Dissociated Vertical Deviation

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Dissociated Vertical Deviation (DVD) is one of the least understood forms of strabismus. It was first described by Stevens as double vertical strabismus, other common names given to this anomaly are, Alternating hyperphoria (Crone), Anaphoria / anatropia (Stevens), Periodic vertical squint (Anderson), Strabismus surroadductorius (Cords). The term "Dissociated Vertical Deviation" was given by Bielschowsky (1938).

This anomaly is intermittent and is characterised by an upward excursion, excyclotorsion, lateral movement. Uniqueness of DVD is that it violates Herring’s law of ocular motility. No movement is seen in the fixing eye when the deviated eye returns for refixation. Traditionally, the upward excursion is labelled as Dissociated Vertical Deviation; the excyclotorsion is called as Dissociated Tortional Deviation and the lateral movement is termed as Dissociated Horizontal Deviation. All these three components are labeled as dissociated strabismus complex.

Clinical features of DVD

DVD does not usually present with visual symptoms; however it may be a significant cosmetic blemish. The patients do not complain of diplopia as there is poor fusion and suppression of the deviating eye. However, occasionally diplopia and confusion has been reported. The characteristic excursion of the eye may be present as phoria (manifesting only under cover) or tropia (when it manifests spontaneously, in conditions of fatigue, daydreaming, inattentiveness or during poor health). On uncovering the eye, it slowly drifts back rather than show a rapid refixation movement as seen in any other hyperphoria or hypertropia.

The condition is usually bilateral and asymmetric. The signs are more profound in an amblyopic, non-dominant or non-fixing eye.

It is rarely seen in isolation and associated features include esotropia, Intermittant Divergent Squint and latent nystagmus. It is best to examine a DVD using a translucent occluder so that the updrift behind the occluder is visible Figure 1. A +4 dioptre lens may also serve the same purpose Figure 2.

Problems with DVD

Visual disturbances -diplopia, rare
Cosmetic (Manifest DVD)
Longstanding DVD ⇒ SR contracture ⇒ true hypertropia
Amblyopia in children
Interference with the measuring of associated vertical strabismus

Classification of DVD

Comitant DVD is said to be present when the vertical deviation (with in ± 7 PD) measures same in abduction, primary position and adduction.

DVD is called incomitant if the when there is difference in the magnitude of deviation in abduction, primary position and adduction. These differences may help in the management of the case.

Measuring DVD

It is difficult to measure the DVD, as there is change in deviation depending upon the alertness and co-operation of the patient. The deviation may increase when the patient is inattentive, day dreaming, tired on the other hand the deviation may be recorded less as the patient is attentive at the time of examination.

In our experience Prism Bar Under Cover Test (PBUCT) is the best way of measurement of DVD. During this test the base down prism and a cover is placed in front of the dissociated eye, now as the cover is shifted in front of the fixing eye note the downward movement of the dissociated eye, keep increasing prisms till no movement is seen on switching occlusion.

Fig.1: DVD demonstrated behind a translucent occluder
Fig.2: DVD demonstrated behind a + 4 dioptre lens

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Hirshberg’s test may also be used to provide a gross estimate.

Depending upon the amount of deviation there has been attempt to classify DVD into mild (0-9 PD), moderate (10-19 PD) and severe (> 20 PD) forms.

**Bielschowky’s phenomenon**

This is known to be present in at least 50% of cases of DVD suggesting that DVD is a sensory anomaly. As the intensity of light shown to the fixing eye is decreased, the dissociated eye gradually comes down. This can be done with the help of neutral density filters and hence one can measure "depth of DVD”

**Red glass test**

If a red glass is presented before either eye the red light is always perceived to be below the white light. The reason for this is, the eye under the red glass dissociates and moves upwards. This test may be used to differentiate DVD from hypertropia as in case of hypertropia the red light would be seen below or above the white light depending upon whether it is placed on the hyper or the hypo deviated eye.

**DVD and inferior oblique overactions (IOOA) Table 1.**

The two entities should be differentiated as both may cause elevation and add to the confusion and diagnosis. DVD is evident in primary position while IOOA is seen in adduction and elevation Figure 3. However, unequal IOOA may give rise to vertical deviation even in primary position. The two can be differentiated as there would be an associated "V" phenomenon with IOOA, also the vertical deviation would increase in adduction and elevation.

