Implants in glaucoma: a minor review

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Introduction
Glucoma filtering procedures have been the mainstay of surgical glaucoma management for the past century. Ever since Cairns described his technique of trabeculectomy in 1968, it has been modified and augmented by surgeons over the years, but the basic principle has remained the same. However, the vision-threatening complications associated with trabeculectomy make it a less suitable option in many cases. Hence has come the era of implants – glaucoma drainage devices (GDDs) and Stents in surgical glaucoma management which we shall briefly review in this article.

Glaucoma drainage devices
They occupy an important place in the treatment of complicated and refractory glaucomas, both as a primary surgical modality and as a secondary procedure. In 1906, a horse hair thread was placed through a corneal paracentesis in an attempt to drain hypopyon externally. The same technique was used subsequently to treat two patients with painful absolute glaucoma.

In 1969, Molteno explained the pathophysiology of bleb resistance and postulated the idea of draining fluid away from the limbus, to increase the success rate and designed a tube. All of the currently available GDDs are based on these fundamental principles.

GDDs work by creating an alternate pathway for aqueous outflow from anterior chamber (AC) through a tube of implant toward subconjunctival space.

Indications
- Failed trabeculectomy.
- Uveitic glaucoma.
- Neovascular glaucoma.
- Sturge–Weber’s syndrome.
- Penetrating keratoplasty with glaucoma.
- Retinal detachment surgery with glaucoma.
- Iridocorneal endothelial syndrome.
- Refractory infantile glaucoma.

Relative contraindications
- Vitreous in AC.
- Eyes with severe scleral and or sclerolimbal thinning.
- Extensive fibrosis of conjunctiva.

Types of implants

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Mechanism of action: Following implantation, a fibrous capsule forms around the endplate and a tube drains aqueous from the AC to the space between the endplate and surrounding non-adherent fibrous capsule. This fibrous capsule around the end-plate creates resistance to flow. Aqueous passes through the capsule by the process of passive diffusion and is absorbed by surrounding capillaries and lymphatics.

Non-valved implants
Molteno implant: The Molteno implant (Figure 1a) consists of a silicone tube (outer diameter 0.6 mm and inner diameter 0.3 mm) that opens onto the upper surface of a circular, acrylic plate 13 mm in diameter. The surface area of the single-plate model is 134 mm. The edge of the plate has a thickened rim 0.7 mm high that is perforated to permit suturing to the sclera, thus preventing plate migration. The double-plate Molteno (Figure 1b) – a second end-plate is attached to the right or left of the original end plate, thus doubling its surface area.

The Baerveldt implant (Figure 2) is made up of silicone episcleral plate with different surface areas – 200 mm², 250 mm², 350 mm², 500 mm², the 350 mm² being the most preferred size. The proximal portion of the plate has a flange with two large fixation holes to allow the growth of fibrous tissues and this aids in scleral attachment.

The Aurolab aqueous drainage implant (AADI) (Figure 3) is based on the principles of Baerveldt implant and serves as a low-cost alternative GDD in cases of refractory glaucoma.
Valved implants
Ahmed Glaucoma Valve (AGV): It provides a more complex mechanism to control aqueous humous outflow. It was developed by Mateen Ahmed and was approved by the FDA in 1993.

The AGV consists of 3 parts (Figure 4a):

1. Plate: silicone, polypropylene or porous polyethylene (depending on the model).
2. Drainage tube in silicone.
3. Thin silicon elastomer membranes which act as a valve.

The valve mechanism of AGV consists of thin silicone elastomer membranes, which are pretensioned and designed to open when intra-ocular pressure is 8 mmHg or more. Hence in hypotony, the flow through the valve ceases and further complications can be avoided.

Site of implantation: The supero-temporal quadrant is the preferred site for the implantation of GDD followed by the infero-temporal quadrant. Supero-temporal site provides the easiest access for the surgeon to implant the plate and is least likely to produce extra-ocular motility disturbances. Supero-nasal quadrant is the least preferred site due to high chances of motility issues. The tube of the AGV is most commonly placed in the AC. However, it may also be placed in the sulcus in a pseudophakic eye and in post corneal transplantation (Figure 4b) cases to prevent corneal decompensation or in the pars plana in case of a vitrectomized eye.

Intraoperative complications
- Perforation and exposure of uveal tissue during fixation of the implant.

Figure 1. (a) Single plate Molteno implant; (b) Double plate Molteno implant.

Figure 2. Baerveldt implant.

Figure 3. The Aurolab Aqueous Drainage Implant – AADI.
Ciliary body hemorrhage.
Vitreous loss.
Leakage around the tube.
Hyphema.
Vitreous hemorrhage.
Suprachoroidal hemorrhage or expulsion.

