Excimer Laser MIGS: The Next Generation of Interventional Glaucoma Care

A novel technology is reshaping disease management and expanding treatment possibilities.

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EVOLVING GOALS FOR AN INTERVENTIONAL MINDSET

Iqbal Ike K. Ahmed, MD, FRCSC

The fundamental goal of glaucoma management is to preserve patients' quality of life over the course of their lifetime. As such, ophthalmologists' focus must extend beyond IOP to encompass *all* aspects of glaucoma care, from the effects of the disease to the effects of its treatment.

An evolution is occurring in our efforts to achieve this goal. Glaucoma care is shifting away from an observational model, in which medications are added and procedures are reserved for advanced disease. New interventions have brought new considerations.

To continue this progress, we must consider the limitations of the current treatment paradigm. Patient adherence to topical glaucoma therapy is poor, and medication stacking is ineffective.[1-3] Sustained IOP control is beneficial for disease stability but suboptimal with current therapies.

Waiting to intervene may contribute to permanent glaucomatous damage. Outflow disease causes inflammatory changes via the accumulation of extracellular matrix in the trabecular meshwork (TM). Over time, this progresses to a more irreversible fibrotic and sclerotic process. Secondary outflow obstruction may also occur with advancing disease.

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> – Iqbal Ike K. Ahmed, MD, FRCSC

Glaucoma is only young once. As we evaluate the safety and efficacy of novel technologies, we must consider where they will be most effective along the patient's journey and how they will best serve our objective to preserve quality of life.

1. Wolfram C, Stahlberg E, Pfeiffer N. Patient-reported nonadherence with glaucoma therapy. *J Ocul Pharmacol Ther*. 2019;35(4):223–228.
2. Neelakantan A, Vaishnav HD, Iyer SA, Sherwood MB. Is addition of a third or fourth antiglaucoma medication effective? *J Glaucoma*. 2004;13(2):130-136.
3. Johnson TV, Jampel HD. Intraocular pressure following prerandomization glaucoma medication washout in the HORIZON and COMPASS trials. *Am J Ophthalmol*. 2020;216:110-120.

ROUTINE PHACO+MIGS: ARE WE THERE YET?

Gus Gazzard, MBBChir, MA, MD, FRCOphth

Glaucoma and cataract are prevalent conditions that will be of increasing concern as the population ages (see *By the Numbers*).[1,2] Approximately 6 million patients with glaucoma or ocular hypertension undergo cataract surgery every year[3]; however, many do not receive the opportunity to address their glaucoma at the time of their cataract procedure.

Cataract surgery may yield some IOP lowering, but it is not enough to change the course of glaucoma. In the Ocular Hypertension Treatment Study,[4] cataract surgery lowered IOP by 1.3 to 2.2 mm Hg, but this reduction was not significant at 1 year. The medication burden was reduced by only 0.4 medications at 2 years. Randomized controlled trials have shown that performing MIGS at the time

BY THE NUMBERS

80 million
people living with glaucoma as of 2022[1]

32 million
people receiving cataract surgery annually as of 2023[2]

of cataract surgery (phaco+MIGS) can yield better and longer IOP control, reduce the medication burden, and eliminate some patient-dependent aspects of care.[5]

PHACO+MIGS: ADVANTAGES AND LESSONS

Performing MIGS at the time of cataract surgery offers several advantages. Surgical control of IOP can minimize diurnal fluctuation, which may slow disease progression.[6-8] Phaco+MIGS may also reduce the rate of functional deterioration and the need for secondary surgical interventions.[5] Reduction of drops after phaco+MIGS can improve the ocular surface and increase tear film stability.[9] In one study, 79% of patients reported an overall improvement in quality of life after phaco+MIGS.[10]

More than a decade of MIGS experience shows that achieving the same or lower IOP with a *lower medication burden* is a valid treatment goal. It has become clear that "phaco-like" safety is a must for glaucoma procedures performed at the time of cataract surgery. Low technical complexity broadens surgeon uptake and patient access. Further, avoiding retained devices may be advantageous. These insights can assist in the evaluation of emerging technologies and their potential in glaucoma care.

PHACO+MIGS WITH ELIOS

Excimer laser trabeculostomy (ELIOS) is a clinically validated MIGS procedure performed with the ELIOS excimer laser (Elios Vision). The procedure creates 10 microchannels (210 µm) in the TM to facilitate aqueous outflow into Schlemm's canal and reduce IOP.

