Artículo de Opinión

GLAUCOMA THERAPIES: PAST, PRESENT AND FUTURE

Terapias para el Glaucoma: Pasado, Presente y Futuro

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ABSTRACT

Glaucoma management stands at an inflection point. The convergence of sustained drug delivery, implant-free laser platforms, gene therapy, and AI-driven diagnostics is reshaping a $9 billion global market away from the daily eye drop and toward interventional, precision-targeted care. This shift matters because glaucoma remains the leading cause of irreversible blindness worldwide, affecting over 80 million people today with projections exceeding 110 million by 2040. Despite decades of effective IOP-lowering medications, up to 60% of patients fail to adhere to daily drop regimens, a compliance crisis that drives vision loss even when treatments exist. The new generation of devices and Drug delivery directly attacks this fundamental gap, offering physician-administered, long-acting solutions that bypass patient adherence entirely. The key is that glaucoma treatment paradigm is shifting from "drops first, drops always" to proactive interventional management: combining laser, MIGS, sustained delivery, and eventually neuroprotection and gene therapy into a precision medicine framework.

Keywords: Glaucoma therapies, laser treatment, drug delivery, Interventional Glaucoma, Pipeline, AI.

RESUMEN

El tratamiento del glaucoma se encuentra en un punto de inflexión. La convergencia de la administración sostenida de fármacos, las plataformas láser sin implantes, la terapia geneticas y los diagnósticos basados en IA está transformando un mercado global de 9 mil millones de dólares, alejándolo del uso diario de gotas oftálmicas y dirigiéndolo hacia una atención intervencionista y de precisión. Este cambio es crucial, ya que el glaucoma sigue siendo la principal causa de ceguera irreversible en todo el mundo, afectando a más de 80 millones de personas en la actualidad, con proyecciones que superarán los 110 millones para 2040. A pesar de décadas de medicamentos eficaces para reducir la presión intraocular, hasta el 60 % de los pacientes no cumplen con los regímenes de gotas diarias, una crisis de adherencia que provoca pérdida de visión incluso cuando existen tratamientos. La nueva generación de dispositivos y administracion sostenida de farmacos aborda directamente esta deficiencia fundamental, ofreciendo soluciones de acción prolongada administradas por el médico que evitan por completo la dependencia del paciente. La clave reside en que el paradigma del tratamiento del glaucoma está pasando de «gotas primero, gotas siempre» a un manejo intervencionista proactivo: combinando láser, MIGS, administración sostenida y, eventualmente, neuroprotección y terapia génica en un marco de medicina de precisión.

Palabras clave: Terapias para el glaucoma, tratamiento con láser, administración de fármacos, glaucoma intervencionista, proyectos en desarrollo, IA.

1. Laser Technologies: Toward Incision-Free Treatment

SLT Validated as First-Line Therapy

The LiGHT trial (718 patients, 6-year follow-up) has fundamentally rewritten treatment algorithms [1,2]. At 6 years, 69.8% of patients randomized to SLT-first remained at target IOP without any medications or surgery, with 90% requiring only 1 [2]–2 laser sessions. SLT-first patients showed 29% slower visual field progression (−0.26 vs. −0.37 dB/year, p=0.006) and required dramatically fewer trabeculectomies (13 vs. 32 eyes) and cataract surgeries (57 vs. 95 eyes). These data have prompted the European Glaucoma Society (EGS), American Academy of Ophthalmology (AAO), and National Institute for Health and Care Excellence (NICE) to list SLT as initial first-line therapy alongside medications.

Contactless Automated SLT: Alcon Voyager

Alcon's Voyager DSLT (acquired from Belkin Vision for up to $385M including milestones) represents the next evolution: a contactless, automated SLT laser that delivers 120 pulses in 2.4 seconds without requiring a gonioscopy lens. FDA-cleared in December 2023 and commercially launched in the US in February 2025, the Voyager's significance lies in democratization, by eliminating gonioscopy skills, it enables a broader range of eye care professionals to deliver SLT, potentially expanding access dramatically. The GLAUrious trial (201 patients) demonstrated equivalent efficacy to conventional SLT [3,4] with a favorable safety profile.