**Table 1: Comparison of features between DVD and IOOA.**

<table>
<thead>
<tr>
<th>Differential Diagnosis</th>
<th>DVD</th>
<th>IOOA</th>
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<tbody>
<tr>
<td>Elevation</td>
<td>ab an, 1(^o), addn</td>
<td>Only adductn</td>
</tr>
<tr>
<td>SOOA</td>
<td>May (+/-)</td>
<td>Never</td>
</tr>
<tr>
<td>V pattern</td>
<td>—</td>
<td>+</td>
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<tr>
<td>C/L SR</td>
<td>—</td>
<td>+</td>
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<tr>
<td>Pseudoparalysis</td>
<td>Saccadic velocity of refixation</td>
<td>Slow: 10-200(^{0}/)sec</td>
</tr>
<tr>
<td>Bielschowsky’s Phenomenon</td>
<td>+</td>
<td>—</td>
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Presence of Superior oblique over action may point towards DVD rather than IOOA. The rapid re-fixation movement of IOOA would be approx 200-400 degrees/sec, while the slow redressing movements of DVD would range from 2-200 degree/sec. Further clinical tests like the red filter test and Bielschowsky’s phenomenon may help to differentiate the two.

A difficult situation can arise when there is DVD in presence of IOOA. In such cases the rapid re-fixation movement of the hypotropic eye can be measured with the help of prism bas cover test. Then the total upward deviation may be measured using the PBUCT. DVD is the difference between the two readings.

**Non surgical management of DVD**

*Observation:* it is believed that the condition improves with the age

*Encourage fusion of bifixation:* This step is meant to enhance the fusion. Proper refractive correction should be given, as the image blurr may lead to break in fusion and worsening of DVD may take place. Conversely, a clear image encourages the fusion and may lead to better control of DVD. Associated amblyopia need to be addressed and treated. If strabismus is present, it may need surgical or prism correction as it may promote peripheral fusion.

*Switching fixation:* Trying to switch fixation to the non dominant eye with the help of occlusion or mild refractive blur of the fixing eye may help in control of DVD as now the eye with the DVD will be used for fixation.

**Surgical management**

*When to perform surgery?*

Surgery is often indicated when DVD is increasing in frequency and a phoric deviation is gradually converting to a manifest. This can deteriorate the peripheral fusion and there is an increased risk of amblyopia in children. Anomalous head posture, if present, helps to control the magnitude of DVD or gain peripheral fusion. If the head...
posture is to the opposite side then it indicates a poorer control or a larger magnitude of DVD. Surgery may thus be indicated to improve the head posture. A large and cosmetically unacceptable deviation is another indication for surgical intervention.

Options in surgical management:
The surgical modalities advocated are:
Recession with anterior positioning IO (Figure 4)
Superior rectus-recession 7-10 mm with or without retroequatorial myopexy
Inferior rectus-resection 5 mm

Check for inferior oblique over action:
IOOA & mod. DVD (<5 pd in abduction)
Recommended treatment modality: Recession with anterior positioning IO
IOOA & Severe DVD (>5 pd in abduction)
Recommended treatment modality:
Recession with anterior positioning IO +
Superior rectus-recession 7-10 mm
DVD & no IOOA:
Superior rectus-recession 7-10 mm +
Inferior rectus resection
DVD & SOOA:
Superior rectus-recession 7-10 mm +
Posterior tenectomy of Superior oblique
Frequently the DVD is bilateral but asymmetrical so much so that the other eye is missed pre-operatively. As DVD is asymmetric, it is important to check both the eyes for DVD. Even if the DVD in the other eye does not appear to be clinically significant it is preferred to operate both the eyes for the DVD as the other eye starts to manifest the DVD post-operatively. One can do asymmetric surgery with greater amount of surgery in the manifesting eye.

References:
Iridocorneal endothelial syndrome (ICE) are not very common but can pose a diagnostic and management challenge to ophthalmologists. This article is an endeavor to increase the understanding of ICES and prepare us better in our approach to manage them. Close follow-up of intraocular pressure and early detection of glaucoma are important steps to preserve visual functions in patients with ICE syndrome.

