

## CURRENT OPTIONS FOR SURGICAL TREATMENT OF GLAUCOMA

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### Abstract

The purpose of this study is to review current surgical treatment and new and better alternatives for patients with glaucoma.

Glaucoma refers to a group of related eye disorders that have in common an optic neuropathy associated with visual function loss. It is one of the leading causes of irreversible blindness worldwide.

Optic nerve damage and glaucoma-related vision loss can be prevented or limited by early diagnosis and treatment. Surgery offers a better control of the intraocular pressure than medical therapy. Nowadays, research continues for improving current surgical alternatives for treatment.

**Keywords:** glaucoma, surgical treatment, stent, eye implant.

### Introduction

The term glaucoma refers to a group of diseases that have in common an optic neuropathy associated with visual function loss. Glaucoma is the second most frequent cause of irreversible blindness in the world.

The number of patients suffering from glaucoma is estimated at 67 million, making this disease a huge public health impact.

#### Filtering surgery

Filtering surgery in glaucoma is indicated when medical treatment and laser therapy are unable to prevent, stop or delay the progression of the disease. It is known that surgery offers a better control of intraocular pressure (IOP) than medical treatment. Even so, the traditional

filtering surgery is a challenge, especially in advanced glaucoma, for it can be accompanied by complications and failure.

Trabeculectomy is considered the “gold standard” of non-penetrating surgery in glaucoma; it is the surgical technique from which all the others are derived, newer procedures, with better efficacy and safety.

Surgical procedures are based on one of the two mechanisms to reduce IOP:

1. Improving drainage of aqueous humor (AH)

2. Reducing production of AH.

1. The first technique is the one usually used. There are two types of procedures: *ab externo* and *ab interno*.

- 1.1 non-penetrating anterior filtering techniques:

- 1.1.1 deep sclerectomy (DS) (simple or assisted by a CO<sub>2</sub> laser)
- 1.1.2 canaloplasty
- 1.2 penetrating anterior filtering techniques:
  - 1.2.1 trabectome
  - 1.2.2 Fugo blade
  - 1.2.3 Excimer laser assisted trabeculectomy.
- 1.3 penetrating posterior filtering techniques:

**1.1 Non-penetrating anterior filtering techniques**

**The efficacy of antiglaucoma non-penetrating surgery:**

- the rate of success varies between 45% and 69%;
- the rate of complete success is 34.6% for deep sclerectomy and 63.4% for deep sclerectomy with collagen implant, after 48 months [1].
- the qualified success can be up to 69-100%.

**Indications for non-penetrating anterior filtering techniques:**

- primary open angle glaucoma (POAG)
- pigmentary glaucoma
- pseudoexfoliative glaucoma
- non-penetrating deep sclerectomy for : glaucoma due to high myopia, uveitic glaucoma, primary juvenile glaucoma, glaucoma caused by increased episcleral venous pressure.

**Contraindications for non-penetrating anterior filtering techniques:**

- scares from an anterior trabeculectomy;
- patients with scaring of the Schlemm's canal caused by laser, surgical procedures or corneo-scleral trauma;
- anomalies of the camerular angle;
- primary angle-closure (PAC) (for non-penetrating deep sclerectomy);
- open-angle glaucoma due to ocular trauma (for non-penetrating deep sclerectomy).

**Complications of non-penetrating anterior filtering techniques:**

- hyphema
- early or late elevation of IOP

- suture detachment
- Descemet detachment
- iris prolapse
- hypotonia
- inflammation
- failure of the procedure

**1.1.1 Deep sclerectomy**

**1.1.1.1 Non-penetrating simple deep sclerectomy**

Through this technique the Schlemm's canal is opened and the partial excision of the external and internal walls and of a part of the trabecular meshwork is made (Fig. 1).

The most frequently used technique is to make two scleral flaps, one superficially situated with the base at the limbus and another, more profound, as a mark for the opening of Schlemm's canal.