Post-operative complications

- Hypotony: More common in non-valved implants. Excess flow can result in a flat AC, prolonged hypotony and choroidal detachment.
- Tube obstruction: Can happen with blood, fibrin, vitreous, iris plug or kinking.
- Tube retraction: Retraction of the tube from the AC may be managed by placing an extender sleeve with a larger inner diameter over the existing tube.
- Bleb encapsulation: Managed with aqueous suppressants.
- Corneal endothelial touch.
- Corneal graft failure.
- Ocular motility disturbance.
- Endophthalmitis.
- Vision loss.

Figure 4. (a) Ahmed glaucoma valve; (b) AGV in a post PK eye.
Modifications to prevent hypotony with non-valved implants

- **Stent - Internal tube occlusion:** Aqueous drainage through a non-valved device can be regulated in the early post-operative period by passing a 4-0 or 5-0 prolene or nylon suture through the lumen of the implant. Once the fibrous capsule is formed around the implant, the suture suture is removed at slit lamp.

- **Ligature – External tube occlusion:** The flow of aqueous through a non-valved device is restricted by placing a suture ligature around the external aspect of the tube.

- **Two-stage procedure:** In the first stage, only the plate is anchored to the globe and the tube is left in the subconjunctival space without entering the eye. Four to six weeks later, once the capsule has been formed around the implant, the conjunctiva is opened and a tube is inserted into the chamber to establish the flow.

Post-operative events

**Hypotensive phase:** It is particularly common in nonvalved implant from immediate post op period up to 3–4 weeks. However, in few cases it can be seen in valved implants too.

**Hypertensive phase:** It is more commonly seen with the AGV. It is defined as IOP more than 21 mmHg from 3–6 weeks to 6 months post surgery that was not a result of tube obstruction, retraction or malfunction. Topical anti-glaucoma medications are needed to control the intraocular pressure (IOP) in this stage.

Let us look at a few important studies involving GDDs.

**Ahmed Baerveldt comparison study**

This study compared surgical outcome of Ahmed and Baerveldt implants in a total of 276 patients. Mean IOP was lower after Baerveldt placement after 1 year of follow-up (15.4 mmHg Ahmed group vs. 13.2 mmHg Baerveldt group, \( p = 0.007 \)), and use of adjunctive glaucoma medications was similar with both aqueous shunts (1.8 medications Ahmed group vs. 1.5 medications Baerveldt group, \( p = 0.07 \)).

Although the cumulative probability of failure at 1 year was not significantly different, patients who received a Baerveldt implant, experienced significantly more early post-op complications during the first 3 months after surgery (43% Ahmed group vs. 58% Baerveldt group, \( p = 0.016 \)). No significant difference in the rate of late post-op complications was observed between the two aqueous shunts (29% Ahmed group vs. 37% Baerveldt group, \( p = 0.16 \)). The lower IOP observed with the Baerveldt implant can be explained by the larger end plate; however, the greater efficacy of the Baerveldt implant in reducing IOP occurs at the expense of a higher rate of surgical complications.

**Tube versus trabeculectomy (TVT) study**

This is one of the landmark trials which compared surgical outcomes of trabeculectomy vs Baerveldt implant. Tube shunt surgery had a higher success rate compared to trabeculectomy with MMC at 5 years of follow-up in the TVT Study.\(^{15,17}\) Both procedures were associated with similar IOP reduction and use of supplemental medical therapy at 5 years. The cumulative probability of failure at 5 years of follow-up was 29.8% in the tube group and 46.9% in the trabeculectomy group. The rate of reoperation for glaucoma was 9% in the tube group and 29% in the trabeculectomy group.

**Stents in glaucoma**

Trabeculectomy and GDDs remain the gold standard for surgical glaucoma management; however, during the past few years, the interest and use of less invasive glaucoma surgeries has gradually evolved.\(^\text{18}\) ‘Micro Incision Glaucoma Surgeries-MIGS’ encompasses a group of procedures which are characterized by minimum external dissection, short operating times, good safety profile and rapid recovery. Tubular stents, composed of different materials, which lower IOP, without the associated risks form an important component of MIGS.\(^\text{19}\)

In the following section, we shall be covering a few of these stents.

**iStent**

The iStent (Glaukos Corporation, Laguna Hills, CA, USA) is a 1 × 0.3 mm heparin-coated titanium implant, which is placed ab interno, through the trabecular meshwork into the Schlemm’s canal. This bypasses the juxtacanalicular trabecular meshwork and the inner wall of the Schlemm’s canal (which is the major component of aqueous outflow resistance) and allows drainage of aqueous into the collector channels. It is a L-shaped device, with a pointed tip which penetrates the trabecular meshwork. It has a 1-mm long trough which is placed in the Schlemm’s canal and a ‘snorkel’ that faces the AC to drain aqueous from it (Figure 5a). It is implanted with the use of a disposable inserter via a gonioscopic guided approach through a paracentesis opening. The iStent has been US FDA approved since 2012 for use in combination with cataract surgery in patients with ocular hypertension and in mild-to-moderate glaucoma on anti-glaucoma medications.\(^\text{20}\)

The results of the iStent study group, which is the largest RCT to date (240 patients), compared

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**References:**

1. Modi G, et al. Hypotensive phase: It is particularly common in nonvalved implant from immediate post op period up to 3–4 weeks. However, in few cases it can be seen in valved implants too.
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IOP drop and medication reduction between patients who underwent cataract surgery alone vs cataract surgery combined with a single iStent. The study group showed an 8% drop in IOP and 87% medication reduction compared to 5.5% drop in IOP and 73% medication reduction in the control group at the end of 1 year, with the medication reduction being statistically significant ($p = 0.005$).