ICE is a group of disorders that share a number of clinical characteristics having common pathogenetic mechanism. Three variants of ICE are generally recognized—Essential (progressive) iris atrophy, Chandler's syndrome and Iris nevus (Cogan-Reese) syndrome. Primary abnormality in the ICE syndrome is proliferation of an abnormal corneal endothelium and deposition of aberrant Descemet's membrane. As this membrane crosses the angle, it provides resistance to aqueous outflow and eventually leads to formation of anterior synechiae, with subsequent glaucoma. Growth of this membrane across the iris leads to synechiae and atrophy, with the hole and nodule formation. By specular microscopy, an abnormal appearing population of endothelial cells is identified.

Glaucoma is a common characteristic of ICE syndrome, reportedly occurring in 50% to 80% of patients. Some studies have found more are the chances of glaucoma in essential iris atrophy and iris nevus syndrome than with Chandler’s syndrome. Those patients having total or diffuse endothelial involvement have more glaucoma (71%) as compare to those having patchy or subtotal ICE (18%).

Clinical Presentation

- Typically a female in early to mid adulthood with no typical family history.
- The disease is nearly always unilateral, although bilateral cases have been reported, and sub clinical abnormalities of the endothelium have been noted in fellow eye.

Progressive Iris Atrophy

Progressive thinning and atrophy of the iris with hole formation is the predominant clinical feature. Peripheral anterior synechiae (PAS) progressing both onto the cornea as well as circumferentially cause correctopia and ectropion uveae.

Chandler Syndrome

Dominant feature is corneal edema often normal or only moderate levels of intraocular raised pressure. The pupil is usually oval or round with relatively less prominent iris atrophy.

Cogan-Reese (Iris-Nevus) Syndrome:

Characterized by abnormal iris pigmentations ranging from multiple, pedunculated, diffuse or nodular lesions, stromal breaks, ectopic pupil. PAS, corneal edema and labile glaucoma are characteristic features.

Pathogenesis of Glaucoma in ICE:

- Elevated IOP may occur with primarily open angles as a consequence of trabecular obstruction by endothelial membrane
- Secondary to synechial angle closure as the disease progresses.

Differential Diagnosis

Other disorders of the cornea and iris, many with associated glaucoma, can be confused with ICE syndromes. Three categories of disorders:

1. Corneal endothelial disorders:
   - Posterior polymorphous dystrophy (PPD)
     - Rare, bilateral, hereditary endothelial dystrophy
     - May have associated glaucoma, as well as changes of the angle and iris that resemble ICE syndrome
     - Differentiating features: bilateralism, hereditary and different posterior corneal abnormalities which can be identified by specular microscopy.
   - Fuchs’s endothelial dystrophy
     - Have clinically similar corneal changes to ICE syndrome, but none of the angle or iris features.

2. Iris abnormalities
   - Axenfeld-Rieger syndrome
     - Has strikingly similar clinical and histopathological findings
     - Differentiating features: congenital nature, bilaterality and associated systemic features.
Peter's anomaly:
- congenital central corneal leukoma with synechiae extending from the central iris to the periphery of the corneal opacity. Some patients have keratolenticular adherence, while others have anterior polar cataracts.

Iridoschisis
- Characterized by separation of the superficial layers of the iris stroma, usually in the elderly
- Associated angle closure type glaucoma is common.

Aniridia

Congenital Iris Hypoplasia
- Lacks the angle defects

3. Nodular lesions of the iris
- nodular lesions of neurofibroma and melanosis of the iris, inflammatory nodules, e.g. sarcoid
  Differential Diagnosis of darker colored iris with glaucoma (heterochromia)
  ➢ Cogan-Reese syndrome
  ➢ Diffuse iris nevus
  ➢ Latanoprost use
  ➢ Malignant melanoma of the iris
  ➢ Melanomalytic glaucoma
  ➢ Neovascular glaucoma
  ➢ Neurofibromatosis
  ➢ Pigmentary glaucoma
  - Differential Diagnosis of lighter colored iris with glaucoma (heterochromia)
  ➢ Chronic iridocyclitis
  ➢ Fuchs heterochromic iridocyclitis
  ➢ Glaucomatocyclitic crisis.

Management of Glaucoma in ICE

It is primarily case specific and should be dictated by severity of secondary glaucoma and corneal edema. Management of glaucoma in this disorder can be challenging. Medical therapy often fails to control IOP, necessitating surgical treatment. Similarly, the failure rate of filtering surgery is also high, often necessitating multiple procedures.

