

Excimer Laser Trabeculostomy

Normalizing IOP and restoring physiologic outflow in glaucoma.

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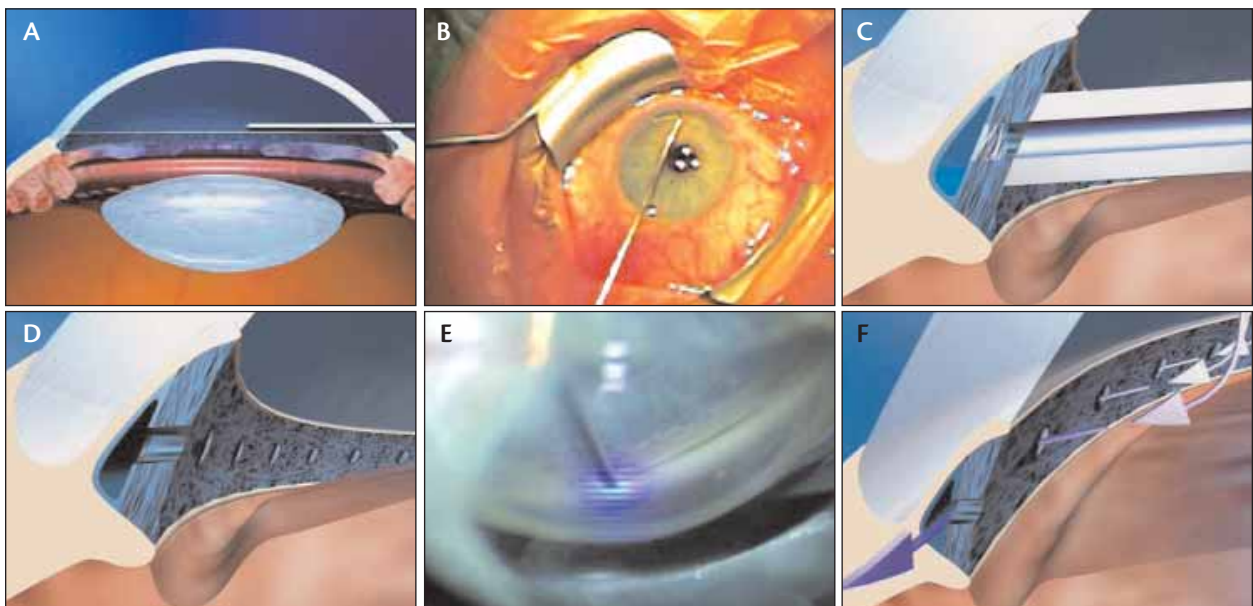
The obstruction of aqueous outflow at the juxta-canalicular trabecular meshwork and the inner wall of Schlemm's canal is the primary cause of elevated IOP in most cases of open-angle glaucoma (OAG).^{1,2} Experimental and clinical studies with ruby, Nd:YAG, and argon lasers have shown that they cannot achieve a permanent perforation of the trabecular meshwork to fistulize the anterior chamber to an internal, rather than external, outflow channel. Attempts with these photothermal and photodisruptive lasers were initially successful in puncturing the meshwork, but the effect was of short duration due to inflammatory and healing responses.³⁻¹⁰

The goal of excimer laser trabeculostomy (ELT) is to re-establish the natural aqueous outflow of the eye without inciting a healing response at the target tissue.

CONCEPT TO REALITY

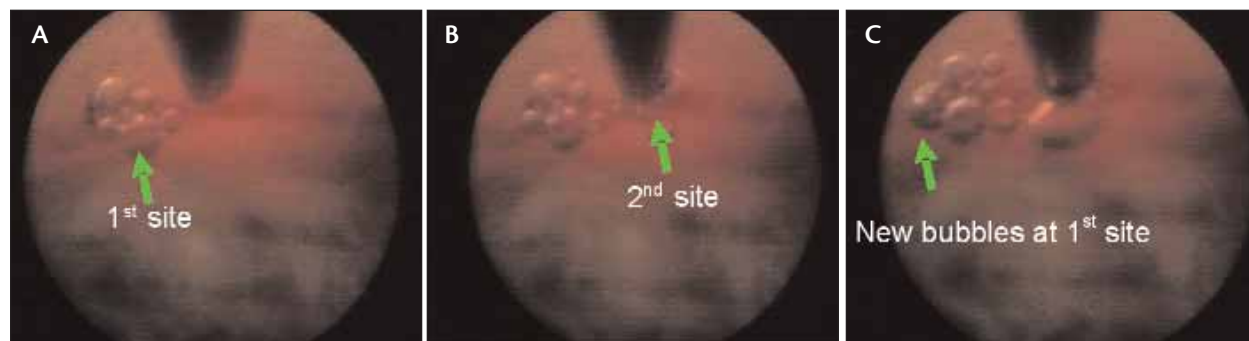
During the development of nonthermal, short-pulsed, 193-nm argon-fluoride excimer lasers for corneal refractive surgery, it became apparent that excimer lasers could also remove tissue in the angle, trabecular meshwork, and sclera while causing almost no thermal damage, unlike all prior lasers used to treat the angle tissues. Ablation with these excimer lasers therefore minimized inflammation and the formation of scar tissue. Because ultraviolet wavelengths are readily absorbed by the cornea, however, a delivery system into the eye was needed to allow excimer lasers to be clinically useful for the treatment of tissue in the trabecular meshwork and angle.