With an idea that multiple iStents appear to provide better IOP control, Glaukos has manufactured a second-generation iStent called iStent Inject (Figure 5b) which is designed to be used both left- and right-handed and comes preloaded with 2 stents. Studies show a 48% reduction in IOP with the iStent Inject at the end of 12 months.

Common complications are minimal hyphema from Schlemm’s canal, transient IOP spike, corneal edema and stent malposition.

**Hydrus Microstent**
The Hydrus Microstent (Ivantis Inc., Irvine, CA, USA) is an 8 mm long nickel-titanium device which resembles an intracanalicular scaffold. It has three windows along its length and is open on the posterior surface. It dilates approximately one quadrant of the Schlemm’s canal which allows the aqueous to bypass the trabecular meshwork and gain access to multiple collector channels. It is inserted via an ab interno gonioscopic approach.

The device is available only for investigational use in the USA. Studies, however, have shown a significant drop in IOP (almost 50%) and medication reduction when combined with cataract surgery.

**Xen GEL implant**
The XEN GEL Implant (Allergan NYSE:AGN, Dublin, Ireland) is a 6-mm cylinder of collagen derived gelatine, crosslinked with glutaraldehyde, which is biocompatible and non-biodegradable. It comes pre-loaded in an injector and is implanted ab interno through a clear corneal incision under gonioscopic visualization. It creates a drainage pathway between the AC and subconjunctival space (Figure 6). Conjunctival dissection is not required. Currently, 45 nm lumen-sized tube is recommended for clinical use.

Galal et al. have reported significant drop in mean IOP, from $16 \pm 4$ mm of Hg to $12 \pm 3$ mm of Hg postoperatively, after 1 year of follow-up in 13 POAG patients who underwent XEN 45 gel implant surgery with Mitomycin C. There was significant drop in the number of glaucoma medications from preoperative 1.9 $\pm$ 1 to postoperative 0.3 $\pm$ 0.49.

**EX-PRESS glaucoma filtration device**
The EXPRESS glaucoma filtration device (Alcon Laboratories Inc., Fort Worth, TX, USA) is a stainless steel implant which is $<3$ mm in length. It is implanted ab externo under the scleral flap with an injector. It creates a communication between the AC and subconjunctival space. It does not require peripheral iridectomy. Studies have shown almost similar IOP lowering ability of ExPRESS shunt compared to conventional augmented Trabeculectomy.

The higher cost of this implant is a matter of consideration when deciding for primary Ex-PRESS implant insertion.

**Cypass microstent: suprachoroidal space**
The Cypass stent (Alcon Surgical, division of Novartis Pharma, USA) is a fenestrated polyamide tube 6.35 mm in length, with a 300 um lumen. It is designed to be implanted ab interno with the help of a guide wire and inserted between the ciliary body and the sclera (Figure 7).

The Compass trial is a multicenter randomized controlled trial on 505 mild-to-moderate POAG patients who underwent phacoemulsification with IOL and Cypass stent implantation and only phacoemulsification with IOL implantation.
At 2 years of follow-up Cypass group has shown significant better IOP control and reduction in the number of glaucoma medications compared to only phacoemulsification group.\(^\text{26}\) The CyCLE (Cypass clinical experience) study has also shown similar efficacy of the device.\(^\text{27}\)

### InnFocus Microshunt

The InnFocus Microshunt (InnFocus Inc., Miami, FL, USA) is a synthetic tube that diverts aqueous from the AC to the subconjunctival space. The MicroShunt is made of a highly biocompatible material, SIBS. It is inserted ab externo under a sclera flap.

![Sub conjunctival placement Of Xengel implant](image)

**Figure 6.** The XenGel implant.

**Figure 7.** CYPASS implant.
A study by Batlle et al. on 23 eyes, with InFocus microstent implantation with or without cataract surgery, has shown that over 80% patients had IOP <14 mm Hg at 3 years with significant decrease in the number of anti-glaucoma medications.

Conclusion
GDDs have sufficient evidence to prove their efficacy and safety profile as discussed above, but the same does not hold true for MIGS. Large multicenter randomized control trials to assess IOP lowering ability, operative ease and safety profile will further add insight into their use. Their high cost and lack of data in Indian eyes remain a major stumbling block for their use in surgical glaucoma management in our part of the world. However, with time and technological advances, it is to be seen if MIGS becomes the next trabeculectomy in glaucoma.

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References