Glaucoma Drainage Devices

A Practical Illustrated Guide

Monica Gandhi
Shibal Bhartiya
Editors

Springer

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Preface

Glaucoma Drainage Devices: A Practical Illustrated Guide is the collaborative effort of some of the best clinician scientists and surgeons across the globe. We have tried our best to keep this book free of unnecessary text, concentrating more on what is relevant clinically, emphasizing on the surgical technique. You will find the book full of algorithms and flowcharts and lots of images for illustration of surgical steps. Each of the chapters is accompanied by videos that demonstrate the surgical techniques and tips and tricks that improve surgical outcomes. There are enough videos by some of the most skilled surgeons in the world, detailing modifications of surgical techniques which you can try in your surgical practice and choose one that suits you best.

You will, therefore, find the *Glaucoma Drainage Devices: A Practical Illustrated Guide* to be a handy reference for when you are in the glaucoma clinic, deliberating what would be the best choice for your patient, surgically. You will find that the book and the accompanying videos are your best friends when you are learning how to implant a glaucoma drainage device or to refine your technique. So whether you are a glaucoma surgeon in training or a trained glaucoma practitioner, we are sure this book will prove to be invaluable in your operating room.

We hope you enjoy reading the book to be a learning experience, editing it has definitely changed the way we look at glaucoma drainage devices in our clinical practice.

With best wishes,

New Delhi, India — Monica Gandhi
Gurgaon, India — Shibal Bhartiya

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About the Editors

Monica Gandhi is currently working as Associate Medical Director and Senior Consultant in Glaucoma and Anterior Segment Services at Dr. Shroff's Charity Eye Hospital, New Delhi, India. She is an alumnus of Maulana Azad Medical College and Guru Nanak Eye Centre, under the University of Delhi. A former glaucoma fellow at the Glaucoma Imaging Centre under Prof. NN Sood, she has several publications and book chapters on glaucoma to her credit. Besides her keen interest in clinical and surgical training for fellows, she is also committed to mentoring fellows and trainees in their research work.

Shibal Bhartiya is currently working as a senior consultant glaucoma surgeon at Fortis Memorial Research Institute, Gurgaon, and Fortis Flt. Lt. Rajan Dhall Hospital, New Delhi, India. She has a special interest in glaucoma diagnosis and management and ocular surface diseases. She was a senior clinical research fellow in the glaucoma services of the Department of Clinical Neurosciences, University of Geneva, Switzerland. Prior to that, she did her glaucoma training as senior research associate in the cornea and glaucoma services at Dr. R P Centre for Ophthalmic Sciences, AIIMS, New Delhi.

She has published extensively on glaucoma, contributing numerous articles and book chapters alike. She has coedited the prestigious *ISGS Textbook of Glaucoma Surgery*, *Manual of Glaucoma*, and *Practical Perimetry*; has coauthored *Living with Glaucoma*; and is the managing editor of the *Video Atlas of Glaucoma Surgery*.

An avid educator and researcher, she has been responsible for the design and execution of many clinical trials involving both clinical and basic research. She serves as a reviewer for many ophthalmology journals and is the executive editor of the *Journal of Current Glaucoma Practice*, the official journal of the International Society of Glaucoma Surgery. She is also the editor in chief of *Clinical and Experimental Vision and Eye Research*.

1 The Glaucoma Treatment Paradigm: An Overview

Shibal Bhartiya, Parul Ichhpujani, and Monica Gandhi

1.1 Introduction

The only evidence-based, accepted, and the most practiced therapeutic modality for management of glaucoma patients is reducing intraocular pressure. Topical ocular hypotensive medications, as well as laser and incisional glaucoma filtering surgeries, all aim to decrease the IOP, thereby preventing visual field damage by decreasing the rate of retinal ganglion cells death.

This chapter aims to provide an objective overview of current glaucoma practice in order to help decision-making for clinicians.

