

## New Technologies for Treating Glaucoma in Patients Undergoing Cataract Surgery

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### Abstract

New surgical technologies, such as the EXPRESS™ shunt, iCath™ canaloplasty, Trabectome™ and endoscopic cyclophotocoagulation (ECP), have been developed to provide safe and effective control of intraocular pressure (IOP) while avoiding many of the complications associated with trabeculectomies or traditional glaucoma drainage implants. A benefit of some of the newer technologies, especially for patients for whom traditional glaucoma surgeries may not previously have been considered, is that they can be readily performed at the time of cataract extraction. Many surgeons are combining these new surgical techniques with cataract surgery because of the low rate of serious complications, limited manipulation of ocular tissue (especially the conjunctiva) and/or faster visual recovery than traditional glaucoma surgeries.

### Keywords

EXPRESS™ shunt, iCath™ canaloplasty, Trabectome™, endoscopic cyclophotocoagulation (ECP), iStent®, SOLX® Gold Shunt, Aquashunt™, glaucoma surgery

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The development of a visually significant cataract in a patient with glaucoma is a common and often expected event. The decision-making process regarding the timing and type of surgery offered for a patient with a visually significant cataract and glaucoma is complex, and depends on factors such as vision, visual potential, intraocular pressure (IOP) control, medication use and tolerance, optic nerve damage, visual field loss and the aetiology of the patient's glaucoma. Typically, traditional glaucoma surgery (a trabeculectomy or tube shunt) has been performed in combination with cataract surgery for patients with poorly controlled IOP or progressive visual field loss, and/or for patients with good to marginal IOP control on multiple IOP-lowering drops. Newer surgical technologies, such as the EXPRESS™ shunt, iCath™ canaloplasty, Trabectome™ and endoscopic cyclophotocoagulation (ECP), have been developed to provide safe and effective IOP control while avoiding many of the complications associated with trabeculectomies or traditional glaucoma drainage implants. A benefit of some of the newer technologies, especially for patients for whom traditional glaucoma surgeries may not have been considered, is that they can be readily performed at the time of cataract extraction.

Current mainstays for the surgical treatment of glaucoma are trabeculectomy and first-generation glaucoma drainage implants. As demonstrated by numerous retrospective and prospective studies, traditional surgical therapies for glaucoma can successfully control IOP and limit glaucomatous vision loss.<sup>1-3</sup> However, limitations to these traditional IOP-lowering surgeries have been well documented. Complications of trabeculectomy with adjunctive 5-fluorouracil or mitomycin C include cataractogenesis, hypotony and hypotony

maculopathy, bleb leaks, blebitis and bleb-related endophthalmitis, bleb dysesthesia, ciliochoroidal effusions, peripheral anterior synechiae formation, posterior synechiae, scleral melt and relatively high rates of long-term clinical failure.<sup>4,5</sup> The placement of tube-shunt devices (e.g. Ahmed, Molteno, Baerveldt) shares many of the same complications associated with trabeculectomy, as well as tube–cornea touch, obstruction or migration of the tube, valve malfunction and/or erosion of the conjunctiva over the tube or plate.<sup>6,7</sup>

As previously mentioned, the decision to perform incisional glaucoma surgery requires the consideration of multiple factors. In general, many of the newer surgical techniques are indicated for the same types of patient who traditionally would have been considered candidates for selective laser trabeculoplasty (SLT) or trabeculectomy. Due to their low rate of serious complications and limited destruction or manipulation of ocular tissue (especially the conjunctiva), many of the newer surgeries, such as Trabectome or ECP, are considered earlier in the course of treatment than traditional glaucoma surgeries. In addition, failure of a newer surgery to obtain a desired IOP often does not limit the successful implementation of a traditional surgery.

### EXPRESS Shunt

The EXPRESS mini glaucoma shunt (Optonol Ltd, Neve Ilan, Israel) is a small (~3mm-long) stainless steel tube-like device with an anchoring footplate (see *Figure 1*). The EXPRESS shunt diverts aqueous from the anterior chamber through its 50 or 200µ lumen. When the EXPRESS shunt was first introduced, the recommended technique involved insertion of the device at the limbus, directly under the conjunctiva, in the belief that the small lumen size would restrict flow and prevent

hypotony.<sup>8</sup> However, complications due to sustained hypotony and implant exposure led to the current implantation technique: under a trabeculectomy-type scleral flap with antimetabolite augmentation.