Medical: In early stages, glaucoma can be controlled medically. Topical aqueous suppressants are mainstay medical treatment of choice for secondary glaucoma to ICE syndromes as by the time IOP is elevated the angle is often largely covered by membrane or closed by synechiae. Therefore medication that increases the outflow is typically less effective as compared to drugs decreasing aqueous production. Because of same reason laser trabeculoplasty is generally not effective. Patients having corneal edema may benefit from lowering intraocular pressure even if it is already within normal limits. However, cornea may remain edematous even at lowest achievable pressures wherein hypertonic saline drops may be given as an adjunctive to medical therapy.

Surgery: If intraocular pressure cannot be controlled medically, filtering surgery is required. Glaucoma associated with ICE syndrome can be managed successfully surgically, although multiple procedures are often needed. The success rate of trabeculectomy in ICE syndrome is comparable to that for POAG, though there is a risk of closure of sclerotomy site by abnormal membranes, with subsequent surgeries required in a different location. In one study, 22 of 25 patients with ICE and glaucoma failed to medical therapy. The success rates of trabeculectomy were 63% at 1 year, 44% at 2 years, 23% at 5 years. At the end of first year 60% of first surgeries, 20% of second and 17% of third were functional.

Filtering surgery with Antifibrotic agent: Due to high risk of failure of traditional filtering procedures, use of antifibrotic agent is recommended. The mitomycin on scleral bed in concentration of 0.4mg/ml for 1 to 4 min
has been used in these cases with reasonable success rates. Another study reported survival of trabeculectomy with antifibrotic agent (mitomycin-C or 5-fluorouracil) to be 73% at 1 year, 44% at 2 years, and 29% at 5 years.

Implant surgery: Glaucoma drainage devices, or the tube shunts, appear to have a higher success rate in long term. Though they have their own inherent complications. Most of time tubes tend to migrate in either of direction anteriorly or posteriorly causing corneal or iris decompensation respectively, due to contractile This occurs due to forces generated by expanding endothelial membrane. It has been suggested to cut tube longer then normal to allow reposition in future if required.

**Diode laser Cyclophotocoagulation**: Severe uncontrolled glaucoma not responding to any medical or surgical method, can be treated with DLCP

**Penetrating Keratoplasty**: If visually significant edema remains after lowest level of achievable pressures, then penetrating keratoplasty is usually required. Prognosis of corneal graft is good if pressure remains controlled, though this procedure will not affect abnormalities in the anterior chamber angle and iris. Recurrences of the endothelial abnormalities that is specific for ICE syndrome have not been noted to develop in donor cornea.

**Clinicopathological pearls**

**Corneal alterations:**

Normal endothelial cells appear light with dark intercellular junctions and are of fairly regular size and polygonal shape, where as, ICE cells are larger and more pleomorphic, appearing as dark cells with light surround and white central spot. They may coexist with relatively normal endothelial cells or may replace the entire endothelium.

**Slit Lamp**: fine hammered silver appearance (less coarse than in Fuch’s endothelial dystrophy)

**Specular microscopy**: Diffuse pleomorphism in size and shape, dark areas within certain cells (ICE cells) and loss of clear hexagonal margins

**Anterior chamber angle abnormalities:**

Typically progressive, peripheral anterior synechiae, extending to or beyond Schwalbe’s line.

**Associated glaucoma:**

Occurs in approximately 50-80% of all patients with ICE syndrome; mostly unilateral, more severe in patients with progressive iris atrophy and Cogan-Reese syndrome than in Chandler’s syndrome. The severity does not correlate with amount of PAS but does correlate with the type of ICE tissue.

**Diagnostic pearls**

Specular microscopy as it may also be a predictor of glaucoma.

Treatment pearls summarized as

1. **Corneal edema:**
   - lowering IOP
   - hypertonic saline
   - bandage contact lenses to decrease pain
   - penetrating keratoplasty as a last resort

2. **Glaucoma:**
   - drugs that reduce aqueous humour production, e.g. blockers/carbonic anhydrase inhibitors.
   - trabeculectomy with Mitomycin C in higher strengths 0.4mg/ml
   - In implant surgery, it has been suggested to cut tube longer then normal.

3. **Prevention of endothelial proliferation**: Experimental antiviral early if viral etiology
   - immuno-toxin found that inhibits proliferation of human corneal endothelial cells in tissue culture.