1.2 Medical Management of Glaucoma

1.2.1 How to Initiate Therapy

The primary aim of medical treatment is to obtain the target IOP, which is defined as the IOP range at which the clinician judges that progressive disease is unlikely to affect the patient's quality of life. Risk stratification helps to guide target IOP (Table 1.1). The burdens and risks of therapy should be balanced against the risk of disease progression [1].

Therefore, important determinants when prescribing include choosing drugs with maximal efficacy, compliance, safety, persistence, and affordability (Table 1.2).

Regular follow-up is necessary to detect progression and reassess target IOP, which might require escalation or downregulation of therapy. The follow-up duration depends on the stage of the disease, stability, and access to healthcare [2].

1.2.2 How to Augment Therapy

In case, monotherapy is unable to meet the target IOP, and the first drug has been proven to be efficacious, a second drug may be added to the treatment protocol. Advantages of fixed combination preparations include ease of use, improved patient adherence, less preservative toxicity, and better tolerability.

Maximal Medical Therapy (MMT): Maximal medical therapy can be defined as the minimum number and concentration of drugs (within the combination of different classes of medications) that provides maximum lowering of IOP. It has to take into account factors including efficacy, compliance, tolerability, and affordability of glaucoma treatment, customized to the needs of the individual patient.

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Table 1.1 Risk categories to guide treatment targets for POAG (Adapted from Asia-Pacific Glaucoma Guidelines, 2nd edition, 2008)

Risk category	Description	Treatment targets
High	Moderate to advanced GON with VFD Higher IOP Rapid progression Bilateral visual field defects Pigmentary or pseudoexfoliative glaucoma Split fixation Glaucoma-related visual disability Younger age	≥40% IOP reduction or 1–2 SD below population mean (9–12 mmHg)
Moderate	Mild GON with early VFD Mild-moderate GON with low IOP Younger age	>30% IOP reduction or population mean
Glaucoma suspect with moderate risk	Fellow eye of established GON: (excluding secondary unilateral glaucoma) OHTN with multiple risk factors: thin CCT, high IOP, suspicious discs GLC gene mutations associated with severe POAG Recurrent disc hemorrhages Pseudoexfoliation Younger age	Monitor closely for change or treat depending on risk and patient preferences Treat if risk(s) increase(s) with ≥20% IOP reduction or 1 SD above population mean
Glaucoma suspect with low risk	OHTN Older age Pigment dispersion with normal IOP Disc suspect Positive family history of glaucoma Less important: Steroid responder Myopia β-peripapillary atrophy Diabetes mellitus Uveitis Systemic hypertension	Monitor

GON glaucomatous optic neuropathy, *VFD* visual field defects, *IOP* intraocular pressure, *OHTN* ocular hypertension, *SD* standard deviation

Table 1.2 Broad classification of common ocular hypotensive agents

IOP-lowering agent class	Important drugs	Dosage	Side effects	Contraindications
Prostaglandin analogues	Latanoprost Travoprost Bimatoprost Tafluprost	A day, at bedtime	Red eyes, dry eyes Iris pigmentation Eyelid skin darkening Longer, thicker lashes	Trimester 3 pregnancy (uterine contractility) Herpes infections of the eye Uveitis
β-blockers	Timolol (0.25 or 0.5%) Betaxolol (0.25 or 0.5%)	Once or twice a day	Bradycardia Bronchospasm Syncope, impotence Lipid disturbances Allergy	Heart block Asthma/COPD Caution in heart failure Betaxolol is cardioselective and has fewer pulmonary complications
α_2-agonists	Brimonidine (0.15 or 0.2%), apraclonidine	Twice a day	Allergy, tachyphylaxis Hypotension	Avoid brimonidine in children <10 years of age
Carbonic anhydrase inhibitors	Brinzolamide Dorzolamide	Twice or thrice a day	Blurred vision Stinging, of dry eye Sulfonamides: Stevens-Johnson syndrome, blood dyscrasias Allergy	Sulfonamide allergy
Cholinergics	Pilocarpine (1, 2 or 4%)	Two to four times a day	Headache, cataract, epiphora, change in vision, increased salivation, abdominal cramps	

There are many promising options for glaucoma medical therapy in development such as netarsudil (a Rho kinase inhibitor), latanoprostene bunod (a nitric oxide donor and prostaglandin analog), trabodenoson (an adenosine receptor agonist), and bamosiran (a small interfering RNA) [3].