The EXPRESS shunt obviates the need to create a sclerectomy during trabeculectomy surgery. The surgeon can perform a trabeculectomy according to his/her usual routine (i.e. limbal or fornix-based). After creation of the partial-thickness scleral flap, a sclerostomy is created using a 25–27-gauge needle passed under the scleral flap into the anterior chamber in the plane of the iris. The EXPRESS shunt is then inserted into the anterior chamber through the sclerostomy under the scleral flap, and the flap is closed with interrupted or releasable sutures as per the surgeon's standard trabeculectomy flap closure. Like the traditional trabeculectomy, a bleb is still created; however, an iridectomy is not necessary.<sup>9</sup>

Indications for the EXPRESS shunt are similar to those for traditional trabeculectomy, including uncontrolled IOP and/or advanced glaucoma with prior failed glaucoma surgical procedures. The EXPRESS shunt is one of the few novel technologies that can obtain very low IOPs, similar to a traditional trabeculectomy. Contraindications for EXPRESS shunt placement include congenital glaucoma, acute/chronic angle-closure glaucoma and chronic narrow-angle glaucoma.

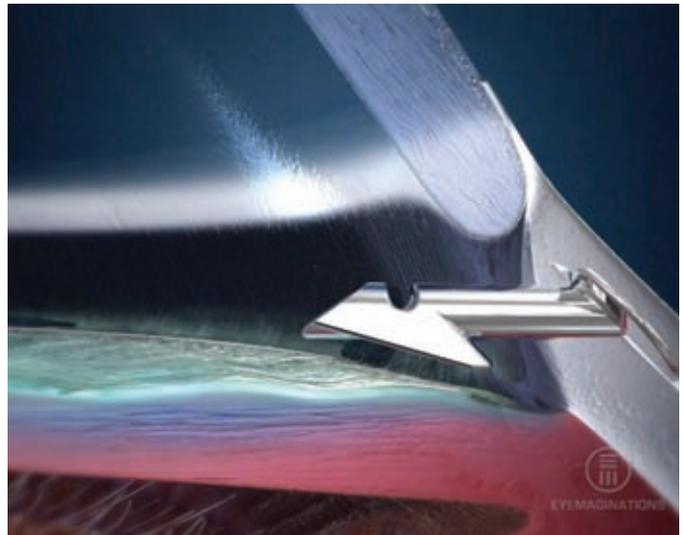
Outcomes appear to be positive in the short term, as identified in a retrospective matched comparative group study of the EXPRESS shunt with standard trabeculectomy evaluating 153 eyes with a follow-up of 12 months.<sup>9</sup> Results demonstrated a 50.9% IOP reduction for the EXPRESS group compared with 44.6% for the trabeculectomy group. Hypotony was observed in 12% of EXPRESS cases compared with 21% of trabeculectomy cases. The overall success rate, defined as IOP  $\leq$ 21mmHg with or without medication at one year, was 79% for EXPRESS shunt patients and 69% for trabeculectomy patients.

Advantages of the EXPRESS shunt over trabeculectomy include standardisation of the creation of the sclerectomy/sclerotomy, decreased inflammation and intraocular manipulation due in part to the avoidance of the creation of a peripheral iridectomy and lower rates of hypotony due to some degree of flow restriction through the implant.<sup>10,11</sup> Disadvantages of the EXPRESS shunt include the cost of the device, the potential for malposition of the implant resulting in corneal decompensation, obstruction of the tube by the iris or other intraocular tissue or debris and erosion of the tube into the anterior chamber or through the conjunctiva.

### iCath Canaloplasty

iCath canaloplasty is a non-penetrating procedure that is believed to improve aqueous outflow by some combination of mechanically stretching the trabecular meshwork and creating filtration through a Descemet's window while maintaining 360° of patency of Schlemm's canal. To perform the surgery, Schlemm's canal is unroofed under a scleral flap, a Descemet's window is created and Schlemm's canal is intubated with a specialised cannula, the iCath (iScience Interventional, Menlo Park, CA, US). The iCath has an illuminated tip that assists in identifying the position of the cannula as it is passed through Schlemm's canal (see *Figure 2*). The iCath also has a lumen through which viscoelastic can be injected to dilate the canal. Finally, once the cannula is threaded circumferentially in Schlemm's canal, a 10-0 prolene suture is tied to the cannula and pulled through the canal as the cannula is withdrawn. Tying off the prolene suture provides tension

**Figure 1: EXPRESS Shunt Placed Under a Scleral Flap**



**Figure 2: iCath Illuminated Probe Tip and Power Source**



that holds the canal open. The scleral flap and conjunctiva is closed, such that there should be no bleb.

