Titanium-Sapphire Laser Trabeculoplasty in the Treatment of Open-Angle Glaucoma

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INTRODUCTION

Laser trabeculoplasty is accepted as an effective treatment in patients with open-angle glaucoma. Success rates of 30% IOP reduction have been reported although the effect may be temporary.1-4 There are several types of lasers currently used in glaucoma treatment including argon, diode, krypton and neodymium:YAG.2,5-11 Argon laser trabeculoplasty (ALT) is, by far, the most commonly used treatment, but may be associated with early anterior chamber reaction, local irritation, peripheral anterior synechia (PAS) formation and IOP spikes.5,9,11

Argon laser trabeculoplasty is thought to lower IOP by triggering a biological response within the trabecular meshwork (TM). However, scarring of the trabecular meshwork that is associated with ALT limits its effectiveness in subsequent applications.6,11-14 As a result of this limitation of ALT, selective laser trabeculoplasty (SLT) was developed as a gentler method of IOP reduction without the unnecessary scarring of the trabecular meshwork.

Selective laser trabeculoplasty (SLT) utilizes a frequency-doubled neodymium:YAG laser (Nd:YAG SLT) and has been shown to be at least as effective as ALT but with less ocular inflammation and fewer IOP spikes after treatment.1,3,15-19 The lack of trabecular scarring after SLT may allow repeated treatments in patients with previous ALT.

We present a third treatment option, Titanium-Sapphire laser trabeculoplasty (TiSLT) that was developed in attempt to improve the efficacy of laser therapy of the trabecular meshwork (Fig. 1).

The physical parameters of the Ti-Sapphire laser are: a wavelength of 790 nm; exposure time of 7 mSec, and a spot size of 200 microns. (Figs 2 and 3) Such infrared wavelength is associated with deeper penetration into the TM, affecting tissues like juxta-canaliculare region and inner wall of Schlemm’s canal (SC) (Fig. 4). An in vivo study comparing the histology of 3 different lasers (ALT, SLT and TiSLT) in an enucleated human eye confirmed that TiSLT penetrates deeper with disruption of inner wall of Schlemm’s canal (Presented at the unpublished data) (Figs 5 and 6). If indeed this effect occurs ‘in vivo’ there would be an earlier and greater reduction of IOP after TiSLT.

In the present study, we evaluate the safety and efficacy of TiSLT in patients with medically uncontrolled OAG with no previous history of filtration surgery or laser treatment.

MATERIALS AND METHODS

Eighteen patients with medically uncontrolled open-angle glaucoma were enrolled and were treated with. Mean age was
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<table>
<thead>
<tr>
<th></th>
<th>ALT</th>
<th>Solix® 790 Laser</th>
<th>SLT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser type</td>
<td>Argon</td>
<td>Titanium: sapphire</td>
<td>Frequency doubled Q-switched Nd: YAG</td>
</tr>
<tr>
<td>Wavelength</td>
<td>488 and 514 nm (blue-green)</td>
<td>790 Nm (infrared)</td>
<td>532 Nm (green)</td>
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<tr>
<td>Energy/power per pulse</td>
<td>0 to 1 watt</td>
<td>30 to 80 millijoules</td>
<td>0.1 to 2.0 millijoules</td>
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<tr>
<td>Pulse duration</td>
<td>0.1 to 1 second</td>
<td>7 microseconds</td>
<td>3 nanoseconds</td>
</tr>
<tr>
<td>Pulse rate</td>
<td>Continuous wave</td>
<td>Single shot and 1 Hz</td>
<td>Single shot</td>
</tr>
<tr>
<td>Spot size</td>
<td>50 to 500 micron</td>
<td>200 micron</td>
<td>400 micron</td>
</tr>
<tr>
<td>Peak power (max)</td>
<td>2 W</td>
<td>11 kW</td>
<td>666 kW</td>
</tr>
</tbody>
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Fig. 2: Comparative parameters of ALT, SLT and SOLX laser

<table>
<thead>
<tr>
<th></th>
<th>ALT</th>
<th>Solix® 790 Laser</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Absorption</td>
<td>Strong</td>
<td>Moderate</td>
<td>Strong</td>
</tr>
<tr>
<td>Penetration</td>
<td>Short</td>
<td>Deep</td>
<td>Short</td>
</tr>
<tr>
<td>Energy</td>
<td>High</td>
<td>Moderate</td>
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<tr>
<td>Peak power</td>
<td>Very low</td>
<td>Moderate</td>
<td>Very high</td>
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<tr>
<td>Pulse duration</td>
<td>Long</td>
<td>Moderate</td>
<td>Very short</td>
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<tr>
<td>Thermal damage</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
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<tr>
<td>Repeatable</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
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Fig. 3: Comparative parameters of ALT, SLT and SOLX laser

Fig. 4: Comparison of depth of penetration of the individual lasers
Patients underwent complete eye examinations including visual acuity, IOP, gonioscopy, slit-lamp biomicroscopy and visual field testing (Humphrey, 24-2, stimulus 3, Carl Zeiss AG, Oberkochen, Germany). To qualify for inclusion was a minimum IOP of 24 mm Hg over the course of 2 pressure checks.