Laser Trabeculotomy: ViaLase FLigHT

The most potentially transformative technology is ViaLase's FLigHT procedure: a femtosecond laser that creates precise 500×200µm drainage channels through the trabecular meshwork using OCT guidance—entirely from outside the eye, without any incision. First-in-human data (17 eyes) showed 34.6% IOP reduction sustained through 24 months with no channel closure—addressing the critical limitation of biological healing that undermines many surgical approaches. CE-marked in August 2024, ViaLase treated its first US IDE trial patient in December 2025, with the randomized controlled trial comparing FLigHT to SLT designed for PMA clearance [5,6]. If the pivotal data hold, this technology could become a first-line alternative to both drops and SLT.

Picosecond Green Laser Platform: EyeX Solutions

EyeX Solutions, Inc. is developing a multimodal picosecond green laser (532nm) platform that represents a fundamentally different approach to laser-based glaucoma treatment. EyeX leverages ultrashort-pulse picosecond energy at the 532nm wavelength, capitalizing on the peak absorption of melanin in trabecular meshwork tissue while maintaining excellent transmission through clear ocular media. The platform's architecture supports multiple treatment modalities from a single base in clinic unit, including SoftMesh (a gentler, tissue-sparing enhanced SLT alternative), and PicoLumen (a next-generation laser trabeculotomy), each engineered to titrate thermal versus photomechanical tissue effects with greater precision than conventional nanosecond SLT systems [7].

A key strategic advantage is that the 532nm picosecond platform shares a common Nd:YAG laser pump architecture with 355nm (third harmonic) and 1064nm wavelengths, enabling a single-platform, multi-indication product roadmap that extends beyond glaucoma into corneal crosslinking and capsulotomy [8]. If the company demonstrates the hypothesized advantages, in office small platform access with wider therapeutic options, this platform could establish a differentiated position in the rapidly evolving laser trabeculoplasty market.

Excimer Laser Trabeculostomy: Elios Vision / Bausch + Lomb

Bausch + Lomb's Elios excimer laser trabeculostomy (acquired December 2024 [9]) creates 10 microchannels through the trabecular meshwork using "cold" 308nm excimer energy that ablates tissue with minimal thermal damage to surrounding structures. Long-term follow-up data spanning 8 years demonstrate sustained IOP reduction from a baseline of 19.3 mmHg to 15.4 mmHg, with a favorable safety profile and the ability to repeat treatment as needed [10]. Two FDA IDE clinical trials are currently enrolling in the United States,

positioning Elios for potential US market entry within 2–3 years. The excimer approach is notable for its fundamentally different tissue interaction mechanism compared to both conventional SLT and femtosecond platforms: the 308nm ultraviolet wavelength breaks molecular bonds via photochemical ablation rather than thermal or photodisruptive effects, potentially offering a complementary or alternative option for patients who have failed or are not candidates for SLT.

Micropulse Transscleral Cyclophotocoagulation

Micropulse transscleral cyclophotocoagulation (MP-TCC), delivered via the IRIDEX Cyclo G6 system with the MicroPulse P3 probe, has undergone a significant repositioning in the glaucoma treatment algorithm [11]. Originally reserved for refractory end-stage disease, accumulating evidence now supports its use in moderate and even mild-to-moderate glaucoma, offering a non-incisional, conjunctiva-sparing, repeatable option. The micropulse delivery mode applies 810nm diode laser energy in rapid on/off cycles (0.5ms on, 1.1ms off), allowing the ciliary epithelium to cool between pulses and thereby reducing the risk of the tissue destruction, chronic inflammation, and phthisis associated with traditional continuous-wave cyclophotocoagulation. Clinical studies report approximately 30–35% IOP reduction with the ability to titrate effect through repeat treatments, and the procedure can be performed in an office or ambulatory surgery center setting under topical or sub-Tenon's anesthesia. As the evidence base for earlier-stage application grows and longer-term safety data mature, MP-TCC is increasingly viewed as a valuable tool in the interventional glaucoma armamentarium—particularly for patients seeking to reduce medication burden without undergoing incisional surgery. Table 1.