1.3 Lasers in Glaucoma

A detailed description of all the laser procedures is beyond the scope of this section; the indications of each of the procedures and the target tissue are mentioned below [4].

1.3.1 Iris

(a) Laser Peripheral Iridotomy (LPI): LPI is the preferred procedure for treating angle-closure glaucoma caused by relative or absolute pupillary block. LPI eliminates pupillary block by allowing the aqueous to pass directly from the posterior chamber into the anterior chamber, bypassing the pupil.
Indications
- Acute angle-closure glaucoma
- Primary angle-closure glaucoma
- Aphakic or pseudophakic pupillary block
- Occludable angle with acute angle-closure glaucoma in the fellow eye
- Luxated or subluxated crystalline lens
- Anterior chamber intraocular lens
- Pupillary block from silicone oil after vitrectomy

(b) Peripheral Iridoplasty: Selected narrow angles may be widened by peripheral iridoplasty, particularly if the narrowing is not due to pupillary block. In iridoplasty, the laser causes thermal contraction of stromal collagen, which is primarily responsible for the immediate anatomical change.
Indications
- Plateau iris
- Adjunct for cases that retain appositional closure of the angle after LPI
- Cases where an LPI cannot be initially created

1.3.2 Trabecular Meshwork

(a) Laser Trabeculoplasty: The exact mechanism by which trabeculoplasty works is not precisely known, but studies have shown that the laser energy applied to the trabecular meshwork initiates structural and/or physiologic changes that promote aqueous outflow. Types of trabeculoplasty available include:
- Argon laser trabeculoplasty (ALT)
- Selective laser trabeculoplasty (SLT) [5]
- Pattern laser trabeculoplasty (PLT)
- Micropulse diode laser trabeculoplasty (MDLT)

Indications
- Alternative to topical glaucoma medications as a first-line treatment for open-angle glaucoma (OAG)
- OAG (Primary or secondary) patients uncontrolled on topical medications
- OAG patients noncompliant with medications

1.3.3 Ciliary Body

Cyclophotocoagulation

(a) Transscleral diode cyclophotocoagulation (TSCPC): TSCPC reduces aqueous humor production by coagulating proteins of the pigmented cells. Laser closes nearby capillaries and ablates the ciliary epithelium without destroying the ciliary body itself. This slows the aqueous humor production [6].
Indications
- Refractory patients in whom multiple glaucoma surgeries have failed
- Patients deemed to be at high risk for complications after a filtering surgery
- Patients with low visual potential for whom an invasive procedure is not reasonable

(b) Endoscopic cyclophotocoagulation (ECP): Endoscopic cyclophotocoagulation (ECP; Endo Optiks, Little Silver, New Jersey, USA) employs a fiber optic cable to deliver pulsed, continuous-wave diode laser energy to the ciliary processes under direct endoscopic visualization using a video monitor [7].

Indications

- Patients with refractory glaucomas, often having failed maximum tolerated medical therapy and prior glaucoma surgery
- Refractory glaucoma with relatively good visual potential
- Refractory glaucoma patients who are on anticoagulation medications or are monocular

ECP Plus: ECP via pars plana approach combined with pars plana vitrectomy is an option for end-stage glaucoma patients in whom multiple glaucoma surgeries and possibly multiple tube shunts have failed. Due to the distinct angle of approach, it cannot be performed in phakic eyes.

1.4 Glaucoma Surgery

Traditionally, surgery was reserved for patients if progression was noted despite maximum medical therapy. Other factors like socioeconomic considerations, age, bilateral advanced disease, and general health of the patient may warrant a primary surgery. The decision to operate must be customized to the individual patient, after a detailed discussion of risks, benefit, available alternatives, and patient preference.