Patients were examined before laser treatment and at 1 hour, 1 day, 1 week, 1 month and then every three months thereafter or as deemed necessary from their glaucoma status. Patients with follow-up of less than 3 months were excluded from the study and were considered as dropouts.

Success was defined as IOP <=18 mm Hg or 30% reduction in IOP without anti-glaucoma medications. In eyes where the targeted IOP was not achieved, anti-glaucoma medications were given. Patients with glaucoma progression or uncontrolled IOP, despite maximally tolerated medical management underwent trabeculectomy and were defined as failures.

**Laser Treatment**

TiSLT Laser treatment was performed under topical anesthesia at 180° nasal of the trabecular meshwork in all cases. The patients were treated using a fixed laser setting of 790 nm wavelength with pulse duration of 7 microseconds and a spot size of 200 µm. Treatment was started with a 50 mj spot size and was titrated down to 30 mj if deemed necessary. A Goldman 3-mirror goniolens was placed on the eye with 1% methylcellulose. The aiming beam was focused onto pigmented TM, and 50 adjacent, but non-overlapping laser spots were placed over 180° of the TM. The endpoint of each laser application was mini-bubble or a burst of pigment. There was no use of topical apraclonidine pre-operatively or steroid eyedrops post-operatively.

IOP was assessed immediately after 1 and 2 hours, 1 day, 1 week, 1 month and every 3 months thereafter up to 18 months.
RESULTS

The mean IOP reduction was 8.3 (± 2.7) mm Hg to 17.1 (± 2.7) mmHg postoperatively (P < 0.001, paired samples t test). On average, there was an IOP reduction of 32% (± 10%). The number of anti-glaucoma medications remain unchanged [1.4 (±1.0) pre-operatively to 1.3 (±1.0) postoperatively (P = 1.0, paired samples t test)].

There was a drastic initial early post-operative drop of IOP. (Mean IOP at 2 hours post-op was 17.9 mm Hg).

One patient had an IOP spike (defined as an increase of IOP > 6 mm Hg) 1 hour and 2 hours post-treatment, respectively (Fig. 7).

The IOP decrease observed at 1 month was a good predictive value of the final decrease in IOP for all patients (r = 0.5, P = 0.002 and r = 0.3, P = 0.7 for 1 month and 1 week respectively).

In term of treatment failures and complications, 1 patient underwent trabeculectomy and was considered as a failure. Gonioscopy revealed an open angle without ant sign of peripheral anterior synechiae (PAS). There was no significant deterioration in visual fields at the final visit.

DISCUSSION

TiSLT was effective in this series of eyes. There was a drastic initial early post-operative drop of IOP, this early IOP reduction may suggest deeper penetration of TiSLT with disruption of inner wall of Schlemm’s canal. However, this effect was short lived and IOPs had a trend to return from low teens to mid-teen levels.

Despite the efficacy of ALT, there are limitations to this procedure due to early IOP spikes (31% according to GLT study) and PAS formation. Studies in monkey eyes have shown trabecular destruction followed by scarring and obstruction to aqueous flow after ALT. Such changes are the main reason for limiting ALT to 2 sessions of 180 degrees each. Too extensive ALT treatment in monkeys has been shown to trigger refractory glaucoma. In the current study we found no PAS formation in our glaucoma patients. This may indicate that long-term TiSLT may be safer than ALT. As far as early IOP spikes in our series, our patients had a relatively low occurrence (11%).

Other laser techniques such as selective laser trabeculoplasty (SLT) have been shown to be safe and effective in treatment of glaucoma. Previous studies comparing selective vs. argon laser trabeculoplasty in OAG patients report similar decrease in IOP. Damji and associates compared SLT and ALT in OAG and found similar decreases in IOP in both groups after 1 year. The SLT group achieved a 5.9 mmHg IOP decrease compared to a 6.0 mm Hg IOP decrease in the ALT group. Similarly, both groups had a 25% reduction in pre-treatment IOP at the end of follow-up. At 6 months, Martinez-de-la-casa and associates report 22 and 20% decrease in IOP in

![Fig. 7: Pre- and post-treatment IOP for OAG patients treated with titanium sapphire laser trabeculoplasty](image)
ALT and SLT groups respectively. Additional studies support these findings. We report the success of TiSLT in decreasing IOP in OAG patients over a period of 2 years; however, the majority of patients still required the same number of anti-glaucoma medication in order to control IOP.

In this preliminary study we had a relatively small number of patients. We believe that TiSLT may serve as an additional valuable tool in addition to other trabeculoplasty lasers in the reduction of IOP.

There was no PAS formation the TiSLT group may suggest a non-necrotic response in the trabecular meshwork with possible multiple re-treatments. Further studies with larger numbers of patients and longer follow-up are needed to further explore the benefits of TiSLT in the treatment of OAG.

REFERENCES