2. Sustained Drug Delivery: Solving the Compliance Crisis, Table 2.

The sustained drug delivery revolution addresses glaucoma's most intractable problem: 50–80% of patients are non-adherent to daily eye drops, and up to 90% fail to continuously refill prescriptions. Two FDA-approved intracameral implants now offer physician-administered alternatives, with a rich pipeline behind them.

Durysta (AbbVie)

Durysta (approved March 2020) was the first FDA-approved sustained-release intracameral implant, delivering 10µg bimatoprost over 4–6 months from a biodegradable polymer matrix [12]. Real-world data show 88.6% of eyes needed no additional IOP-lowering treatment at 6 months, declining to 77.7% at 18 months [13]. Impact has been constrained by FDA label restricting to a single dose per eye due to endothelial cell loss concerns.

iDose TR (Glaukos)

iDose TR (approved December 2023) represents a generational advance: a titanium micro-housing anchored in the trabecular meshwork that continuously delivers travoprost for 12+ months. Phase 3 data (1,150 patients) showed IOP reductions of 6.6–8.4 mmHg with 81% of subjects completely medication-free at 12 months [14]. In January 2026, the FDA approved a labeling supplement allowing re-administration, transforming iDose TR from a one-time intervention into a repeatable platform [15]. At a wholesale acquisition cost of $13,950 per implant, iDose TR is expensive relative to generic drops but competitive when factoring in non-compliance costs.

Emerging Sustained Delivery Pipeline

The pipeline is remarkably rich: SpyGlass Pharma's bimatoprost-eluting IOL showed 43.7% IOP reduction with 100% of patients off drops at 18 months [16]. OTX-TIC (Ocular Therapeutix) demonstrated clinically meaningful reductions through 6 months [17]. PolyActiva's PA5108 is a biodegradable latanoprost implant in Phase IIb. Ripple Therapeutics has partnerships with both AbbVie and Glaukos for polymer-free implant platforms. Glaukos' GLK-311 (iLution) explores transdermal eyelid drug delivery—applied to the skin surface.

3. MIGS Devices: The Interventional Revolution, Table 3.

The MIGS landscape has matured from a single device (iStent, FDA approved 2012) into a sophisticated

Table 1. Laser Platform Comparison					
Platform	**Mechanism**	**IOP Reduction**	**Contact Req.**	**Repeatable**	**Status**
Conventional SLT	532nm TM stimulation	20–30%	Gonio lens	Yes	Gold standard; LiGHT 6yr data
Voyager DSLT	Automated 120-pulse SLT	Equiv. to SLT	Contactless	Yes	FDA cleared Dec 2023; US launch Feb 2025
ViaLase FLigHT	fs-laser trabeculotomy	34.6% (24mo)	Non-contact	TBD	CE Aug 2024; US IDE Dec 2025
Elios Excimer	308nm TM channels	~20%	Gonio probe	Yes	Acquired by B+L; 2 FDA IDE trials
Cyclo G6 MP3	Micropulse CPC	~33%	Probe	Yes	Expanding to earlier disease stages
EyeX Solutions	532nm picosecond	TBD	Non-contact	TBD	Ph I