Conventional glaucoma surgeries are typically reserved for those with moderate to advanced glaucoma due to the invasiveness of the procedure and possible complications. The newer micro invasive glaucoma surgery (MIGS) procedures are creating new options for those with early and moderate glaucoma since they have a better safety profile with fewer complications and a more rapid recovery time. They have been shown to be effective in decreasing IOP as well as a patient's need for medications, which becomes relevant because of the low compliance rate reported for medication adherence.

An ideal glaucoma procedure is the one that is easy to perform, reproducible, with a low incidence of early postoperative hypotony, and long-term adequate IOP control. It should be minimally cataractogenic, allow rapid visual recovery, and have the potential to be combined with phacoemulsification without one procedure potentially affecting the outcome of the other. Unfortunately, the quest for an ideal glaucoma procedure is still far from over.

Available surgical options include:

1.4.1 Trabeculectomy and Variations

Trabeculectomy is the most widely performed glaucoma filtration surgery, where a fistula is formed through the sclera to subconjunctival space to create a filtering "bleb" [8].

Indications

(a) This is indicated for patients with failed maximal tolerated antiglaucoma medications or failed laser surgery with any of the following:
  - Progressive glaucomatous optic nerve head cupping
  - Glaucomatous visual field progression
  - Anticipated optic nerve head damage and/or visual field damage as a result of excessive IOP
  - Intolerable adverse effects from multiple topical antiglaucoma medications
  - Lack of compliance with anticipated or documented progressive glaucoma damage

(b) Variations of trabeculectomy include:
  - Trabeculectomy with MMC
  - Trabeculectomy with biodegradable collagen matrix (Ologen)
  - Trabeculectomy with Ex-Press shunt
  - Trabeculectomy with adjustable/releasable sutures

1.4.2 Glaucoma Drainage Devices

Glaucoma drainage implants are devices, which allow aqueous outflow by creating a communication between the anterior chamber and sub-Tenon's space [9].

Indications

(a) These have been used for refractory glaucomas or those unlikely to respond to the conventional filtration surgery, such as:
   - Open angle glaucoma with failed trabeculectomy
   - Refractory congenital glaucoma
   - Neovascular glaucoma
   - Traumatic glaucoma
   - Uveitic glaucoma
   - Penetrating keratoplasty with glaucoma
   - Retinal detachment surgery with glaucoma
   - Iridocorneal endothelial syndrome
   - Sturge-Weber syndrome

(b) Lately, these are considered as a primary surgical choice over a filtering surgery. The implants can be classified as valved and non-valved.

   Valved implants
   - Ahmed glaucoma valve (AGV)
   - Optimed
   - Krupin disc
   - Krupin band
   - Joseph Hitchings

   Non-valved Implants
   - Baerveldt glaucoma implant (BGI)
   - Molteno shunt
   - AADI
   - Schoket band

1.4.3 Non-penetrating Glaucoma Surgeries

Non-penetrating surgeries are based on the premise that aqueous egress occurs at the level of Schlemm's canal and its efferents and that the selective removal of the external part of the trabecular meshwork is mainly involved in aqueous outflow resistance (inner wall of Schlemm's canal and the adjacent trabecular meshwork) while leaving intact the innermost trabecular meshwork layers. Thus the outflow facility is increased while retaining a degree of residual outflow resistance by leaving a membrane between the anterior chamber and the scleral dissection [10]. The procedures are:

(a) Deep sclerectomy
(b) Viscocanalostomy
(c) Canaloplasty

1.4.4 Minimally Invasive Glaucoma Surgeries

These procedures may serve as an excellent surgical option for patients who require postoperative IOPs in the mid-to-high teens. They may be offered to patients with primary open-angle, pigmentary, and pseudoexfoliative glaucoma. They may also be used in patients who have previously undergone filtering surgery [11]. These include:

(a) Trabectome
(b) Cypass
(c) Istent
(d) Hydrus
(e) Suprachoroidal shunt
(f) Xen gel implant
(g) Gonioscopy-assisted transluminal trabeculotomy
(h) Excimer laser trabeculotomy

1.5 Conclusion

The aim of glaucoma therapy is to preserve vision and preserve blindness at a cost which is acceptable to the patient. Therefore, every effort must be made to treat the patient, and not the intraocular pressure. A corollary to this is the need for an individualized therapeutic index, tailored for that patient only: potential benefit of intervention for that patient, versus the possibility of causing harm.