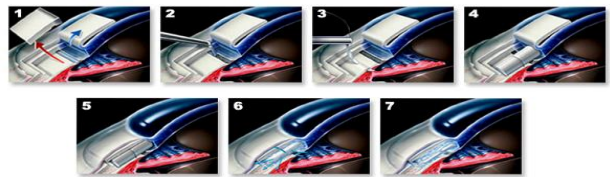


Fig. 1 The technique of the deep sclerectomy

The profound flap is excised, eliminating the internal and external walls of the Schlemm's canal. The drainage of the aqueous humor is observed. All the anatomical planes are sutured [2].

**1.1.1.1 CO<sub>2</sub> laser assisted deep sclerectomy (CLASS)**

First, the conjunctiva is incised for making a flap with the *ab externo* base. A rectangular sclera flap is made (1/3 or 1/2 of the sclera's thickness), with the base at the limbus (Fig. 2).

The CO<sub>2</sub> laser is applied, along with the HENE guidance. The CO<sub>2</sub> laser will excise the external wall of the Schlemm's canal.

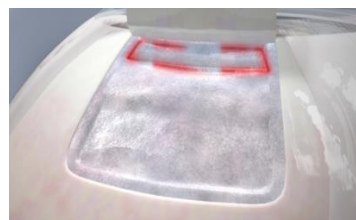


Fig. 2 Scleral flap in CO<sub>2</sub> laser assisted deep sclerectomy

A study was conducted on 15 patients to prove the efficacy of this procedure. An average IOP reduction of  $13.1 \pm 4.3$  mm Hg (45.1%) and  $11.5 \pm 5.5$  mm Hg (39.2%) at 6 and 12 months was seen. The complete success rate after 12 months was 45.5%, whereas qualified success was 90.9%. Mitomycin C was used in 76.9% of the CLASS subjects [3].

### Trabeculectomy versus deep sclerectomy

There are numerous randomized studies that reveal the superiority of non-penetrating surgery concerning safety; when it comes to efficacy, the results are different in studies.

The trabeculectomy lowers the IOP to greater extent compared to viscocanaloplasty; the rate of complications is higher for the trabeculectomy [4],[5].

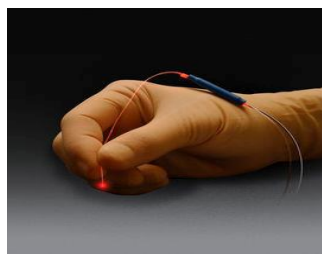
Comparing deep sclerectomy with trabeculectomy, using the Kaplan Meier cumulative survival curve, the trabeculectomy patients had a better complete success rate than the non-penetrating deep sclerectomy patients at 18 months post-operatively. There were statistically significantly fewer complications in the non-penetrating deep sclerectomy group [6].

A study conducted on 39 patients revealed there is no significant difference between trabeculectomy and deep sclerectomy for POAG concerning the lowering of IOP, but the rate of complications is lower for the sclerectomy (12 months follow-up) [7].

The sclerectomy with collagen implant has a success rate comparable to trabeculectomy, with a lower complication rate as proven by a study conducted on 100 patients [8].

#### 1.1.1 Canaloplasty

For this type of non-penetrating surgery, a wire is introduced in the Schlemm's canal, guided by an optic fiber micro catheter (Fig.3).



**Fig. 3** Micro catheter used in canaloplasty

The wire dilates and keeps tension in Schlemm's canal, reestablishing the flow of aqueous humor through the physiological paths.

A viscoelastic product is injected for opening the Schlemm's canal.

The tension created has a pilocarpin-like effect, improving flow through the trabecular meshwork.

A study conducted on 726 patients concluded that canaloplasty produced a sustained long-term reduction of IOP in black Africans with POAG independent of preoperative IOP. As a bleb-independent procedure, canaloplasty may be a true alternative to classic filtering surgery, in particular in patients with enhanced wound healing and scar formation [9].

### Advantages

- the 360° controlled opening of Schlemm's canal
- the possibility to combine the procedure with deep sclerectomy for better lowering of the IOP

### Disadvantages

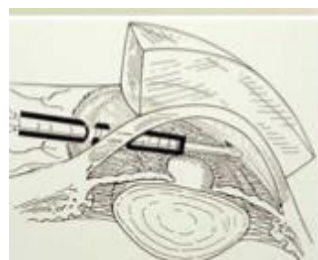
- expensive device
- unknown long term effect of the implant in Schlemm's canal

## 1.2 Penetrating anterior filtering techniques

### 1.2.1 Trabectome

The trabectome (Fig. 4) is a surgical instrument used for controlled partial endoelectro ablation of the trabecular mesh, under gonioscopic guidance.