Table 2. Sustained Drug Delivery Products & Pipeline						
Product	**Company**	**Drug**	**Duration**	**Phase**	**Med-Free**	**Key Note**
Durysta	AbbVie	Bimatoprost	4–6 months	Approved	78% (6mo)	Single-use limit
iDose TR	Glaukos	Travoprost	12+ months	Approved	81% (12mo)	Re-admin approved 2026
iDose TREX	Glaukos	Travoprost	~24 months	Ph IIb/III	TBD	2x drug capacity
SpyGlass IOL	SpyGlass	Bimatoprost	~36 months	Ph I/II	100% (18mo)	Drug-eluting IOL
OTX-TIC	Ocular Tx	Travoprost	~6 months	Ph II	Meaningful	Hydrogel implant
PA5108	PolyActiva	Latanoprost	~6 months	Ph IIb	TBD	Biodegradable
GLK-311	Glaukos	Undisclosed	Daily skin	Ph I	N/A	Transdermal eyelid

ecosystem of seven commercially significant platforms, each targeting different segments of the aqueous outflow pathway with distinct efficacy-safety profiles [18,19].

Trabecular Bypass Devices

Glaukos' iStent family now spans three generations culminating in the iStent infinite (FDA cleared August 2022), the first standalone trabecular microbypass approved for refractory glaucoma without concurrent cataract surgery. Five-year real-world data on 271 eyes shows 16.5% IOP reduction with a 72.3% decrease in medication burden [20]. The Hydrus Microstent (Alcon) differentiates through its 8mm nitinol scaffold spanning 90° of Schlemm's canal. The landmark HORIZON trial (556 patients, 5-year follow-up) demonstrated 66% medication-free rates versus 46% for cataract surgery alone, with a critically important finding: a 47% reduction in visual field progression rate (−0.26

Table 3. MIGS Device Comparison Matrix						
Device	**Approach**	**IOP Reduction**	**Med-Free Rate**	**Standalone Approved**	**Key Trial**	**Status**
iStent inject W	Trabecular bypass	9–31%	~75%	No*	Pivotal RCT	FDA Approved
Hydrus Microstent	Schlemm's canal	~20%	66% (5yr)	No	HORI-ZON	FDA Approved
OMNI System	Canal.+Trabec.	34–35%	74–80%	Yes	GEMINI	FDA Cleared
KDB Goniotomy	TM excision	26–28%	~25%	Yes	6-yr data	FDA Cleared
XEN 45 Gel Stent	Subconjunctival	35–37%	Variable	Yes	Meta-analysis	FDA Approved
MINIject	Supraciliary	39–41%	~48%	Yes	STAR-II/III	CE Marked
PreserFlo	Subconj. (ab ext.)	30–40%	~72%	Yes	IMP2	CE Marked
XEN63 Gel Stent	Subconjunctival	30–40%	~70%	Yes	1-yr data	CE Marked

dB/year vs. −0.49 dB/year, p=0.014), the first MIGS device to demonstrate disease-modifying structural protection [21,22].

Implant-Free Approaches

Implant-free approaches are gaining momentum. The OMNI Surgical System (Sight Sciences) performs 360° canaloplasty plus 180° trabeculotomy without leaving any permanent hardware. The GEMINI trial (149 eyes) showed 35% IOP reduction with 80% medication-free rates at 12 months, sustained through 36 months [23]. The Kahook Dual Blade (New World Medical) excises trabecular meshwork via goniotomy, delivering 28% IOP reduction sustained through 6 years [24]. These implant-free devices appeal to surgeons who value conjunctival preservation and the absence of permanent foreign material.

Subconjunctival and Supraciliary Drainage

AbbVie's XEN45 Gel Stent achieves the most aggressive IOP lowering among MIGS devices (~35% reduction) but carries the highest revision burden, with needling rates of 20 [25]–49%. XEN63 is the next Gel Stent generation demonstrating better outcomes, lower needling rates in European data and currently undergoing Phase III trial for FDA approval. The PreserFlo MicroShunt (Santen) has transformed European glaucoma practice—the majority of EU surgeons have shifted from trabeculectomy to PreserFlo—but remains unapproved by the FDA after its pivotal trial fell short [26]. iSTAR Medical's MINIject, the only commercially available supraciliary MIGS device, has demonstrated 38% sustained IOP reduction at 5 years [27].

