Laser Canalostomy (LC) using the TM:YAG

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Introduction

Viscocanalostomy [1], a modified nonpenetrating deep sclerectomy [2] NPDS, is a procedure for POAG surgery with a low postoperative risk profile. Using Stegmann`s microsurgical approach, the outer wall of the canal of Schlemm can be removed ("unroofing of Schlemm`s canal") during the preparation of the deep scleral flap towards the clear Descemet `s membrane in a controlled way. By this surgical preparation, the nasal and temporal orifices of Schlemm`s canal adjacent to the site of the deep sclerectomy are exposed, thus allowing for probing of the surgical ostia (Fig. 1). However, the level of intraocular pressure (IOP) which can be achieved by this procedure is not as low as compared to a successful standard trabeculectomy, especially in cases where the preoperative IOP is only moderately elevated. This may be due to the fact that the major component of the outflow resistance [3-5], the anterior juxta-canalicular trabecular meshwork (TM), remains intact by this surgical procedure.

The objective of adding laser canalostomy (LC) to standard NPDS is to overcome the trabecular meshworks main outflow resistance away from the site of NPDS by an intervention which is supposed to induce minimal trauma to the delicate TM tissue (Fig.2). In contrast to a standard trabeculotomy of Harms and Mackensen, only small openings within the TM are aimed for. The retrograde approach from inside Schlemm`s canal towards the anterior chamber offers the change to avoid damage of the posterior wall of Schlemm`s canal. The development of LC is based on our surgical NPDS modifcation "irrigation trabeculotomy", where balanced salt solution is injected into Schlemm`s canal using especially designed irrigation cannulas at the end of the viscocanalostomy operation. [Burk; EGS Meeting Würzburg 1999].

The purpose of this in vitro study is to describe the feasibility of retrograde TM ablation from inside Schlemm`s canal using two different YAG lasers.

Materials and Methods

Photoablation:

To perform micro ablations of the inner wall of Schlemm´s canal and the adjacent juxtacanalicular trabecular meshwork, we used a Tm:YAG laser and an Er:YAG laser (InPro Hamburg, Germany; Type CUT) in the normal spiking mode. The Tm:YAG emits a radiation of 2.01 µm with a tuneable pulse lengths < 1000 µs and a repetition rate < 10 Hz up to a maximal averaged power of 10 W. The Er:YAG emits a radiation of 2.94 µm with a tuneable pulse lengths < 600 µs and a repetition rate < 10 Hz up to a maximal averaged power of 10 W. The laser was operated multimode with a uniform beam profile. At the tip, the laser beam was coupled into a quarz fiber of 100 microns core diameter. The energy per pulse delivered through the fiber was measured with a joule meter (PEM 10) at its high sensitivity of 81.5V/J. The fluence per pulse was calculated from energy per pulse and the measured spot diameter. The fluence was regulated by changing of the bank voltage.

For the laser canalostomy (LC) procedure, we designed a special probe [6] with a side firing tip in which the energy is coupled out by a gold mirror at an angle of 40°. The design of the tip follows the curvature of Schlemm`s canal with a radius of 7 mm. The maximum outer diameter of the probe is 300 microns (Fig. 10).

In vitro studies

LC deep sclerectomy (Fig. 3) was performed in vitro in three fixated (formalin 4%) and two freshly enucleated human donor eyes which were not suitable for corneal transplantation.

Schlemm`s canal surgery

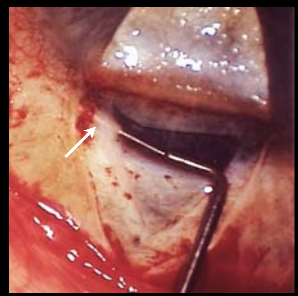


Fig. 1: Viscocanalostomy in clinical setting. The arrow indicates the tip of the cannula.

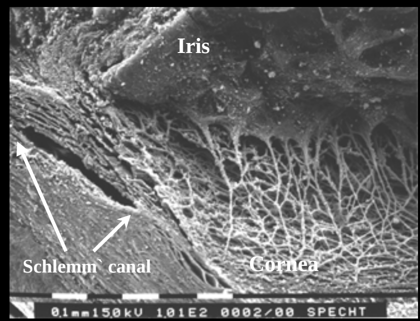


Fig. 2: Scanning electron migrograph (SEM) of chamber angle showing the canal of Schlemm and trabecular meshwork