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>
> – Gus Gazzard, MBBChir, MA, MD, FRCOphth

ELIOS preserves the TM, is implant-free, and is broadly adoptable by surgeons. Combined with phacoemulsification, ELIOS provides an opportunity to address cataract and glaucoma—a valuable pursuit in the effort to optimize quality of life.

1. Tham YC, Li X, Wong TY, et al. Global prevalence of glaucoma and projections of glaucoma burden through 2040: a systematic review and meta-analysis. *Ophthalmology*. 2014;121(11):2081-2090.
2. Data on file with Elios Vision.
3. Hughes R, Aristodemou P, Sparrow JM, et al. Surgeon effects on cataract refractive outcomes are minimal compared with patient comorbidity and gender: an analysis of 490 987 cases. *Br J Ophthalmol*. 2023;107(4):488-494.
4. Mansberger SL, Gardiner SK, Gordon M, et al. Cataract surgery lowers intraocular pressure and medication use in the medication group of the Ocular Hypertension Treatment Study. *Am J Ophthalmol*. 2022;236:53-62.
5. Montesano G, Ometto G, Ahmed IIK, et al. Five-year visual field outcomes of the HORIZON trial. *Am J Ophthalmol*. 2023;251:143-155.
6. Pyfer MF, Gallardo M, Campbell A, et al. Suppression of diurnal (9AM-4PM) IOP fluctuations with minimally invasive glaucoma surgery: an analysis of data from the prospective, multicenter, single-arm GEMINI study. *Clin Ophthalmol*. 2021;15:3931-3938.
7. Posarelli C, Ortenzio P, Ferreras A, et al. Twenty-four-hour contact lens sensor monitoring of aqueous humor dynamics in surgically or medically treated glaucoma patients. *J Ophthalmol*. 2019;2019:9890831.
8. Asrani S, Zeimer R, Wilensky J, et al. Large diurnal fluctuations in intraocular pressure are an independent risk factor in patients with glaucoma. *J Glaucoma*. 2000;9:134-142.
9. Jones L, Maes N, Qidwai U, et al. Impact of minimally invasive glaucoma surgery on the ocular surface and quality of life in patients with glaucoma. *Ther Adv Ophthalmol*. 2023;15:25158414231152765.
10. Al Habash A, Nagshbandi AA. Quality of life after combined cataract and minimally invasive glaucoma surgery in glaucoma patients. *Clin Ophthalmol*. 2020;14:3049-3056.


MODERN PERSPECTIVES ON OUTFLOW PHYSIOLOGY

Neeru A. Vallabh, MBBS, FRCOphth, PhD, and Carl Sheridan MSC, BSc, PhD

The TM is a complex 3D structure that plays a major role in IOP regulation. The majority of aqueous outflow (70% to 90%) occurs through the conventional trabecular outflow pathway. Aqueous humor passes through cell-lined beams of the TM before moving into the canal and collector channels. SC endothelial cells help to maintain the blood-aqueous barrier.

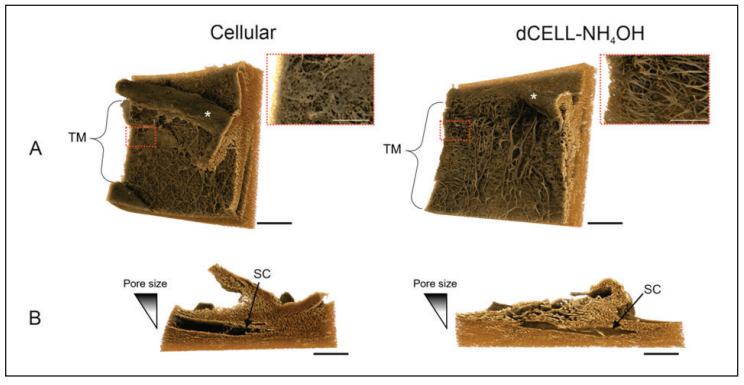

Figure 1. MicroCT images of cellular and decellularized human TM in front-on (A) and cross-sectional (B) orientations.

A noninvasive imaging tool called microcomputed tomography (microCT) has been developed to enable 3D reconstruction of the TM and help visualize the tissue's architecture.[1] Work done at the University of Liverpool depicts a healthy TM with cells following decellularization with ammonium hydroxide (Figure 1). With decellularization, the complex structure and decreasing porous nature of the TM are apparent.

Under normal physiological conditions, the uveal and corneoscleral meshwork do not offer resistance to outflow; instead, resistance to outflow is generated in the juxtacanicular TM–canal interface. Scanning electron microscopy, which helps depict the TM's surface structure, shows clear physical alterations in structure with primary open-angle glaucoma. In a healthy TM, pores through which aqueous travels are visible, whereas in a glaucomatous TM, a dense plaque-like material obstructs outflow.