Traditional Glaucoma Drainage Devices

Traditional glaucoma drainage devices—the Ahmed Glaucoma Valve, Baerveldt, and the newer Paul Glaucoma Implant—remain essential for advanced and refractory disease, achieving 47–55% IOP reductions but with higher complication profiles. The Paul Implant, with its smaller-bore tube design, is rapidly gaining popularity, showing median 53% IOP reduction with superior outcomes versus the Ahmed at 18 months [28].

4- Therapeutics Pipeline: New Mechanisms to Gene Therapy

ROCK Inhibitors and Nitric Oxide Donors

Rho-kinase (ROCK) inhibitors represent the first new mechanism of action in glaucoma in decades,

Table 5. Key Therapeutics Pipeline Candidates					
Candidate	**Company**	**Mechanism**	**Phase**	**Target**	**Key Data / Note**
NCX 470	Nicox	NO-donating PGA	NDA prep	IOP	Non-inferior to latanoprost; superior at multiple timepoints
Sepetaprost	Santen/Ube	FP/EP3 agonist	Approved (JP)	IOP	Japan launch Oct 2025; US development ongoing
QLS-111	Qlaris Bio	K-ATP channel	Phase II	EVP	3.2–3.7 mmHg add-on reduction; NTG trial underway
GVB-2001	IVIEW	AAV2 gene therapy	Phase I	TM outflow	First patient treated 2025; IOP trend down at 2wk
ER-100	Life Biosci.	CRISPR/MYOC	Phase I	TM outflow	IND cleared; first-in-human planned Q1 2026
BL1107	Bausch+Lomb	α2 agonist	Phase II	Neuroprotect.	Stat. sig. VF improvement; Phase III planned
Nicotinamide	Academic	NAD+ booster	Phase III	Neuroprotect.	1,300+ pts globally; results expected late 2027
NT-501	Neurotech	CNTF implant	Phase II	Neuroprotect.	Two trials; completion est. mid-2026

uniquely targeting trabecular meshwork outflow and episcleral venous pressure. Netarsudil (Rhopressa) and its combination with latanoprost (Rocklatan) are now integrated into Alcon's portfolio [29]. NCX 470 (Nicox)—an NO-donating bimatoprost—combines the most potent prostaglandin backbone with nitric oxide-mediated conventional outflow enhancement. Two Phase 3 trials (Mont Blanc, n=691; Denali, n=696) met primary non-inferiority endpoints, with an NDA submission expected in H1 2026 [30,31].

Novel Receptor Agonists

Omidenepag isopropyl (OMLONTI), FDA-approved September 2022, introduces a first-in-class EP2 prostaglandin receptor agonist that increases both conventional and uveoscleral outflow—distinct from traditional FP receptor prostaglandins [32]. Sepetaprost, a dual FP/EP3 agonist launched in Japan in October 2025, adds another receptor target. QLS-111 (Qlaris Bio) is the first drug targeting episcleral venous pressure reduction via ATP-sensitive potassium channels.

Gene Therapy

Gene therapy for glaucoma has reached human testing. GVB-2001 (IVIEW Therapeutics) delivers a dominant-negative RhoA transgene via AAV2 vector in a single intracameral injection. The first patient was treated in 2025 with no adverse events and a downward IOP trend [33]. CRISPR/Cas9 approaches targeting MYOC mutations entered Phase 1 in 2024, with Life Biosciences' ER-100 IND-cleared for first-in-human trials planned Q1 2026 [34]. Realistic approval timelines remain 2030–2032 at earliest.