Patients with early disease, or ocular hypertension, may be offered selective laser trabeculoplasty, as well as the newer conjunctiva sparing surgeries, before embarking on conventional medical management. Patients presenting with advanced, especially bilateral, disease who are at risk of progressing to sight loss despite treatment should be offered the option of primary surgery.

There is no "one size fits all" algorithm for management of glaucoma, and so, the treatment protocol for each patient must be tailored to their individual needs.

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2 Indications of Glaucoma Drainage Implant

Julie Pegu, Amit Purang, and Monica Gandhi

2.1 Introduction

Tube implants have been in vogue for over three decades. Its inception has brought a paradigm shift in the management of secondary glaucomas, where the only option earlier was cyclodestructive procedure. From the time of its innovation, however, it was restricted primarily to patients who were at a high risk of failure from conventional glaucoma filtration surgery. But the indications at present encompass a wide variety of secondary and primary glaucomas. Glaucoma drainage implants (GDIs), both valved and nonvalved, are available. This chapter focuses on the possible indications of GDIs in the current glaucoma management.

GDI surgery is usually indicated in the following settings (Table 2.1):

1. Patients with failed trabeculectomy/multiple failed glaucoma surgeries
2. Secondary glaucomas uncontrolled on maximal tolerated medical therapy
3. Patients at a high risk of failure of conventional glaucoma filtration surgery

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2.1.1 Traumatic Glaucoma

GDIs are indicated in post-trauma eyes with a conjunctival or scleral injury that precludes conventional filtration surgery. In cases of blunt ocular injury with disturbance of lens and the vitreous body, GDIs are indicated, and the tube is directed in a position away from the affected site to prevent its blockage by the disturbed vitreous.

2.1.2 Inflammatory Glaucoma

The likelihood of trabeculectomy failing is high if there is an ongoing inflammation in the eye despite treatment, such as in uveitic glaucoma (Fig. 2.1) and neovascular glaucoma (Fig. 2.2). GDIs are indicated in these cases to control the IOP.

Table 2.1 Common indications of GDI as a primary procedure

Traumatic glaucoma
Neovascular glaucoma
Uveitic glaucoma
Post-penetrating keratoplasty glaucoma
Glaucoma associated with keratoprosthesis
Silicone oil glaucoma
Glaucoma following vitreoretinal surgery
Infantile/juvenile glaucoma
Glaucoma in aphakia/pseudophakia
ICE syndrome with glaucoma
Axenfeld Reigers syndrome with glaucoma
Glaucoma in Sturge-Weber syndrome
Glaucoma due to epithelial ingrowth
Scleral thinning

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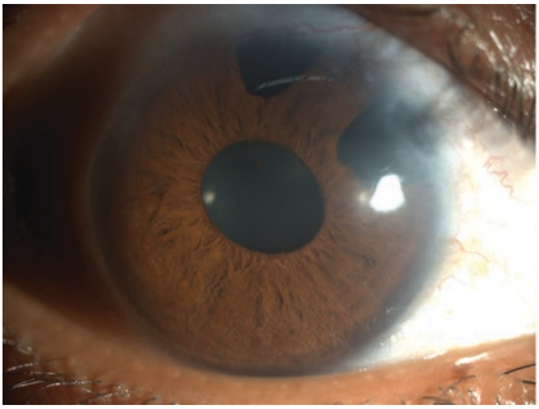