**References**

12. Andrew Doan, M.D., Ph.D., Wallace Alward, MD. Iridocorneal Endothelial Syndrome (ICE) - case report 14, University of Iowa, Feb 2005
The corneal epithelium is exposed repeatedly to environmental insult and is protected from direct trauma and exposure through the action of the eyelid and the trilayer tear film. Fuchs coined the term keratitis punctata superficialis, nearly 100 years ago, for the small dot like epithelial changes he saw in association with epidemic conjunctivitis. Superficial Punctate Keratitis (SPK) is a general descriptive term indicating morphological appearance and not implying etiology or the clinical course. SPK remains a source of confusion because of the inconsistent terminology and great voids in our knowledge.

**Diagnosis of Superficial Punctate Keratitis (SPK)**

SPK is not a diagnosis per se except when referring to the specific entity of Thygeson’s SPK. Rather the term indicates a broad group of corneal epithelial changes. Diagnosis is based on evaluation of

1. Morphology of changes
2. Distribution of changes
3. Associated ocular and periocular findings.

This approach will lead to a diagnosis in most cases of punctate epithelial disease commonly seen in practice. Correct diagnosis is essential to institute appropriate therapy.

**Morphology of SPK**

Superficial punctate changes of the cornea can be classified according to their morphology as superficial punctate epithelial erosions (SPEEs), superficial punctate epithelial keratitis (SPEK), or combined epithelial and subepithelial punctate keratitis.

**Superficial punctate epithelial erosions (SPEEs)**

SPEEs are fine, slightly depressed spots that are nearly invisible without the aid of fluorescein dye. When Fluorescein is instilled the lesions stain brilliantly. Scanning
electron microscopy depicts that loss of microvilli and premature desquamation are the histological correlates of SPEEs.

SPEEs are a non specific response to injury and hence occur in wider variety of circumstances. They may occur without any ocular findings in ultraviolet injury and minor chemical burns or may appear in association with SPEK. They are prominent features of staphylococcal blepharoconjunctivitis, keratitis sicca, exposure keratitis and toxicity reactions among others. The patients presents with chief complaints of photophobia and foreign body sensation.

**Superficial Punctate Epithelial Keratitis (SPEK)**

SPEK consists of small greyish white opacities in the epithelium, the hallmark of which is visibility without Fluorescein dye. The lesions generally stain poorly with Fluorescein and stain well with Rose Bengal. However they may be associated with SPEEs. The lesion size varies from very fine to coarse enough to be seen without biomicroscope. These lesions represent accumulations of epithelial cells surrounded by inflammatory cell infiltrate and are present in a wide variety of clinical settings.

Filamentary Keratitis is a subgroup of SPEK in which desquamated epithelium and mucus form a strand of variable length and are attached to the epithelium at one end. Most cases (95%) are associated with keratitis sicca although it can occur in a variety of clinical settings. Filamentary keratitis is a component of Superior Limbic Keratitis in 1/3 of cases.

**Combined Epithelial & Subepithelial Punctate Keratitis**

Adenoviral infection can produce a characteristic sequence of corneal changes involving a combination of epithelial and subepithelial findings.

