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ORIGINAL ARTICLE

Evaluation of the effects of selective laser trabeculoplasty on anterior segment parameters by anterior segment optical coherence tomography

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Abstract

To prospectively examine the effects of selective laser trabeculoplasty (SLT) on the anterior chamber angle (ACA) and its related parameters using anterior segment-optic coherence tomography (AS-OCT). Fifty eyes of 50 patients with primary open angle glaucoma (POAG) and ocular hypertension were included in the study. AS-OCT was performed before SLT application, immediately after and at 1 day and 1 month. Intraocular pressure (IOP), central corneal thickness (CCT) and anterior chamber depth (ACD) were also recorded and evaluated. No statistically significant difference was determined in ACA and other AS-OCT parameters (AOD, angle opening distance at 500 and 750 mm; TISA, trabecular-iris space area at 500 and 750 mm) before and 1 day after SLT application ($p > 0.05$). However, a statistically significant increase was determined in both the temporal and nasal ACA, AOD and TISA values between the baseline and day 30 ($p < 0.001$). No statistically significant change was observed in the CCT or ACD values ($p > 0.05$). SLT resulted in an increase in ACA, AOD and TISA when evaluated using AS-OCT. We think that this study provides a different perspective concerning the effects of SLT in the angle region and the involved mechanism.

Keywords Selective laser trabeculoplasty · Anterior segment optical tomography · Glaucoma

Introduction

Selective laser trabeculoplasty (SLT) is an effective intraocular pressure (IOP) reducing technique widely used in the treatment of primary open angle glaucoma (POAG) and ocular hypertension (OHT). SLT can be used as the first-choice treatment in these diseases, and it is also employed to reduce the numbers of topical glaucoma medications and prevent the need for surgery [1]. However, the effect mechanisms of this widely used treatment are still not fully understood [2].

Anterior segment optic coherence tomography (AS-OCT) has recently become an effective, reliable and repeatable imaging tool in clinical practice [3]. The laser energy in SLT applied to the angle region may be expected to cause histopathological and microstructural changes [2, 4]. Previous studies have investigated AS-OCT findings in patients undergoing YAG laser capsulotomy [5], laser peripheral iridoplasty [6] and peripheral laser iridotomy [7]. However, our review of the literature revealed no previous studies using AS-OCT in eyes undergoing SLT. The purpose of our study was to investigate the probable effects of SLT on the anterior chamber angle (ACA) and its related parameters using AS-OCT.

Methods

Study population

Local clinical ethical permission was obtained before the study commenced. Fifty eyes of 50 patients diagnosed with POAG and OHT were included. If both eyes were suitable for inclusion in the study, the right eye was selected as the outcome measurements from both eyes of the same subject tended to be positively correlated [8].

The eyes of volunteers aged over 18, with no previous history of intraocular surgery, SLT, iridoplasty, or iridectomy, were included following the receipts of the consent forms.

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Selective laser trabeculoplasty

One-hundred-shot SLT (LIGHTLas SLT Deux SLT/YAG Combination Laser, Lightmed) was applied by increasing the power by 0.1 mJ/pulse until bubbles formed in the region exposed to the laser at a 360° trabecular mesh, 400 μm spot size, 3 ns duration and an initial power of 0.6 mJ/pulse.

Topical anaesthesia was applied to all patients before treatment. Carbomer Gel (Viscotears, Novartis Pharma AG, Basel, Switzerland) was applied to the goniolens to provide viscosity.

Steroid drops were used 6 times daily for 1 week by all patients. Patients previously receiving antiglaucomatous treatment were allowed to continue with this.

AS-OCT

AS-OCT (NIDEK RS-3000, NIDEK Co. Ltd, Japan) measurements were performed before SLT and were repeated on days 1 and 30. The same AS-OCT operator performed all measurements, and the operator was blind to this treatment. Images of the nasal and temporal quadrants (180° and 0° meridians) were taken with patients in a darkened room using the ACA line until adequate centration and quality were achieved for analysis. The cornea radial scan pattern was used to measure the central corneal thickness (CCT).