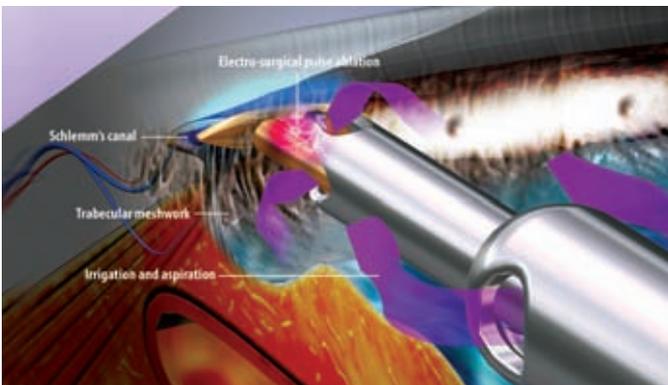
Indications for canaloplasty are similar to those for trabeculectomy surgery. Contraindications include narrow-angle glaucoma, steep peripheral or plateau iris, angle-closure glaucoma, peripheral anterior synechiae, chronic inflammation or neovascularisation, prior trabeculectomy, prior implantation of an aqueous shunt, prior laser trabeculoplasty with scarring or any other procedure that would prevent full 360° cannulation of Schlemm's canal. Canaloplasty alone has been found to lower IOP by 38%. When combined with cataract surgery, IOP was lowered by 44% at 24 months.<sup>12</sup> Successful canaloplasty typically results in IOPs in the mid-teens, which may not be low enough for some patients.

Canaloplasty is not dependent on bleb formation, so advantages include avoiding post-operative complications associated with blebs such as bleb leaks, dysesthesia or bleb-associated endophthalmitis. Successfully performed canaloplasty should avoid post-operative hypotony, since resistance from the trabecular meshwork, collecting channels and episcleral venous pressure limits the reduction in IOP.<sup>13,14</sup> There should also be a lower incidence of acute post-operative endophthalmitis, since

**Figure 3A: Intraoperative Image Demonstrating the Trabectome *Ab Interno* Goniotomy**



**Figure 3B: The Trabectome™ Instrument Tip**



Note the collector channels exposed after the trabecular meshwork is ablated.

canaloplasty is a non-penetrating procedure.<sup>12</sup> A final advantage of canaloplasty is that there are no flap sutures to remove and no bleb formation to modulate, so post-operative management often requires fewer visits than trabeculectomy patients.<sup>15</sup>

One major disadvantage of canaloplasty is that it is a technically complex surgery, requiring techniques and dissections that many surgeons may not be comfortable performing. In addition, canaloplasty requires a significant amount of conjunctival dissection, which may limit the execution of subsequent traditional glaucoma surgeries. Finally, as mentioned before, successful canaloplasty typically results in IOPs in the mid-teens, which may not be low enough for some patients.

## Trabectome

The Trabectome (NeoMedix Corp., Tustin, CA, US) is a novel method for performing an *ab interno* goniotomy (see Figure 3A), lowering IOP by improving aqueous access to Schlemm's canal outflow channels. Unlike traditional incisional goniotomy or trabeculectomy, the Trabectome system uses electrocautery to ablate an area of the trabecular meshwork and the inner wall of Schlemm's canal. The handheld Trabectome instrument (see Figure 3B) is inserted into the anterior chamber through a clear corneal incision and enters Schlemm's canal through the trabecular meshwork. The inner aspect of the tip ablates a 90–120° segment of trabecular and

juxtacanalicular tissues, while the outer aspect protects collector channels draining Schlemm's canal from thermal damage.

Indications for the Trabectome are similar to those for SLT or trabeculectomy. The procedure may be more effective for patients who start off with higher levels of IOP than those eyes whose IOPs are in the low teens but require further reduction.<sup>16</sup> Relative contraindications for the procedure include conditions that limit visualisation of angle structures, inflammatory glaucoma, steroid-responsive glaucoma or extensive peripheral anterior synechiae. In addition, successful Trabectome outcomes typically result in IOPs in the mid-teens, so the procedure is generally not indicated for patients requiring lower IOPs.

A retrospective case series demonstrated that trabeculectomy by Trabectome effectively controlled IOP in open-angle glaucomas.<sup>16</sup> The series included 1,127 Trabectome surgical procedures, of which 738 were Trabectome-only procedures and 366 were Trabectome–phacoemulsification surgeries. Patients who had Trabectome-only procedures had mean pre-operative IOPs of 25.7±7.7 mmHg that were reduced by 40% to 16.6±4mmHg at 24 months. Patients who had Trabectome combined with phacoemulsification saw baseline IOPs of 20.0±6.2mmHg decreased by 18% to 15.9±3.3mmHg at 12 months. Patients in both groups also required fewer medications at 24 months. There were no cases of prolonged hypotony, choroidal effusion, choroidal haemorrhage or infections. Medications decreased from 2.93 to 1.2 by 24 months.