<table>
<thead>
<tr>
<th>Table: Ocular findings associated with superficial punctate keratitis</th>
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<tr>
<td><strong>Conjunctival Changes</strong></td>
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<tr>
<td>Follicles: Viruses (adenovirus, primary herpes simplex, herpes zoster, molluscum contagiosum): Chlamydia (inclusion conjunctivitis, trachoma)</td>
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<tr>
<td>Giant papillae: Vernal disease, giant papillary conjunctivitis associated with contact lenses, retained sutures etc</td>
</tr>
<tr>
<td>Scarring: Steven Johnson syndrome, ocular pemphigoid, trachoma, epidemic keratoconjunctivitis</td>
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<tr>
<td><strong>Discharge</strong></td>
</tr>
<tr>
<td>Serous: Viruses (adenovirus, herpes simplex, herpes zoster, molluscum contagiosum)</td>
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<tr>
<td>Mucoid: Keratitis sicca</td>
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<tr>
<td>Mucopurulent: Bacterial (Neisseria, if hyperacute), severe epidemic keratoconjunctivitis, Reiter’s syndrome, Steven's Johnson syndrome, vernal keratoconjunctivitis, inclusion conjunctivitis, trachoma</td>
</tr>
<tr>
<td><strong>Eyelid Lesions</strong></td>
</tr>
<tr>
<td>Ulcers or vesicles: Herpes simplex, herpes zoster, vaccinia, pemphigoid</td>
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<tr>
<td>Nodules: Molluscum contagiosum, warts, acne rosacea</td>
</tr>
<tr>
<td>Blepharitis: Staphylococcal disease, seborrhea, allergy</td>
</tr>
<tr>
<td>Entropion, trichiasis: Mechanical insult to cornea</td>
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<tr>
<td>Ectropion: Exposure</td>
</tr>
<tr>
<td>Loss of lashes: Staphylococcal disease, leprosy</td>
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<tr>
<td>Burns: Thermal ultraviolet, chemical</td>
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<tr>
<td>Lymphadenopathy: Viral infection: adenovirus, primary herpessvirus, vaccinia Chlamydia: inclusion conjunctivitis, acute trachoma (preauricular)</td>
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<tr>
<td><strong>Abnormal tear function</strong></td>
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<tr>
<td>Low Schirmer's test: Keratitis sicca</td>
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<tr>
<td>Rapid tear film breakup time: Hypovitaminosis A, ocular pemphigus, Stevens Johnson syndrome, chemical or thermal burns, drug induced disorder, trachoma</td>
</tr>
<tr>
<td><strong>Superficial Punctate Epithelial Keratitis</strong></td>
</tr>
<tr>
<td>Fine: Bacterial infection: staphylococcalViral and chlamydial infections: adenovirus, herpes, molluscum contagiosum, inclusion conjunctivitis trachoma Drying and mechanical sources: Keratitis sicca, exposure Allergic sources: vernal, atopic Viral infections: herps simplex, vaccinia, varicella voster Keratitis sicca</td>
</tr>
<tr>
<td>Coarse and blotchy: Chemical sources: acid or alkali burns, Vitamin A deficiency, Xray exposure, Thygeon's superficial punctate keratitis Superior limbic keratoconjunctivitis</td>
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<tr>
<td>Pemphigoid, ocular: Keratitis sicca Superior limbic keratoconjunctivitis erosion Vitral infections: herpes, vaccinia, adenovirustrOclusionPost corneal abrasion, After cataract or corneal surgery Miscellaneous: postiasis, keratocouns, chronic blepharospasm, aniridia, ocular albinism, recurrent erosion</td>
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Initially it involves only the corneal epithelium (SPEK) and develops shortly after the onset of conjunctival changes. The characteristic subepithelial infiltrates appear at least 2 weeks after surgery. The subepithelial opacities may persist for many months, long after the other findings disappear. These opacities disappear with topical steroids treatment but may reappear on cessation.

The size of the lesions and their rate of evolution is dependent on the strain involved. Serotypes 3, 4 & 7 are associated with fine to medium opacities whereas serotypes 8 & 19 give rise to coarser opacities. The corneal lesions of adult inclusion conjunctivitis are very similar to adenoviral lesions. Clues to differentiation are the tendency of predominantly upper 1/3 of cornea involvement in inclusion conjunctivitis.

**Distribution of lesions in superficial punctate keratitis**

A combination of morphology of individual corneal lesions and their distribution allows grouping of diagnostic possibilities. Some patterns of distribution can be diagnostic. For example, a tarsal foreign body is suspected when a typical vertical linear SPEEs is seen. Most patterns are less diagnostic but suggest a list of possibilities.

**Associated ocular & periocular findings**

Superficial punctate changes may be the only abnormality detected on clinical examination but in wide variety of cases the corneal changes are associated with other ocular and periocular changes. In evaluating SPKs, five categories of changes are of particular importance: conjunctival changes, eyelid lesions, limbal lesions, lymphadenopathy and abnormal tear function.
Lid surgeries are one of the most challenging ocular surgeries as it demands the best possible functional and cosmetic outcome. The lids are extremely specialized mobile tissue which serve as a protective curtain in front of the eyeball and helps in spreading and maintaining the integrity of the tearfilm, thus maintaining a smooth ocular surface. The upper eyelid has a more important role in globe protection as it covers a greater area of the cornea. An understanding of the basic principles of repair and reconstruction of the eyelids helps in preserving these basic eyelid functions. Trauma and tumor excision are the most important causes of eyelid defects requiring repair and reconstruction. An in-depth knowledge of the surgical anatomy of the lids is an absolute prerequisite for a successful lid surgery.