ACA width was calculated by measuring the angle between the posterior angle of the cornea and the tangential iris line. Following the manual identification of the apex of the iris recess and scleral spur, the ACA width was analysed using standard parameters. Angle opening distances (AOD) at 750 mm (AOD 750) and AOD at 500 mm (AOD 500) were measured as the perpendicular distances from the trabecular meshwork at 750 mm and 500 mm, respectively, anterior to the scleral spur to the anterior surface of the iris. Trabecular iris space area (TISA) was defined as the trapezoidal area (TISA 750 or 500) bounded by the AOD 750 or 500, the anterior iris surface, the inner corneo-scleral wall and the perpendicular distance between the scleral spur and the opposing iris (Fig. 1).

Anterior chamber depth (ACD) was evaluated before and 30 days after SLT using a Monitor A&B Scan biometry. After corneal anaesthesia, the biometry probe was placed vertically at the centre of the cornea. ACD was determined by calculating the mean of five consecutive measurements. CCT values were also measured and recorded.

IOP measurements were also repeated using Goldmann applanation tonometry before and 30 days after SLT.

Statistical analysis

After compatibility with the normal distribution of the study data had been confirmed with the Kolmogorov-Smirnov test, statistical calculations between two dependent groups were performed using the t test. P values < 0.05 and < 0.001 were regarded as statistically significant. These analyses were conducted with the SPSS software, version 20.0 (SPSS Inc., Chicago, IL).

Results

Demographic data

The mean age of the patients in the study was 52.7 ± 11.8 years (range: 38–79). Among the patients, 27 were women and 23 were men; 38 right eyes and 12 left eyes were included. Twenty-nine patients were diagnosed with POAG and 21 with OHT. Additionally, 19 patients were treatment naïve, and 31 were already receiving antiglaucomatous therapy.

Findings

The mean pre-SLT IOP was 25.1 ± 4.7 mmHg, which statistically and significantly decreased to 18.8 ± 4.3 mmHg on day 30 ($p < 0.001$). The CCT values before and 30 days after SLT were 521.3 ± 44.7 μm and 523.9 ± 42.1 μm, respectively ($p = 0.27$). No significant change was observed between the initial and day 30 ACD values ($p = 0.18$). All IOP, CCT and ACD parameters are summarised in Table 1.

No statistically significant differences were observed in the ACA, AOD 500 and 750 and the TISA 500 and 750 parameters before and immediately after SLT application ($p > 0.05$). A statistically significant increase was found in the temporal and nasal regions ACA, AOD and TISA values between the baseline and 30 days after SLT ($p < 0.001$). All of the AS-OCT and ACD parameters, before and after SLT applications, are summarised in Table 2.

Discussion

Our study found a decrease in IOP values during the follow-up in the first month after SLT. According to the results of several clinical and review studies and meta-analyses, SLT is an effective means of reducing the IOP and is widely employed in clinical practices [9–11]. However, the effect mechanisms of SLT on IOP are not yet fully understood. In addition, the physiological, histopathological and structural changes occurring in the region of SLT application have also not been fully explained.

Latina and Park reported that the laser applied at SLT to the trabecular region in clinical practice affected both the trabecular pigmented cells and the peripheral non-pigmented cells [12]. One study on human autopsy specimens examined ALT and SLT and reported histopathological changes and damage due to thermal and coagulative effects in both laser treatments,