BEYOND THE TM

Aqueous outflow beyond the TM is a dynamic process. TM cells have baroreceptor properties, and fluctuations of these valve-like conduits help to open and close Schlemm's canal. Using ultra high-resolution OCT, Johnstone et al[2] showed how the

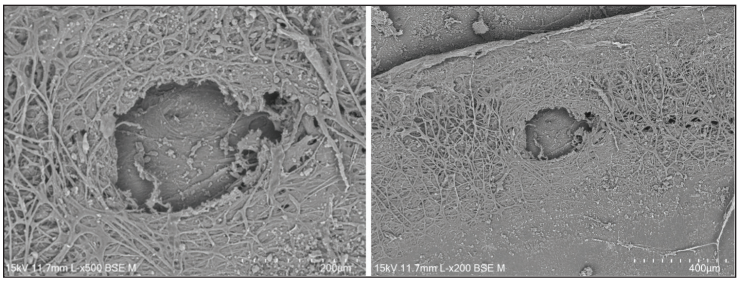

Figure 2. Well-defined microchannels in the TM created by the ELIOS laser.

TM distends and pulls on the collector channels ostia entrance in response to a pulse, causing the channels to open and close. The outflow pathway has similar lymphatic-like characteristics that allow drainage through valves into distal collector channels and vessels.

ELIOS TREATMENT IN DETAIL

My colleagues and I used the ELIOS laser to create microchannels in donor human TM. Scanning electron micrographs (Figure 2) show the well-defined microchannels. The treatment is 120 µm in depth, and the Schlemm's canal lumen space remains patent adjacent to and beyond the pore. Maintaining the natural physiology of aqueous drainage is key—and it is possible with the ELIOS laser.

1. Crouch DJ, Sheridan CM, Behnsen JG, Bosworth LA. An optimized method to decellularize human trabecular meshwork. *Bioengineering*. 2022;9(5):194.
2. Johnstone M, Xin C, Tan J, et al. Aqueous outflow regulation – 21st century concepts. *Prog Retin Eye Res*. 2021;83:100917.

EXCIMER LASER MEETS GLAUCOMA SURGERY

Cedric Schweitzer, MD, PhD, FEBO

A laser's effect on tissue is defined by three key parameters: (1) wavelength, ranging from short (UV light) to long (infrared); (2) energy density, defined as fluence or irradiance; and (3) pulse duration/exposure time. These parameters determine the type of treatment effect achieved (Table).

EXCIMER LASER FUNDAMENTALS

The excimer laser's mechanism of action involves a reaction between a noble gas and a halogen gas. Under strong electrical discharge, the atoms are excited and form an unstable molecule called excited dimer (hence *excimer*). As the photons return to their original state, energy is released. The wavelength of this energy depends on the noble gas used.

Excimer lasers emit a short wavelength in the UV light range. A powerful energy release is emitted, particularly in pulsed mode, and because the pulse duration is short, little to no heat is generated.

Whereas corneal excimer lasers use argon as a noble gas, the ELIOS laser uses xenon. Thus, the ELIOS laser's wavelength is longer than that used in corneal refractive surgery (308 nm vs 193 nm), and the ELIOS laser energy can be transmitted through optical fibers.

TABLE. LASER TREATMENT EFFECTS

Treatment Effect	Glaucoma Procedure	Other Procedures
Photothermal	Argon laser trabeculoplasty (ALT)	Retinal detachment, retinopathy of prematurity, proliferative diabetic retinopathy
Photodisruption	Peripheral iridotomy (PI)	Capsulotomy, anterior vitreolysis
Photochemical	Selective laser trabeculoplasty (SLT)	Crosslinking, photodynamic therapy
Photoablation	Excimer laser trabeculostomy (ELIOS)	LASIK, PRK

TRABECULOSTOMY VERSUS TRABECULOPLASTY

With ELIOS, the excimer laser uses a photoablative effect to create trabecular microperforations that allow aqueous humor bypass with direct passage into the canal. The effect on the tissue is permanent. In contrast, argon and selective laser trabeculoplasty (ALT and SLT) use a photothermal or photochemical effect, respectively, to enable extracellular matrix renewal. This effect is transient, as it triggers a cellular and biochemical cascade within the TM during transmission.