Fig. 3: Laser probe inserted into the canal of Schlemm in vitro

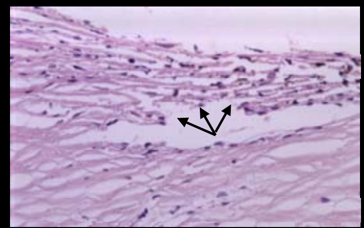


Fig. 4: Light micrograph shows selective ablation of inner TM (10 pulses, Er:YAG)

Fig. 5: SEM displays ablation of inner wall of Schlemm`s canal

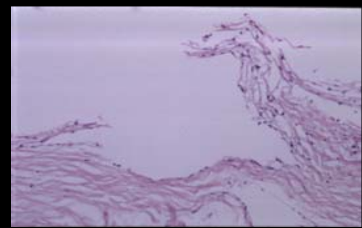
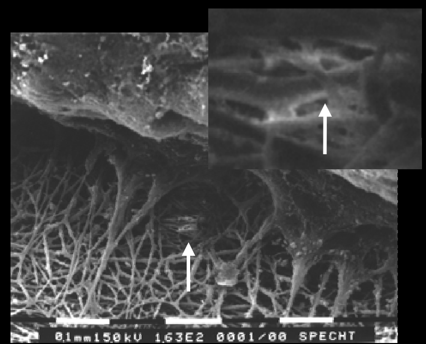


Fig. 6: Light micrograph shows complete ablation of TM from the inside of Schlemm`s canal (20pulses, TM:YAG)



Figs. 7: SEM demonstrates retrograde microablation of the trabecular meshwork from inside the canal of Schlenmm with minimal thermal damage

Figs. 8: SEM demonstrates retrograde microablation of the trabecular meshwork from inside the canal of Schlenmm

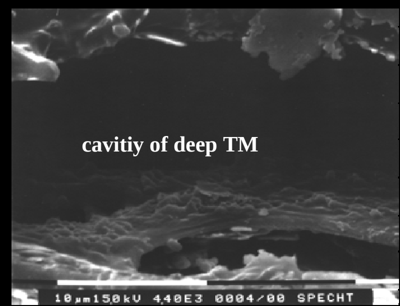


Fig. 9: SEM demonstrates retrograde microablation of the trabecular meshwork (higher magnification from Fig. 8).

Fig. 10: Prototype of laser probe for laser canalostomy

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Bausch & Lomb GmbH, Heidelberg manufactured the laser tip according to our specifications

Fig. 11: Prototype of TM:YAG and Er:YAG Laser

Surgical procedure

A lamellar scleral flap of approximately one-third scleral thickness with a 5 mm base at the limbus was prepared using the microsurgical viscocanalostomy set (Grieshaber AG, Switzerland). Inside the area of the initial flap a second triangular flap was dissected down to the level to unroof Schlemm`s canal. The orifices of the canal of Schlemm were dilated using high viscous hyaluronic acid (Healon GV). Then the laser probe was gently introduced into the canal and photoablation was started.

Light microscopy

After fixation in formalin 4%, serial sections of 5 microns thickness were obtained with a microtome Jung RM 2035 (Leica, Germany) and stained with Hematoxilin Papanicolaou 1a, Eosin Yellow.

Electron microscopy

To record scanning electron micrographs, the autopsy eyes were fixated in glutaraldehyd and coated with a gold sputter. The microscope used was a Phillips SEM 505.

Results

The light micrographs (Fig. 4, Fig. 6) display the ability of both the TM:YAG laser and the Er:Yag laser to perform a retrograde trabecular meshwork tissue ablation. The effect of the TM:YAG was less titrateable compared to the Er:YAG, depending on the formation of cavitation bubbles. The scanning electron micrographs (Fig. 5, 7-9) obtained from the Er:YAG show little thermal damage at the sites of the photoablation zones. This finding suggest that only a mild wound healing response might be expected if a procedure reduces the induction of tissue traumatization.

Discussion

First attempts to lower the IOP using laser application to structures of the trabecular meshwork were performed by Krasnov [7]. Different methods with various lasers have been investigated for trabecular ablation [8,9]. Berlin et al. (UV-laser) [10] and Hill et al. (IR-laser) [11] started working with photo ablative laser, they have shown that trabecular meshwork could be ablated with minimal collateral thermal damages. All authors, exept for the group of Kampmeier [14], used the technique of ab interno laser trabecular ablation with tips sizes of 300 to 600 microns in diameter.

This study has shown that the special design of the tip allows for probing of Schlemm`s canal. The following selective retrograde TM photoablation can be performed without damaging the posterior wall of Schlemm`s canal.

Further studies are needed to prove whether minimal invasive retrograde Schlemm`canal surgery can be considered a benefical adjunct in POAG surgery.

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