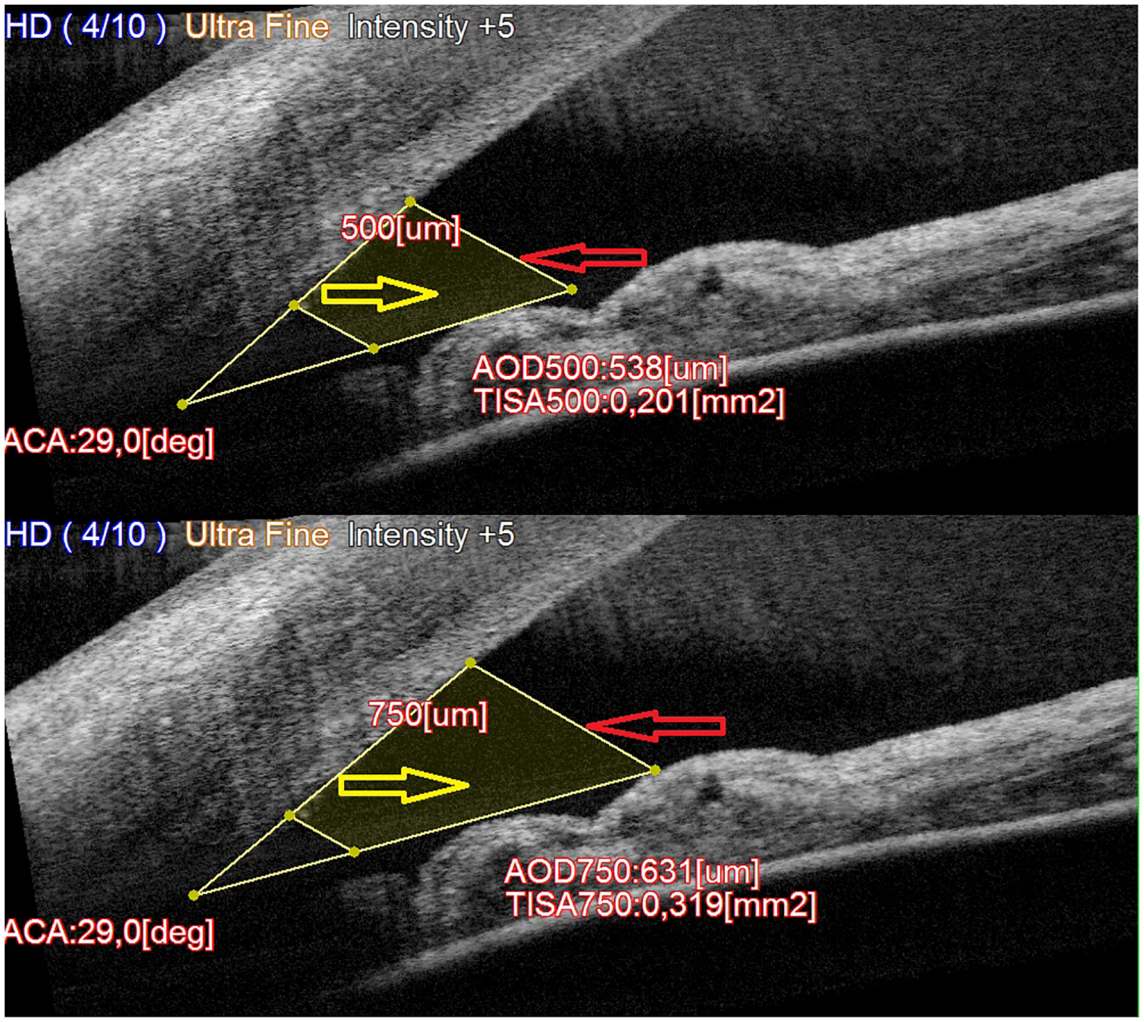

Fig. 1 ACA, anterior chamber angle measuring the angle between the posterior angle of the cornea and the tangential iris line; red arrows, AOD (angle opening distance) perpendicular distances from the trabecular meshwork 750 mm and 500 mm; yellow arrows, TISA (trabecular iris space area) the trapezoidal area bounded by the AOD 750 or 500, the anterior iris surface, the inner corneo-scleral wall and the perpendicular distance between the scleral spur and the opposing iris

although the effects were relatively greater in ALT than in SLT [13]. Cvenkel et al. compared the histopathological effects of SLT and ALT on enucleated eyes diagnosed with choroidal melanoma. They reported findings indicative of thermal and coagulative injury in the angle, the corneal endothelium and the root and surface of the iris in both methods, although the injury was milder in SLT [4]. In summary, changes that could result in fibrosis, cell death, tissue necrosis and scar formation, such as the disruption and fragmentation in the trabecular meshwork, the expansion and endothelial damage in Schlemm's canal and the scleral stroma and cellular debris accumulation, were observed. On the basis of the changes