ELIOS: CLINICAL INSIGHTS AND CURRENT EVIDENCE

Henny J.M. Beckers, MD, PhD, FEBOphth

The excimer laser was first introduced clinically in 1996 for corneal surface ablation.[1] This device enabled precise tissue removal and, as a "cool" laser, prevented thermal damage to surrounding tissues. Ultimately, interest expanded to glaucoma, and an excimer laser application was developed for full-thickness sclerostomy. Next, the focus shifted to the TM, and the trabeculostomy technique emerged.[2]

When excimer lasers were first used to treat glaucoma, phacoemulsification was in its early stages. ALT and SLT were gaining popularity, but the industry was focused on new glaucoma medications, especially prostaglandin analogues. Since the advent of MIGS, a dramatic increase in procedural interventions has occurred, and interest in laser technology has grown. Advances in the ELIOS excimer laser system and probe have led to a more sophisticated, user-friendly approach.

> Overall, our first impressions have been very encouraging, and we are motivated to continue to offer this treatment to patients.
> – Henny J.M. Beckers, MD, PhD, FEBOphth

ELIOS: TECHNICAL ASPECTS AND POTENTIAL BENEFITS

The ELIOS laser emits energy through an intraocular fiberoptic probe to create microchannels through the TM up to the inner wall of SC with high precision. The ab interno, nonthermal approach protects adjacent tissues and collector channels and yields minimal scarring and inflammation. ELIOS can be performed as a standalone procedure or in combination with phacoemulsification. The learning curve is short, especially for those familiar with intraoperative gonioscopy.

INITIAL OUTCOMES WITH ELIOS

My colleagues and I analyzed early outcomes of phaco-ELIOS in 21 eyes of 13 patients.[3] We found that mean IOP decreased from 15.1±3.9 mm Hg at baseline to 12.7 ±4.3 mm Hg at 1 month and 12.5 ±2.9 mm Hg at 3 months. The mean number of medications decreased from 2.2 ±1.3 at baseline to 1.8 ±1.4 at 1 month and 1.6 ±1.4 at 3 months. Success (>20% IOP reduction or reduction in medication) was achieved in 76% of eyes (n = 16). Overall, our first impressions have been very encouraging, and we are motivated to continue to offer this treatment to patients.

CURRENT EVIDENCE

Published studies report a 20% to 40% IOP reduction and a decrease in medications with ELIOS.[2,4] Phaco-ELIOS may yield greater IOP lowering than standalone ELIOS or cataract surgery. In one randomized controlled trial, ELIOS yielded greater IOP lowering than SLT, although the sample size was small and not all findings were statistically significant.[5] Complications, while rare, are generally early, mild, and transient.

Two long-term studies of ELIOS and phaco-ELIOS[6,7] have shown sustained IOP lowering to the midteens for up to 8 years and a decrease in the number of medications for several years. The safety profile of ELIOS was favorable in both investigations. ■

1. Vogel M, Lauritzen K, Quentin CD. Targeted ablation of the trabecular meshwork with excimer laser in primary open-angle glaucoma. *Ophthalmologe* .1996;93(5):565-568.
2. Berlin MS, Toteberg-Harms M, Kim E, et al. Excimer laser trabeculostomy: the laser-based MIGS procedure for open-angle glaucoma. In: Samples JR, Ahmed IIK, eds. *New Concepts of Glaucoma Surgery Series*. 2020; 231-244.
3. De Crom RMPC, Beckers HJM. Initial results of combined phaco-emulsification with excimer laser trabeculostomy in glaucoma patients in The Netherlands. Poster presented at: the EGS meeting. June 2024; Dublin.
4. Babighian S, Caretti L, Tavolato M, et al. Excimer laser trabeculotomy vs 180 degrees selective laser trabeculoplasty in primary open-angle glaucoma. A 2-year randomized, controlled trial. *Eye (Lond)*. 2010;24(4):632-638.
5. Durr GM, Toteberg-Harms M, Lewis R, et al. Current review of excimer laser trabeculostomy. *Eye Vis (Lond)*. 2020;7:24.
6. Riesen M, Funk J, Toteberg-Harms M. Long-term treatment success and safety of combined phacoemulsification plus excimer laser trabeculostomy: an 8-year follow-up study. *Graefes Arch Clin Exp Ophthalmol*. 2022;260(5):1611-1621.
7. Berlin MS, Shakibkhou J, Tilakaratna N, et al. Eight-year follow-up of excimer laser trabeculostomy alone and combined with phacoemulsification in patients with open-angle glaucoma. *J Cataract Refract Surg*. 2022;48(7):838-843.

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