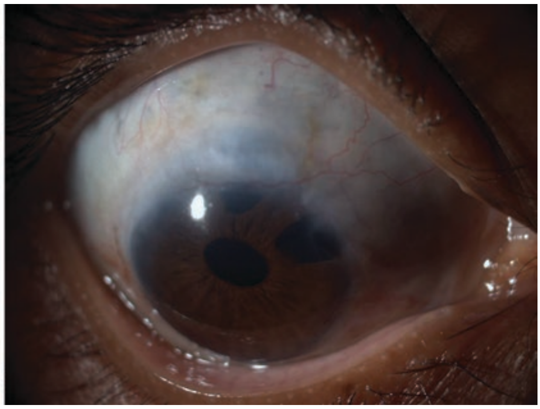

Fig. 2.1 A 24 year old female with chronic uveitis and multiple failed trabeculectomies and uncontrolled IOP

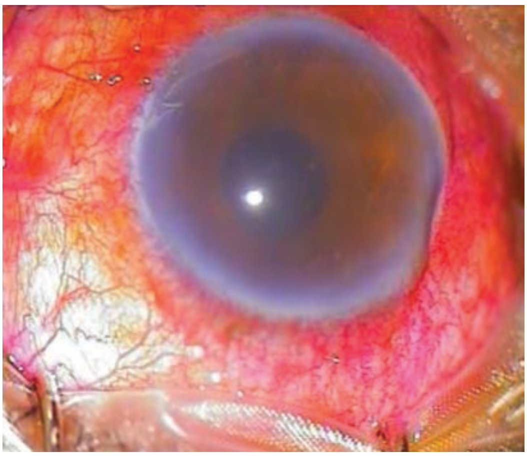

Fig. 2.2 A 64 year old patient with NVG and uncontrolled IOP

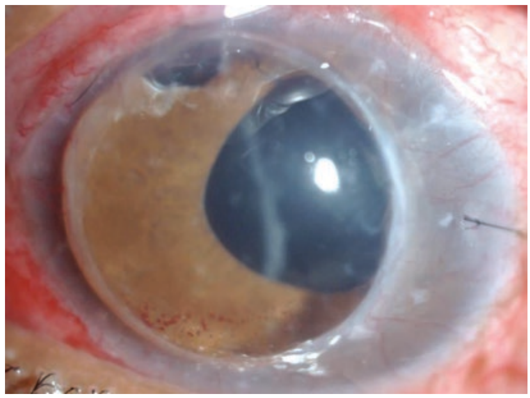

Fig 2.3 A 42 year old patient s/p PKP with Pesudophakia with IOP 42 mmHg on MMT

2.1.3 Post-penetrating Keratoplasty (PPK) Glaucoma

PPK glaucoma is one of the common complications after penetrating keratoplasty (PKP), many of which may require surgical intervention. In PPK glaucoma (Fig. 2.3), the surgical choice depends on the associated ocular condition. In situations where the conjunctiva is intact with a deep anterior chamber, either trabeculectomy or GDI can be done based on the surgeons' preference. But in cases with associated ocular morbidities like extensive peripheral anterior synechiae, aphakia/pseudophakia, and distorted ocular anatomy, the chance of a GDI surviving is higher. A successful control of IOP after GDI was noted in 89% [1] to about 92–100% [2] of eyes 1 year after PKP and 82% [1] at the end of 3 years.

The site of placement of GDI is important and should be placed as far as possible from the corneal endothelial surface. Micro movements of the tube occur with blinking, eye movements, and eye rubbing which may hasten endothelial loss [2, 3] causing graft failure. If the anterior chamber (AC) is deep, the tube can be comfortably placed in the AC close to the iris, farthest from the graft. Sulcus placements are however preferred if the eye is pseudophakic. GDIs can be placed at the same time as in PKP or after PKP. In case of pars plana placement, along with pars plana and core vitrectomy, removal of the vitreous skirt in the PP region is extremely desirable to prevent obstruction of the tube. So the latter can be done only if VR support is available to the surgeon. Pars plana placement was found to have better mean IOP reduction at 1 year as compared with placement in the AC (17 vs 12 mmHg) [2]. In situations where a GDI has failed to control the IOP, a second GDI can be placed in a different quadrant though the risk of corneal decompensation increases with the increased number of GDIs [4]. Specular count of the corneal endothelial cells should be done if the facility exists before and yearly thereafter. In any case of GDI placement in eyes with PKP, multitude causes can lead to graft failure and should be always looked for at every visit.