This ab interno procedure dissects the juxtatrabecular region and eliminates the resistance, creating a direct flow of the aqueous humor through the Schlemm's canal and the collector channels [3].



**Fig. 4** The trabectome

### Indications

- POAG
- pigmentary and pseudoexfoliative glaucoma
- POAG with ineffective filtering.

**Contraindications:**

- angle closure, with or without peripheral synechiae.

**Complications:**

- hyphema
- iridodialysis
- ciclodialysis
- the abrupt elevation of the IOP.

**Advantages:**

- creating a large communication between the anterior chamber and the collector channels
- lack of adjacent tissue damage
- unaffected conjunctival integrity
- no filtering bleb.

**Disadvantages:**

- the opening of the Schlemm’s canal is not circumferential
- a limited lowering of the IOP caused by the pressure in the aqueous veins
- expensive procedure

**1.2.2 Fugo plasma blade – transcliliary filtration**

Approved by the FDA in 2004, Fugo plasma blade (Fig. 5) is the first plasma ablation system that can create precise low-energy incisions on the ocular surface without damaging the adjacent elements, with instantaneous hemostasis.



Fig. 5 Fugo plasma blade device

**Advantages:**

- posterior drainage
- no antimetabolites needed

- the price is not very high
- the short duration of the intervention.

**Disadvantages:**

- the risk of a hyperfiltering
- hypotonia

The Fugo blade technique can also be ab interno by creating fenestrations in the internal wall of Schlemm’s canal, that allow the AH to flow without resistance.

The procedure was found to be effective and safe [10].

**1.2.3 Excimer laser assisted trabeculectomy**

The procedure is ab interno; it creates small gaps in the trabecular meshwork which allows the aqueous humor to pass through the Schlemm’s canal without encountering resistance (Fig. 6). An Excimer xenon-chloride laser is used.



Fig. 6 Intraoperative view during an Excimer laser assisted trabeculectomy

**Advantages:**

- the ab interno approach keeps the conjunctiva intact
- control of the ablation, without alternative tissue damage
- can be combined easily with phacoemulsification
- short duration of the intervention.

**1.3 Non-penetrating posterior filtering techniques**

**Indications:**

- glaucoma unresponsive to medical treatment (AqueSys, ExPress)
- POAG with moderate IOP (Hydrus microstent, CyPass),
- early onset POAG (EyePass),

- failure of trabeculectomy (Gold microshunt, iStent)
- pigmentary glaucoma (iStent)
- pseudoexfoliative glaucoma (iStent)
- Sturge-Weber syndrome (ExPress)
- aphakic glaucoma (ExPress)

**Contraindications:**

- primary angle closure glaucoma (ExPress, iStent, CyPass, Hydrus microstent, AqueSys)
- secondary glaucoma (CyPass, Hydrus microstent, AqueSys)
- acute angle-closure (Gold Microshunt, EyePass)
- uveitic glaucoma, traumatic glaucoma, neovascular glaucoma, iridocorneal endothelial syndrome (Gold Microshunt, EyePass)
- active ocular infection
- ocular surgery in the last 12 months (Gold Microshunt)
- active ocular pathologies : uveitis, ocular infections, dry eye syndrome (ExPress, iStent, Gold Microshunt)
- systemic or ocular disease that can cause postoperative complications.

**Complications:**

- blockage of the aqueous humor flow (ExPress)
- possible peripheral anterior synechiae (iStent)
- hyphema
- hypotonie (Gold Microshunt, EyePass)
- supracoroidian hemorrhage (Gold Microshunt)
- migration of the device
- discoloration of the Descemet membrane (CyPass)

**Advantages:**

- lowered risk of hypotonia (Ex-Press, Gold Microshunt)
- limited risk of athalamia (Ex-Press)
- continuous control of filtering
- reduced inflammation: no iridectomy needed (Ex-Press)
- fixed and continuous drainage through metallic stent (iStent, Hydrus microstent)

