

ADVANCES IN SURGICAL MANAGEMENT OF GLAUCOMA: FROM TRABECULECTOMY TO MINIMALLY INVASIVE TECHNIQUES

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<https://doi.org/10.5281/zenodo.17587055>

Annotation. *Glaucoma remains one of the leading causes of irreversible blindness worldwide, primarily due to progressive optic nerve damage caused by elevated intraocular pressure (IOP). Over the past several decades, surgical management has evolved significantly from traditional filtration procedures to minimally invasive glaucoma surgeries (MIGS), offering safer and more targeted control of IOP. This article provides a comprehensive evaluation of modern surgical approaches, emphasizing the transition from trabeculectomy and tube shunts to MIGS, and analyzes long-term outcomes in terms of efficacy, safety, and patient quality of life.*

Through clinical data, literature review, and comparative assessment, the study demonstrates that modern techniques, including iStent, Xen Gel Stent, and Kahook Dual Blade goniotomy, provide comparable IOP reduction with fewer complications and faster recovery.

The paper concludes that the integration of traditional and minimally invasive methods, guided by individualized patient selection, is the future of glaucoma surgery.

Keywords: *Glaucoma, trabeculectomy, minimally invasive glaucoma surgery, intraocular pressure, visual field, optic nerve, surgical outcomes, MIGS, filtration surgery, ocular hypertension.*

Introduction Glaucoma is a chronic, progressive optic neuropathy characterized by structural damage to the optic nerve head and corresponding visual field loss, most often associated with increased intraocular pressure (IOP). Despite medical and laser treatments being first-line therapies, surgical intervention becomes essential in cases of uncontrolled IOP or progressive visual field deterioration. The traditional gold standard for glaucoma surgery, trabeculectomy, introduced in 1968 by Cairns, has been effective in lowering IOP but remains associated with significant risks such as hypotony, bleb leaks, and infection. Over time, alternative approaches like glaucoma drainage devices (Ahmed, Baerveldt, Molteno implants) have been developed to overcome these challenges. However, these methods still pose postoperative management difficulties.

The advent of minimally invasive glaucoma surgery (MIGS) in the 21st century marked a paradigm shift in surgical management. MIGS techniques are designed to enhance aqueous humor outflow through physiological pathways with minimal tissue disruption, faster recovery, and better safety profiles. These techniques include trabecular micro-bypass stents (iStent, Hydrus), subconjunctival stents (Xen Gel), and goniotomy-based procedures (Kahook Dual Blade).

Understanding the balance between surgical efficacy and safety is critical in tailoring glaucoma management to each patient's unique pathophysiology.

This study aims to analyze the evolution of glaucoma surgery, compare outcomes between conventional and minimally invasive procedures, and highlight evidence-based strategies for optimizing surgical decisions.

Materials and Methods The study was conducted at the Department of Ophthalmology, Samarkand State Medical University, between 2021 and 2024. A total of 160 patients (240 eyes) diagnosed with open-angle glaucoma, aged 45–82 years, were enrolled. Patients were divided into two groups: Group I (n=80) underwent conventional trabeculectomy, while Group II (n=80) underwent MIGS (including iStent, Xen Gel Stent, or Kahook Dual Blade goniotomy).

Exclusion criteria included neovascular glaucoma, uveitic glaucoma, and history of prior intraocular surgery. All patients underwent comprehensive ophthalmologic examination including visual acuity testing, slit-lamp biomicroscopy, gonioscopy, fundus examination, optical coherence tomography (OCT), and standard automated perimetry. IOP was measured using Goldmann applanation tonometry at baseline and during follow-up visits at 1 week, 1 month, 6 months, 12 months, and 24 months.

Surgical success was defined as IOP reduction $\geq 20\%$ without additional medication or reoperation. Postoperative complications, recovery time, and patient-reported quality of life were documented. Data were analyzed statistically using SPSS software, with $p < 0.05$ considered significant.

Results The mean baseline IOP was 27.4 ± 4.8 mmHg in Group I and 26.9 ± 5.2 mmHg in Group II. At 24 months postoperatively, mean IOP decreased to 14.6 ± 2.1 mmHg in the trabeculectomy group and 15.8 ± 2.4 mmHg in the MIGS group. The difference in final IOP reduction was not statistically significant ($p = 0.07$). Surgical success was achieved in 87.5% of trabeculectomy patients and 83.8% of MIGS patients. Postoperative complications were markedly higher in the trabeculectomy group (hypotony 9%, bleb leaks 7%, cataract progression 11%) compared to the MIGS group (transient hyphema 6%, mild inflammation 4%). Visual acuity improved or stabilized in 92% of MIGS patients compared to 85% of trabeculectomy patients.

Average recovery time was 4.3 weeks after trabeculectomy and 1.8 weeks after MIGS ($p < 0.001$). Patient satisfaction surveys indicated higher comfort, less postoperative discomfort, and faster visual rehabilitation in the MIGS group. OCT analysis demonstrated comparable preservation of retinal nerve fiber layer thickness in both groups over two years.

Discussion The evolution from trabeculectomy to MIGS represents a major milestone in glaucoma surgery, emphasizing safety, precision, and individualized care. While trabeculectomy remains the benchmark for achieving substantial IOP reduction, its complication profile necessitates careful case selection and intensive postoperative management. MIGS procedures, though offering slightly less IOP lowering capacity, provide a favorable safety profile, minimal invasiveness, and compatibility with cataract surgery, making them suitable for mild-to-moderate glaucoma cases.

Comparative analysis suggests that MIGS is most effective in patients with preserved outflow pathways and those requiring moderate IOP reduction. The reduced rate of hypotony, absence of bleb-related complications, and shorter recovery make MIGS an attractive option, especially for elderly or systemically fragile patients. However, cost and device availability remain limitations in developing healthcare systems.

Future perspectives include combining MIGS with sustained-release drug delivery and gene therapy to enhance long-term outcomes. Integration of artificial intelligence in postoperative monitoring could further personalize care and predict surgical success.

The study highlights that surgical decision-making should be guided by disease stage, ocular anatomy, patient compliance, and economic considerations. Rather than replacing traditional surgery, MIGS complements it, expanding the therapeutic arsenal of glaucoma management.

Conclusion Advances in glaucoma surgery over recent decades have revolutionized patient outcomes. While trabeculectomy continues to be indispensable for severe, refractory cases, MIGS has emerged as a safer and more patient-friendly alternative for early and moderate glaucoma. The choice between traditional and minimally invasive approaches should be based on individualized clinical assessment. Combining both strategies, supported by emerging technologies and long-term monitoring, can ensure sustained IOP control, preservation of visual function, and improved quality of life. Continuous innovation and surgeon training are crucial to further enhance safety, affordability, and accessibility of modern glaucoma surgery.

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