2.1.4 Glaucoma Associated with Keratoprosthesis

About two third of patients undergoing keratoprosthesis have glaucoma [5] (Fig. 2.4). These patients have very poor ocular surface precluding trabeculectomy. The use of GDI has been found to reduce IOP effectively and is an absolute indication for GDI in these cases. In one study Ahmed glaucoma valve (AGV) was shown to have fewer complications when compared to other GDIs [5].

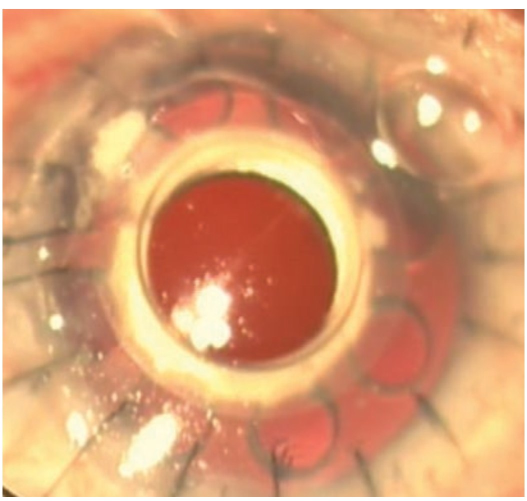

Fig 2.4 Uncontrolled IOP in an eye with Boston K-Pro

2.1.5 Glaucoma in Aphakia and Pseudophakia

With the advent of clear corneal phacoemulsification, both GDI and trabeculectomy can be planned as the initial surgery according to the surgeon's preference, but in aphakic patients and patients with ACIOL, GDI is the preferred treatment. Also in cases where extracapsular cataract extraction or manual small incision cataract surgery has been done, GDIs are the mainstay surgery if the IOP is uncontrolled. In the Tube Versus Trabeculectomy Study, in patients who had undergone previous cataract extraction with intraocular lens implantation and/or failed filtering surgery, GDI had better control of IOP than the trabeculectomy group at the end of 5 years (Fig. 2.5).

In aphakic glaucoma in childhood, trabeculectomy with MMC successfully controlled IOP only in 29% [6] to 33% [7]. Yet in another study [8], there was significant reduction in IOP in both the trabeculectomy MMC group (73.3%) and the GDI group (86.7%). However, it has been found that in treating glaucoma in children less than 2 years, GDIs had a much better control of IOP than trabeculectomy, 19% ± 7% and 53% ± 12%, respectively [9].

2.1.6 Iridocorneal Endothelial Syndrome

Management of glaucoma in ICE syndrome is challenging. GDIs are the preferred surgery to manage these cases, but the lumen tip might get occluded over a period of time as there is continued proliferation of the ICE membrane. To avoid the blockage of the tip lumen, the tube should be left longer than usual, preferably in the sulcus/pars plana region. The patency of the tube in case of blockage by the ICE membrane/iris tissue can be retained by perforating with Nd:YAG. GDIs have been reported to successfully control IOP in about 70% at 1 year and 53% at 5 years [10].