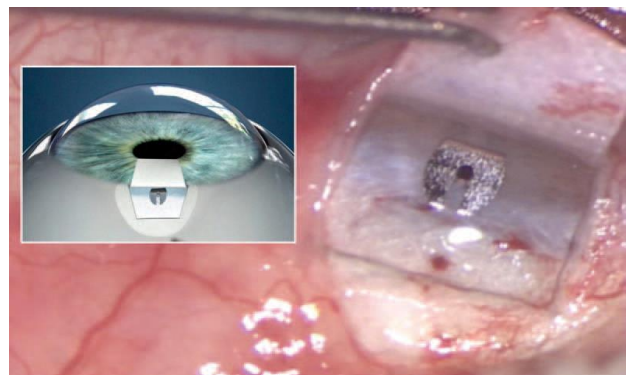
- maintaining the integrity of the conjunctiva (iStent, CyPass, Hydrus microstent, AqueSys)
- possibility of combined surgery (iStent, CyPass, Hydrus microstent, AqueSys)
- possibility of modulating the IOP by changing parameters of the devices (Gold Micro Shunt)
- low risk of creating a filtering bleb (Gold Micro Shunt)
- a permanent communication between the anterior chamber and the supracoroidian space (CyPass)
- excellent biocompatibility (Hydrus microstent)
- a permanent communication between the anterior chamber and the subconjunctival space (AqueSys)
- no adjacent tissue damage (AqueSys)

**Disadvantages:**

- the risk of antimetabolites (Ex-Press)
- the risk of contact with the iris or cornea (Ex-Press)
- the necessity of multiple stents for obtaining a higher flow (iStent)
- the risk of device migration
- difficult procedure
- expensive device
- creating a filtering bleb (AqueSys)
- the possibility of conjunctival damage (AqueSys)
- risk of fibrosis (AqueSys)

**1.3.1 Ex-Press device**

It is an alternative to conventional surgery (Fig. 7).

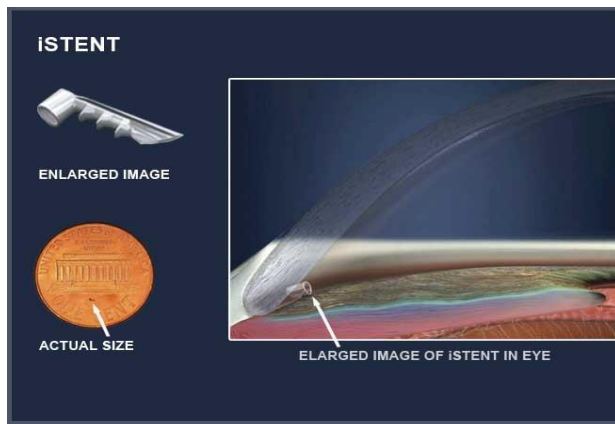


**Fig.7** Intraoperative view after placing an Ex-Press stent

Studies have proven the superior efficacy of the Ex-Press stent to the trabeculectomy: IOP lowering up to 50.9% for the Ex-Press stent and 44.6% for the trabeculectomy after 12 months [11].

In a study on POAG, Ex-PRESS and trabeculectomy provided similar IOP control, but Ex-PRESS was more likely to achieve complete success, with fewer postoperative interventions. Complication rates were similar for the two types of surgery, except for a lower frequency of hyphema in the Ex-PRESS group [12].

### 1.1.1 IStent (Glaukos Corp)



**Fig. 8** The positioning of the IStent shunt

The IStent shunt is the first micro-bypass ab interno implant available for the treatment of glaucoma (Fig. 8). It was designed for reestablishing the physiological flow of the AH, by creating a by-pass through the trabecular meshwork of the Schlemm's canal. The IStent is positioned ab interno through a small incision in the Schlemm's canal, in the inferior nasal quadrant [13].

### 1.1.1 Gold micro shunt

The Gold micro shunt is a micro gold plaque of 24 karats that contains 19 canals. It is used for creating a communication between the anterior chamber of the eye and the supracoroidian region (Fig. 9).