Since 193-nm argon-fluoride cannot be transmitted through fiber optics, investigators used 308-nm xenon-



(Animation stills courtesy of Rudolf G. Peschke)

Figure 1. Paracentesis, viscoelastic, and probe across the anterior chamber during the ELT procedure (A). Probe across the chamber (B). Probe contacts the trabecular meshwork. Laser pulses ablate tissue into gas (C). Ten openings into Schlemm's canal are created (D). Laser pulses excise the trabecular meshwork (E). Patent trabeculostomies enable outflow into Schlemm's canal (F).



(Courtesy of Professor J. Fink)

Figure 2. A coaxial endoscopic view of the trabecular meshwork during the ELT procedure (A). As a second ostium is created into Schlemm's canal (B), the expansion of bubbles is visible at the adjacent ELT site, thus confirming flow and patency into Schlemm's canal (C).

chloride ultraviolet excimer lasers in preclinical animal trials, which began in the 1980s. Histology confirmed that this excimer laser caused minimal thermal damage compared with visible or infrared lasers.¹¹⁻¹³ Unlike argon and selective laser trabeculoplasty, ELT—like LASIK—precisely excises tissue without causing thermal injury to or scarring of the surrounding tissue. This treatment is therefore able to create a long-term anatomic opening that connects the anterior chamber directly to Schlemm's canal.

The early developers of ELT saw that it would be possible to use this laser to precisely excise the juxtacanalicular trabecular meshwork and inner wall of Schlemm's canal in order to increase internal outflow, thus improving the egress of aqueous into Schlemm's canal.

THE PROCEDURE

ELT is performed as an outpatient procedure under topical or peribulbar anesthesia. The surgeon creates a paracentesis and then stabilizes the anterior chamber by instilling a viscoelastic (Figure 1). To avoid the corneal absorption of laser radiation, an optical fiber must be used to deliver the energy intracamerally. The fiberoptic probe is then advanced through the paracentesis and across the anterior chamber to contact the trabecular meshwork. The surgeon visualizes the placement through gonioscopy or via an endoscope. Pulsed photoablative energy is then applied.

In current protocols, the surgeon creates 10 sites in one or two inferior quadrants. A small amount of bloody reflux from Schlemm's canal confirms each opening's patency. The surgeon then removes the probe from the eye and exchanges the viscoelastic for balanced salt solution. Postoperatively, patients use topical antibiotics and steroid drops for 1 to 2 weeks. The IOP decreases immediately after ELT.

CLINICAL RESULTS

The first human clinical trial of ELT was performed in Germany in 1997. In 22 eyes with OAG, the median reduc-

tion in IOP was 7 mm Hg. The minimal trauma to the eye from the procedure left all other options of surgery open.¹⁴

Since this trial, numerous clinical studies have demonstrated ELT's ability to achieve a long-term reduction in IOP while eliminating the need for glaucoma medications in patients with OAG or ocular hypertension who have phakic or pseudophakic eyes, whether the procedure is performed alone or in combination with cataract surgery. In a study by Giers et al, the investigators performed ELT on 33 patients with phakic eyes. After 3 years, there was a 42% mean reduction in IOP (from 27.2 ± 5.95 mm Hg preoperatively to 15.89 ± 3.29 mm Hg) among the subjects. In addition, the number of medications used decreased by 91% on average (from 2.44 ± 1.27 to 0.21 ± 0.40).¹⁵ In the same study, patients with pseudophakic eyes underwent ELT. After 3 years, the mean decrease in IOP in this group was 47%, and the mean reduction in the number of medications was 77%.¹⁵ In another study by Babighian et al, 21 patients with a mean preoperative IOP of 24.8 ± 2.0 mm Hg underwent ELT. Two years later, they had a mean IOP of 16.9 ± 2.1 mm Hg, a reduction of 32%.¹⁶