Table 1 Change in intraocular pressure, central corneal thickness and anterior chamber depth before and after selective laser trabeculoplasty

	n = 50	Before	After (day 30)	*p*
IOP, mmHg	Mean ± SD	25.1 ± 4.7	18.8 ± 4.3	0,000
	Range	21–29	14–23	*HS*
CCT, μm	Mean ± SD	521.3 ± 44.7	523.9 ± 42.1	0.27
	Range	477–591	471–588	*NS*
ACD, mm	Mean ± SD	3.63 ± 0.46	3.89 ± 0.41	0.18
	Range	3,3–4,1	3,5–4,4	*NS*

IOP intraocular pressure, *CCT* central corneal thickness, *ACD* anterior chamber depth, *NS* non-significant, *S* significant, *HS* highly significant

Table 2 Change in angle parameters after and before (day 1, day 30) selective laser trabeculoplasty

	$n = 50$	Before	After (day 1)	After (day 30)	P1 (before vs day 1)	P2 (before vs day 30)
Temporal angle						
ACA T, degree	Mean ± SD	34.97 ± 5.8	35.05 ± 6.11	39.05 ± 7.3	0.31	0,001
	Range	27.8–41.6	27.1–42.5	28.5–48.6	*NS*	*HS*
AOD500 T, μm	Mean ± SD	542.9 ± 85.8	538.7 ± 101.9	589.3 ± 84.3	0.11	0,000
	Range	492–601	485–619	511–654	*NS*	*HS*
AOD750 T, μm	Mean ± SD	720.7 ± 125.8	736.3 ± 131.7	779.6 ± 187.2	0.18	0,000
	Range	687–796	685–802	703–861	*NS*	*HS*
TISA500 T, mm^2	Mean ± SD	0.1992 ± 0.0562	0.2057 ± 0.0671	0.2814 ± 0.0357	0.49	0,001
	Range	0.176–0.218	0.18–0.231	0.212–0.306	*NS*	*HS*
TISA750 T, mm^2	Mean ± SD	0.3222 ± 0.0882	0.3182 ± 0.049	0.4611 ± 0.0704	0.33	0,001
	Range	0.275–0.358	0.29–0.365	0.42–0.517	*NS*	*HS*
Nasal angle						
ACA N, degree	Mean ± SD	36.02 ± 8.7	35.05 ± 6.11	40.53 ± 9.5	0.23	0,000
	Range	28.9–43.8	27.1–42.5	31.4–49.2	*NS*	*HS*
AOD500 N, μm	Mean ± SD	551.8 ± 101.8	549.7 ± 96.5	597.3.3 ± 114.7	0.17	0,001
	Range	502–614	489–600	517–652	*NS*	*HS*
AOD750 N, μm	Mean ± SD	737.9 ± 90.6	726.1 ± 101.5	781.4 ± 165	0.25	0,000
	Range	696–785	703–794	691–881	*NS*	*HS*
TISA500 N, mm^2	Mean ± SD	0.2012 ± 0.0259	0.1943 ± 0.0504	0.2953 ± 0.0576	0.41	0,000
	Range	0.186–0.243	0.177–0.22	0.231–0.334	*NS*	*HS*
TISA750 N, mm^2	Mean ± SD	0.3347 ± 0.0609	0.3382 ± 0.0569	0.4765 ± 0.0954	0.15	0,000
	Range	0.295–0.374	0.275–0.386	0.416–0.591	*NS*	*HS*

ACA anterior chamber angle, *AOD* temporal angle opening distance AOD N, *TISA* nasal trabecular-iris space area, *T* temporal, *N* nasal, *NS* non-significant, *S* significant, *HS* highly significant

recorded in the AS-OCT parameters in our study, we believe that a series of reactions concluding in fibrosis in the angle and surrounding tissues may occur because of the thermal and coagulative effects of SLT.