Neuroprotection

Neuroprotection may finally be approaching clinical viability. Nicotinamide (vitamin B3) has generated compelling Phase 2 data: 3g/day improved visual field in 8 test locations versus placebo and improved pattern ERG amplitudes by 14.8% [35]. Phase 3 trials enrolling over 1,300 participants globally are underway. BL1107 (Bausch + Lomb) showed statistically significant visual field improvements in Phase II. Neurotech's NT-501, an encapsulated cell

therapy releasing CNTF, has two Phase II glaucoma trials estimated for completion mid-2026.

The AGS/AAO issued a position statement recommending against nicotinamide doses ≥3g/day outside clinical trials, following two cases of drug-induced liver injury. Phase 3 results expected late 2027 will be pivotal [36]. Table 4

AI, Telemedicine & Personalized Medicine

Artificial Intelligence in Glaucoma Diagnostics

Deep learning models on fundus images achieve AUCs of 0.90–0.99 for glaucoma detection [37]. Foundation models like RetFound (trained on 1.6 million retinal images) achieve AUC of 0.91 for distinguishing glaucomatous eyes [38]. EyeFound, trained on 2.78 million images from 227 hospitals, outperforms RetFound. Google DeepMind's collaboration with Moorfields Eye Hospital produced a system matching expert performance across 50+ eye conditions from OCT scans [39]. For progression monitoring, AI models can forecast future visual field tests up to 5.5 years ahead.

Home and Continuous IOP Monitoring

The iCare HOME2 is the only FDA-cleared home tonometry system—studies show up to one-third of patients have peak IOP outside clinic hours, modifying treatment decisions in over 50% of cases [40]. Implandata's Eyemate, a CE-certified implantable microsensor, provides permanent on-demand IOP readings via wireless transmission [41]. The integration of continuous IOP data with AI-assisted processing points toward a future of automated treatment adjustment—true closed-loop glaucoma management.

Personalized Medicine & Pharmacogenomics

GWAS studies have identified numerous risk loci (MYOC, OPTN, CAV1/CAV2, CDKN2B-AS1), and pharmacogenomic research has identified associations between ADRB2 polymorphisms and beta-blocker response. However, 20% of POAG patients are non-responders to first-line therapy, and no actionable pharmacogenomic guidelines have been released for IOP-lowering medications. The gap between genetic knowledge and clinical utility remains substantial but narrowing [42].

The next decade of glaucoma care will be defined by a fundamental shift from reactive, medication-dependent management to proactive, interventional precision medicine. Five converging trends are driving this transformation. First, landmark trial data — particularly from LiGHT and HORIZON — have validated the superiority of early procedural intervention over the traditional "watch and wait" approach, establishing laser and MIGS as first-line options rather than last resorts. Second, the emergence of implant-free and incision-free technologies — including femtosecond laser trabeculotomy, contactless DSLT, picosecond platforms, and excimer laser trabeculostomy — promises to lower the procedural threshold further, delivering structural IOP reduction without permanent hardware or conjunctival compromise. Third, sustained drug delivery platforms such as iDose TR and next-generation drug-eluting IOLs are poised to eliminate the compliance crisis that has undermined topical therapy for decades, though their long-term market penetration will hinge on demonstrating health-economic value against low-cost generic alternatives. Fourth, neuroprotection is transitioning from a theoretical aspiration to a testable clinical hypothesis, with nicotinamide, BL1107, and encapsulated cell therapies now in advanced trials that could, for the first time, expand glaucoma treatment beyond IOP reduction to direct retinal ganglion cell preservation. Finally, gene therapy and artificial intelligence — still in their earliest clinical stages — hold the potential to fundamentally reshape the 2030s landscape, offering the prospect of one-dose durable IOP control and autonomous screening at population scale. Taken together, these trends point toward a future in which glaucoma management is earlier, more targeted, less dependent on patient adherence, and increasingly guided by biological and digital precision — a paradigm that would have been unrecognizable just a decade ago. The companies, clinicians, and innovators who navigate the regulatory, reimbursement, and health-economic barriers separating these technologies from widespread adoption will define the standard of care for the next generation of glaucoma patients.

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