When combined with cataract surgery, ELT is performed through the same corneal incision. After completing phacoemulsification, the surgeon creates the 10 ELT sites in the inferior quadrants. In a study by M. Pache, MD, and colleagues (unpublished data, 2003), 60 patients underwent the combined procedure. One year postoperatively, 91% of patients had maintained a reduction in IOP of at least 20% from a mean preoperative IOP of 26.8 ± 3.1 mm Hg. Giers et al also conducted a study in which 33 patients underwent combined ELT and phacoemulsification/IOL implantation procedures. At the 3-year follow-up visit, the mean reduction in IOP was 39%, with a 70% mean decrease in the number of medications.¹⁵

PNEUMATIC CANALOPLASTY

An additional advantage of ELT is that it enables pneumatic canaloplasty. As ELT is performed, both coaxial endo-

scopic views and gonioscopic views reveal the expansion of gas bubbles at the previous ostium created when Schlemm's canal is entered at each subsequent ELT site. The gas flow that creates these bubbles is presumed to confirm patency and continuity of fluid flow into Schlemm's canal (Figure 2).

ELT converts trabecular meshwork tissue into gas by photocoagulation. Investigators have proposed that the pressure of this gas dilates Schlemm's canal and the adjacent collector channels to improve aqueous outflow (Figure 3). Real-time imaging and postmortem histologic studies—in addition to histologic studies after ELT that document the lack of thermal damage in human eye-banked eyes—will be required to confirm this hypothesis and provide a better understanding of the long-term tissue changes associated with ELT.¹¹⁻¹³

CONCLUSION

ELT appears to be a promising, new, minimally invasive treatment for lowering IOP in eyes with OAG. This nonperforating, ab interno procedure seems to be safer than conventional filtering surgery. Trabeculectomy, which may include the use of antimetabolites, is associated with the risks of infection, bleb leak, and hypotony due to the creation of aqueous drainage channels external to the globe. Unlike other new glaucoma procedures that treat the trabecular meshwork to reduce outflow obstruction, ELT does not require the implantation of foreign bodies or cause coagulative damage. ELT, however, is intraocular surgery performed in a surgical suite, whereas argon and selective laser trabeculoplasty may be performed in an office setting. The postoperative care of patients undergoing ELT in the European Union generally consists of two to four visits over the course of 1 to 2 months.

Surgeons performing ELT in Europe have reported a steep

learning curve before they became comfortable with the technical aspects of the procedure. Improvements have been made in an effort to decrease the learning curve with a goal of enabling all cataract surgeons to perform ELT safely and effectively. The cost of the procedure and reimbursement rates vary by country and clinic but range from \$1,000 to \$2,000.

ELT has been approved for use in the European Union for more than a decade. Since then, thousands of ELT procedures have been successful, with some clinics reporting follow-up data of up to 7 years. In several clinics, ELT has replaced trabeculectomy as the surgical procedure of choice, based on correspondence with several colleagues (S. Babighian, U. Giers, L. Kleinerberg, written communication, 2009). Currently, clinical studies are pending in both Canada and the United States, and the next generation of ELT devices is under development. ■

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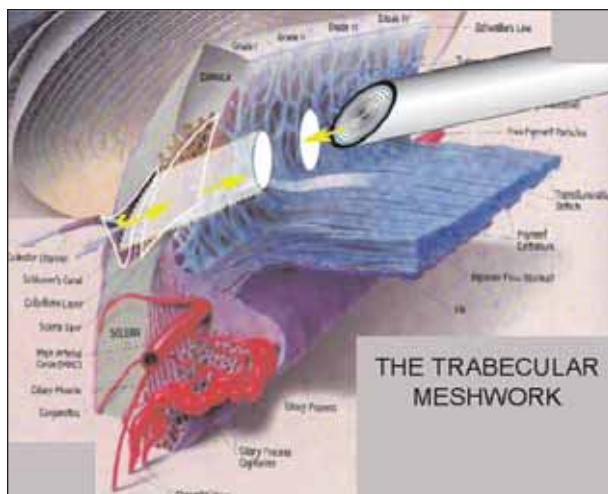


Figure 3. Pneumatic canaloplasty during ELT. The pressure of gas is presumed to dilate Schlemm's canal and the collector channels to increase aqueous outflow.

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