*-test); [c]$P>0.05$ (Mann-Whitney *U* test).

SLT [20]. The present study demonstrated significant changes in Pentacam parameters with increase in CCT and decrease in ACV at post-SLT 1mo in eyes with OHT and POAG. These findings returned back to pre-SLT values at post-SLT 3rd month. In contrast to our results, Lee *et al* [11] reported that the mean CCT values decreased significantly at 1wk post-SLT and returned to baseline values by 1mo. Authors postulated that the statistically significant thinning might be due to the dissipation of heat from the laser energy into the corneal stroma, resulting in temporary thermal contractions of the stromal collagen fibers, similar to the effect seen with laser thermokeratoplasty [11]. The incidence of post-SLT corneal edema has been previously reported as approximately 0.8% [1]. White *et al* [10] reported in a series of 10 patients treated with 180 SLT that subtle endothelial changes were diffusely noted on slit lamp examination but these changes disappeared up to 6wk. Ong and Ong[20] observed that patients who had pigmentation on corneal endothelium in pre-SLT examination, demonstrated more prominent and larger spots at post-SLT evaluation as detected with specular microscopy. They concluded that in corneas with endothelial pigmentation and/or compromised corneas, there may be long term effects of corneal endothelial dysfunction. The reason of CCT increase at post-SLT 1mo in our study might be the corneal edema due to temporary endothelial dysfunction related to laser therapy. Recovery of CCT at post-SLT 3mo is probably due to the decrease of inflammatory process triggered by SLT. Moreover, it is obvious that racial factors might also effect the amount of pigmentation and inflammation that lasts longer causing prolonged corneal endothelial dysfunction in our study. One of the possible reasons for the prolonged inflammation that lasted longer causing prolonged corneal endothelial dysfunction in our study in contrast to Lee *et al*[11] is probably the use of only topical NSAIDs. As Lee *et al*[11] reported that topical steroids were used for 1d immediately following SLT, the inflammation and corneal endothelial dysfunction were less in their study. The linear correction scale shows that IOP changes 2.5 mm Hg for every 50 μm difference in CCT [21,22]. In our study we detected an 18 μm increment in CCT at post-SLT 1mo that corresponds to approximately 1 mm Hg correction of IOP. Although it seems to be a minor change, it has been shown that every 1 mm Hg drop of IOP lowers the risk of glaucoma progression by 10% [23].

Beltran-Agullo *et al* [8] reported that the reduction in IOP after SLT is associated with the increase in tonographic outflow facility, but not related to any change in aqueous production. The decrease in ACV at post-SLT 1mo could be explained by the facilitated aqueous outflow *via* the trabecular meshwork. This result is similar to Hammel *et al*[24], which demonstrated a significant of ACV in 1st postoperative day after insertion of Ex-PRESS miniature glaucoma implant. They explained this decrease in ACV after Ex-PRESS with a transient overfiltration. They reported positive but not satististically significant association between ACV and IOP (higher IOP correlated with higher ACV). Positive correlation between these two parameters were detected in our study as well. The difference did not reach statistical significance, probably due to the limited number of patients. Significant decrease in ACV after pilocarpine and laser iridotomy in patients with occludable angles was reported by Talajic *et al*[25]. They related this result to the anterior shift in the iris-lens diaphragm caused by pharmacologically-induced accomodation[25].

No significant difference in terms of IOP after SLT was detected between OHT and POAG patients in our study. These results are consistent with Ayala and Chen [16] who found no difference in IOP after SLT in patients with OHT and POAG. Additionally we have not found any difference in any of the numerical parameters of anterior segment in OHT and POAG patients as measured with Pentacam.

To the best of our knowledge, this is the first study to demonstrate the effects of SLT on the anterior chamber parameters. Pentacam might be a useful device that can demonstrate the indirect effects of SLT on anterior chamber parameters-for especially scientific investigations. However, this device can not be used solely for monitoring patients with OHT or POAG. The changes in CCT should be taken into consideration when evaluating IOP obtained at first month. Additional studies with longer follow-up and increased number of patients are required to substantiate our results.

ACKNOWLEDGEMENTS

Conflicts of Interest: Guven Yilmaz S, None; **Palamar M**, None; **Yusifov E**, None; **Ates H**, None; **Egrilmez S**, None; **Yagci A**, None.

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