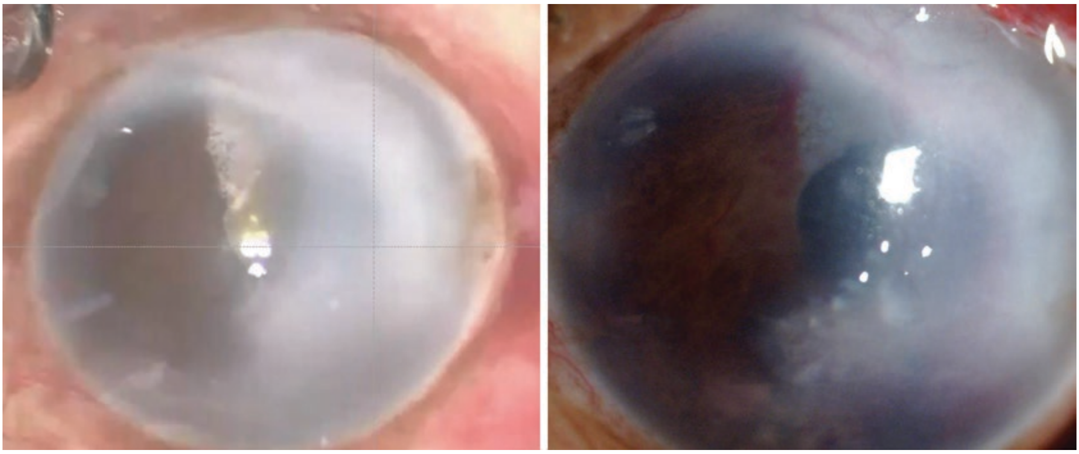

Fig 2.5 Uncontrolled IOP in an eye post cataract surgery with conjunctival scarring. The same eye after placing an AGV in the sulcus in the supero-temporal quadrant

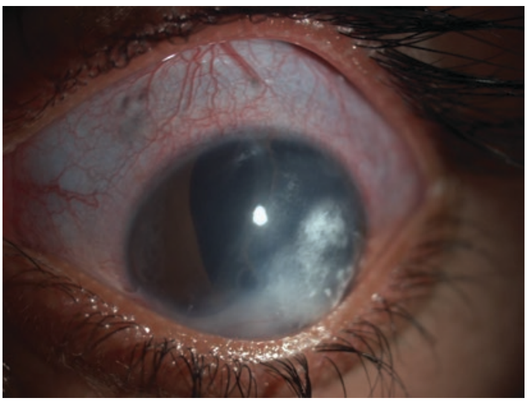

Fig 2.6 A 12 year old girl s/p lensetcomy and vitrectomy with IOP of 38 mmHg on MMT

2.1.7 Glaucoma Following Vitreoretinal Surgery

In secondary glaucoma, following retinal detachment surgery/silicone oil induced (Figs. 2.6 and 2.7), GDI is the mainstay surgery for many reasons if IOP is uncontrolled. GDI can be implanted even if conjunctiva is scarred due to previous vitreoretinal surgery, and in any location, unlike trabeculectomy. In case where the risk of recurrent retinal detachment is high and removal of oil is not feasible, GDI can be placed either in infero-nasal and inferotemporal quadrants. However, it has been found that the risk of failure is higher in eyes with silicone oil compared to eyes not containing oil [11].

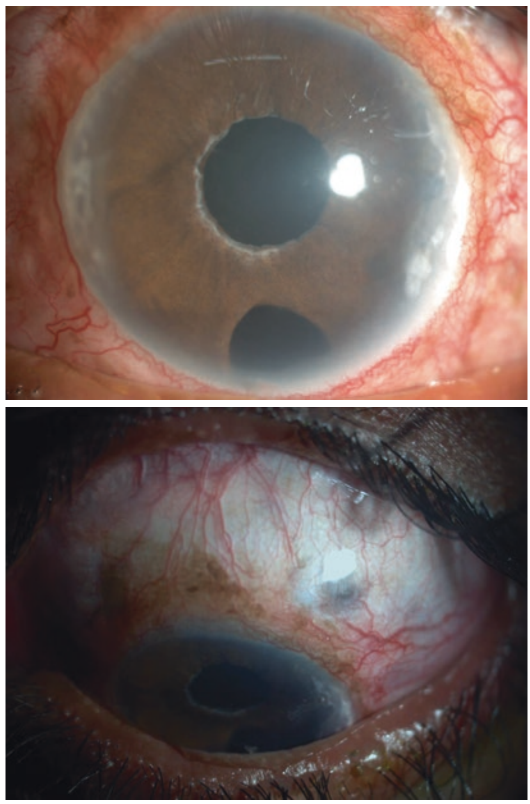

Fig 2.7 A 22 year old male with silicone oil induced glaucoma. We can see the silicon oil droplets in the AC, large inferior PI, thin sclera and aphakia