Significant advantages of Trabectome are that it does not require conjunctival manipulation and results in minimal tissue disruption, so trabeculectomy or other traditional surgical options are possible after the procedure. For this reason, Trabectome is often performed in conjunction with cataract extraction for patients who require IOPs in the mid-teens.<sup>17</sup>

Patients with narrow anterior chamber angles or inflammatory glaucoma may more readily develop peripheral anterior synechia in the areas treated by Trabectome. Successful Trabectome treatment typically results in IOPs in the mid-teens, and is generally not indicated for patients requiring lower IOPs.

## Endoscopic Cyclophotocoagulation

While the devices and surgical techniques discussed above focus on improved outflow methods, ECP (Endo Optiks, Little Silver, NJ, US) decreases aqueous production by ablating ciliary body tissue. Cyclodestruction has historically been performed trans-sclerally and was reserved for refractory cases of glaucoma or for eyes with limited visual potential. ECP allows for direct visualisation and photocoagulation of the ciliary body. The advantage of ECP over trans-scleral cyclophotocoagulation is that more directed photocoagulation spares collateral damage to adjacent ocular structures.

ECP utilises a diode laser that emits pulsed continuous-wave energy at 810nm from a 175W xenon light source combined with a helium–neon laser aiming beam and video camera imaging (see Figure 4A). These components are transmitted by a 18- or 20-gauge fibre optic connected probe (see Figure 4B) that is inserted intraocularly via the anterior chamber, or occasionally through the pars plana. Typically, 180–270° of the pars plicata is treated. ECP can be performed during cataract surgery, after removal of the crystalline lens and prior to placement of the IOL in pseudophakic eyes, and rarely in phakic eyes.

ECP is generally indicated for patients not well controlled on topical IOP-lowering therapy or in well-controlled glaucoma patients with a visually significant cataract who would like to reduce the number of IOP-lowering medications required. Extensive ECP treating the pars plicata and pars plana may also be useful for recalcitrant glaucomas, such as in patients with failed tube shunts.<sup>18</sup> The endoscope of the ECP can also be a useful tool to visualise intraocular structures when corneal or anterior segment pathology limits the surgeon's view posteriorly.

Studies have supported the use of combined ECP/phacoemulsification procedures to decrease IOP and the number of IOP-lowering medications after surgery. One report with 125 eyes showed a 16% IOP reduction at five years, with 76% of treated eyes requiring one or fewer medications and 61% of eyes requiring no medications.<sup>19</sup> Additional studies have supported these claims and also show no differences in the incidence of angiographic CME between eyes undergoing ECP/phacoemulsification and phacoemulsification alone.<sup>20,21</sup>

A disadvantage of ECP is that it involves the photocoagulation or destruction of an important intraocular tissue. Occasionally, ECP can result in significant uveitis, and there is some concern regarding the long-term effect of decreasing aqueous production on intraocular tissues such as the corneal endothelium.

### Devices Under Investigation

#### iStent®

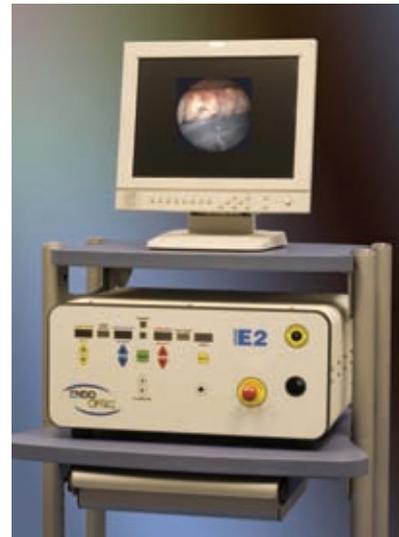
Although not yet US Food and Drug Administration (FDA)-approved, the iStent® Trabecular Bypass Micro Stent (Glaukos Corp., Laguna Hills, CA, US) is a device that is designed to lower IOP by shunting aqueous from the anterior chamber directly into Schlemm's canal without the formation of a filtering bleb. The device is very small: 1.0x0.5mm with a lumen diameter of 0.12mm. The heparin-coated L-shaped titanium iStent is inserted into Schlemm's canal via an *ab interno* transcameral approach. The device is similar in appearance to a miniature snorkel, with one open end protruding into the anterior chamber and the other end inserted into Schlemm's canal to allow aqueous fluid to bypass the dysfunctional trabecular meshwork. The iStent is implanted under direct gonioscopy and is held in place, without sutures, by three ridges on the long arm that is inserted into Schlemm's canal.