One cell culture study on the effect mechanisms of SLT attributed a lowering effect on IOP to the increase in permeability in endothelial cells in Schlemm's canal and the trabecular meshwork mediated by cytokines, such as IL-1α, IL-1β, TNF-α and particularly IL-8, which is considered to be released after SLT [14]. Another study showed an increase in the production and release of IL-1β and TNF-α 8 h after SLT and suggested that this increased the aqueous outflow [15]. A study maintaining that the effect mechanisms of SLT are associated with the permeability of Schlemm's canal [2] showed an expansion in the canal using enhanced depth imaging optical coherence tomography. This study observed the expansion in Schlemm's canal sections and the increased volume in the canal, and these findings were correlated with a decrease in IOP [2]. Although the purpose of the present study was not to investigate the effect mechanisms of SLT, we consider the increase in ASA and other AS-OCT parameters to be a clue explaining the long-term effects of SLT on IOP. Moreover, we believe that our study examined the effects of SLT on ACA and its associated parameters to yield the first evidence using AS-OCT. These findings are compatible with studies suggesting that SLT increases the trabecular outflow [16], permeability in Schlemm's canal cells [17] and cytokine production and secretion [14, 15], and that the expansion and volume in Schlemm's canal sections increase [2].

OCT is a non-invasive, repeatable and reliable imaging technique. AS-OCT, particularly, provides high-quality imaging of the iridocorneal angle and the parameters associated with that angle, including the root of the iris and the scleral spur [3]. In contrast to the weak repeatability of gonioscopy, the fact that AS-OCT is non-contact means that the anterior chamber depth, angle and angle parameters are more reliable [18]. These parameters have been shown to be compatible with the Schaffer angle grading system [19]. Studies investigated the use of AS-OCT for examining changes in the angle following various laser and surgical procedures in a number of diseases. Lee et al. reported a significant increase in angle values following peripheral laser iridotomy [20]. One study on the changes in angle values before and after laser peripheral iridoplasty using AS-OCT observed the expansion of the angle and an increase in the AOD and TISA values [21]. Similar changes were shown when changes in the angle parameters after YAG capsulotomy were evaluated using AS-OCT [5]. Studies have also evaluated AS-OCT in the assessment of open- and closed-angle glaucoma, the aqueous pathway following trabeculectomy and similar surgical procedures in the corneal and conjunctival diseases and surgeries, in the tear film layer and in various other conditions [22]. However, we

encountered no previous studies assessing the effects of SLT, which is widely employed in clinical practice, on the angle or assessing the angle parameters using AS-OCT. We hypothesised that evaluating SLT, which is applied to the angle region and known to cause changes in these tissues, using AS-OCT would be a better idea. Thus, we examined the ACA, AOD and TISA parameters obtained using the spectral domain OCT and the device's own software and found an increase in all three parameters following the SCT application. We interpreted the increases in ACA, AOD and TISA not being observed in ACD to indicate that this effect is limited to the region to which SLT is applied.

The most important limitation of our study is that it does not have a control group. Nevertheless, the AS-OCT operator who performed all the AS-OCT measurements was blind to this treatment to prevent bias.

In conclusion, this study demonstrates that, although SLT effectively decreases the IOP, it leads to ACA expansion in the anterior chamber and an increase in AOD500 and 750 and TISA500 and 750 values. These results provide a different perspective on the effects of SLT on these parameters and on elucidating the effect mechanisms of SLT. We consider AS-OCT to be important in the evaluation of laser and surgical procedures and medications directly affecting the anterior chamber.

Compliance with ethical standards

Conflicts of interest The author declare that they have no conflict of interest.

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