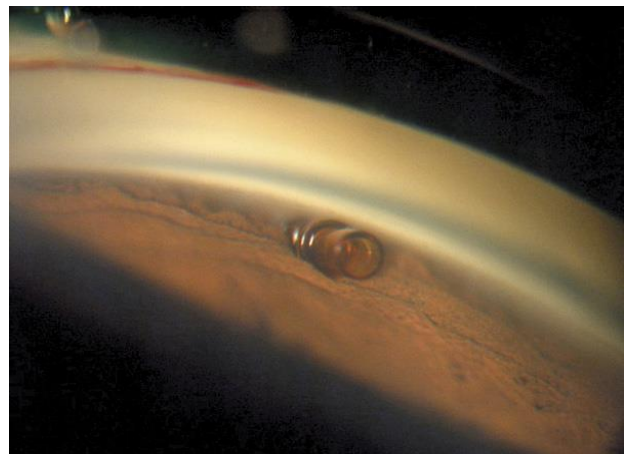
**Fig.9** Gold micro shunt device

The difference of pressure between the anterior chamber and the supraciliary space determines a flow of the aqueous humor through the micro-canals.

The Gold micro shunt is the first implant that uses natural pressure gradient for creating a continuous flow of the AH [14][15].

### 1.3.4 EyePass

EyePass glaucoma implant is a micro tube shaped as a "Y"; it was developed in order to bypass the trabecular meshwork and make a communication between the Schlemm's canal and the anterior chamber (Fig. 10). The procedure is ab externo; both arms of the device have to be placed inside the Schlemm's canal [16].



**Fig. 10** EyePass implant

### 1.3.4 CyPass Micro-Stent

CyPass Micro- Stent is actually a polyamide cannula, with a 6.25 mm length and a diameter of 300  $\mu\text{m}$  (Fig.11).

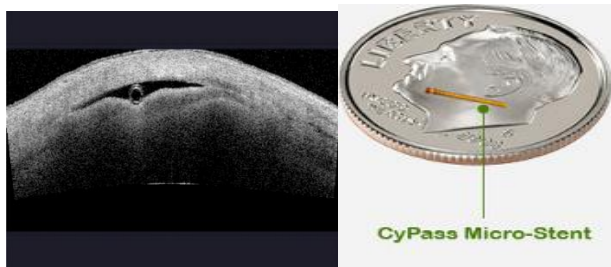


Fig. 11 CyPass device

It is placed in the supraciliary space and the aqueous humor drains through the gaps of this tube [17].

In a study conducted on 142 patients, CyPass Micro-Stent implantation resulted in minimal complications and reduced IOP 12 months postoperatively [18].

### 1.3.6 Hydrus microstent

Hydrus microstent is described as an "intracanalicular scaffolding" (Fig.12).



Fig. 12 Hydrus microstent device

The procedure is done ab interno; it is actually a micro-by-pass that reestablishes flow through the trabecul - Schlemm's canal, using a direct communication between the anterior chamber and the Schlemm's canal.

The device has the size of an eyelash, made of nitinol (nickel-titanium); it is very elastic and biocompatible.

Preliminary data on 28 patients in a study, showed that after 6 months, combined phacoemulsification and Hydrus stent insertion resulted in approximately a 15% decrease in IOP from a baseline of 18 mmHg. The two most common complications were transient hyphema

in 15% and Peripheral Anterior Synechiae (PAS) formation in 10% of patients [19].

### 1.3.7 AqueSys

The AqueSys system is described as the first procedure with an ab interno subconjunctival approach for lowering the IOP. It creates a direct link between the anterior chamber and the subconjunctival space.



Fig. 13 AqueSys device

The implant is flexible, with a gel-like structure; its diameter is that of a human strand of hair (65 $\mu\text{m}$ ) (Fig.13).

## Conclusions

Glaucoma is an optic neuropathy characterized by retinal ganglion cell death and axonal loss. It remains a major cause of blindness worldwide. All current modalities of treatment are focused on lowering intraocular pressure.

The surgical treatment for this disease is considered to be a better alternative than medical therapy. There are various types of surgical technique that can be used to treat glaucoma. All of them have proven to be effective and safe.

It is anticipated that the devices developed will pave the way for future discovery, development, and marketing of novel surgical ways to treat glaucoma and thus help save sight for millions of people afflicted with this slow progressive optic neuropathy.

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