A 24-month prospective, non-randomised, open-label, multicentre clinical trial demonstrated the efficacy and safety of the iStent for the treatment of open-angle and/or pseudoexfoliation glaucoma in patients (n=59) with IOP uncontrolled by their current ocular hypotensive medication.<sup>22</sup> Twenty-four months after placement of the iStent, the mean IOP reduction from the baseline was 5.1±4.2mmHg, and patients required 1.1 fewer IOP-lowering medications.

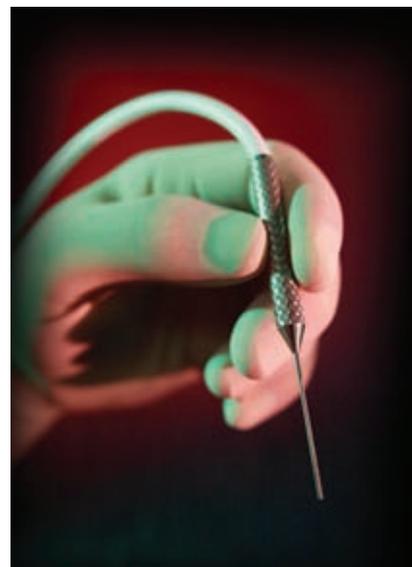
An advantage of using the iStent device is that implantation is a minimally invasive procedure that spares conjunctival tissue, preserving many future treatment options. Since Schlemm's canal is typically not continuous, with septae preventing the circumferential flow of aqueous, the placement of additional iStents may result in further IOP lowering.<sup>23</sup>

Disadvantages of the iStent are that the IOP reduction is limited by the function of the collector channels and episcleral venous pressure. In addition, the long-term stability of the implanted device remains to be elucidated.

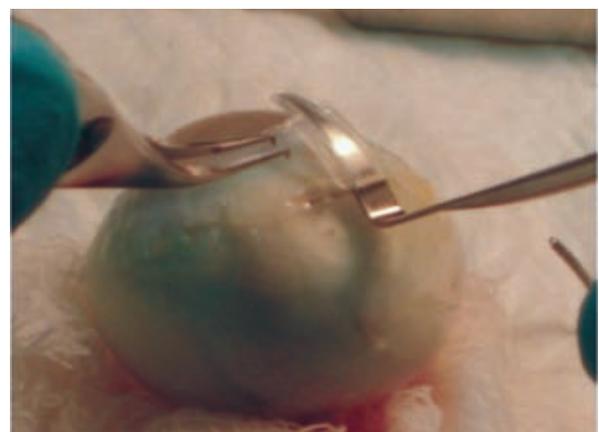
**Figure 4A: Endo Optiks Laser Endoscope Power Source and Video Imaging System**



**Figure 4B: Endo Optiks Endophotocoagulation Probe**



**Figure 5: Clear Polypropylene Aquashunt Device on Metallic Insertion Instrument Next to a Cadaver Eye**



## Suprachoroidal Shunts

### SOLX® Gold Shunt

The SOLX® Gold Shunt is made of biocompatible 24-carat gold, and is designed to facilitate outflow into the suprachoroidal space. The 3mm wide by 6mm long implant contains numerous micro-tubular channels that connect the anterior chamber to the suprachoroidal space. A recent prospective clinical study demonstrated an 8mmHg IOP reduction at one year in 50 of 76 eyes.<sup>24</sup>

### Aquashunt™

The Aquashunt™ (OPKO Health, Inc., Miami, FL, US) is an implantable ribbon-like device made of biocompatible polypropylene that is also designed to drain aqueous from the anterior chamber into the suprachoroidal space (see *Figure 5*). The Aquashunt is 10mm long by 4mm wide and 0.75mm thick, and is implanted via an *ab externo* approach. The device is currently undergoing human trials outside the US.

## Summary

Novel technologies offer evolutionary and revolutionary improvements in the surgical treatment of glaucoma. Early experiences have demonstrated safe and effective IOP control while avoiding many of the complications associated with trabeculectomies or tube shunts. Many surgeons are combining these new surgical techniques with cataract surgery because of the low rate of serious complications,

limited manipulation of ocular tissue (especially the conjunctiva) and/or faster visual recovery than traditional glaucoma surgeries. While further studies are necessary to demonstrate the long-term efficacy and outcomes compared with traditional surgeries, these newer surgical techniques show promise in the surgical management of glaucoma. ■



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