**Surgical anatomy of the eyelids**

The eyelids can be divided into four subunits:

- Eyelid proper
- Medial canthus
- Lateral canthus
- Lid margin

1. **Eyelid proper**: The lids can be seen as containing four basic layers from anterior to posterior.

<table>
<thead>
<tr>
<th>Skin</th>
<th>Orbicularis oculi</th>
<th>Tarsal plate</th>
<th>Conjunctiva</th>
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<td></td>
<td>- Anterior lamella</td>
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The eyelid skin is the thinnest in the body and because of its elasticity can be mobilised easily for transposition and advancement flaps. The tarsal plate acts as skeleton for the lids, providing rigidity and support. Lid has a very rich vascular supply and wound healing is faster here than in other part of the body. The rich vascularity also allows for primary repair to be done even 24 hours after trauma, which may not be possible in other parts of the body.

2. **Medial canthus**:

   The fibrous extension of the tarsus forms the two limbs of the medial canthal tendon which gets attached to the anterior and the posterior lacrimal crest. The lacrimal drainage system is located at the medial canthus. Injury or lid defects that involve the medial canthal region is usually associated with damage to the underlying lacrimal drainage system which needs to be repaired to prevent the postoperative complaints of epiphora.

3. **Lateral canthus**:

   The fibrous extension from the lateral aspect of the superior and the inferior tarsus join to form the lateral canthal tendon which is attached to the lateral orbital tubercle at the inner aspect of the lateral orbital rim. Mobilization of the lids to repair a full thickness lid defect requires dissection at the lateral canthus. In addition the medial and the lateral canthal tendons are essential to maintain the horizontal pull on the lids and for proper lid-globe apposition. Injury involving damage to the canthal tendons must be reapproximated during the repair process to maintain this lid globe apposition.

4. **Lid margin**:

   The lid margin is an approximately 2mm wide strip with an anterior border and a sharp posterior border. At the lid margin the anterior lamella is composed of skin, orbicularis muscle and lash follicles. The posterior lamella in addition to the tarsus and the palpebral conjunctiva shows the opening of the meibomian glands. In between the meibomian gland orifices and the cilia is the ‘grey line’, the mucocutaneous junction at the lid margin and an important surgical landmark. Incision at the grey line will split the lid into two lamella.

**Goals of lid repair and reconstruction**

- To restore adequate eyelid function in terms of mobility, globe protection and tear drainage.
- To restore the anatomic structure of the lid.
- To achieve acceptable cosmetic results.

**General principles of lid repair and reconstruction**

1. A small skin defect can be closed directly or by sliding adjacent skin over the defect. For larger defects requiring a graft, full thickness redundant skin from the opposite upper lid is the best option. The second alternative is a full thickness skin from the post...
auricular area. Other areas from where grafts can be taken are supraclavicular area, inner aspect of the upper arm etc.

2. The lid margin should be preserved as much as possible. If divided, this line must be carefully sutured in layers to avoid lid notching.

3. The skin incision over the lids is given along the line of tension and parallel to the lid margin. For the lower lid, such incision may cause vertical pull at the lid margin causing ectropion or notching. Hence, in the lower lid, the line of incision should be oriented perpendicular to the lid margin.

4. Efforts should be made to minimize the vertical pull on the lid margin and to maximize the horizontal pulling.

5. The orbicularis oculi muscle should be disturbed as little as possible.

6. The palpebral conjunctiva is difficult to mobilize for the purpose of making an adjacent sliding flap. Defects in this layer are better repaired by a conjunctival autograft or mucous membrane graft.

7. The important point is that all layers must be reconstructed according to their initial anatomical position, without excessive pull or stretch, by whatever procedure that provides the same.

Preoperative Evaluation

A proper preoperative evaluation is important for planning the surgical repair and the choice of surgery.

- The anatomical defect should be carefully appraised. The horizontal, vertical and deep dimensions of the defect should be determined.
- Involvement of the lid margin should be noted.
- Location of the defect—medial, lateral and central should be charted out.
- Involvement of the canthal tendons if any should be noted.
- Involvement of the lacrimal drainage system should be looked for.
- Involvement of the orbital septum and levator aponeurosis should be carefully observed.
- Age of the patient is of immense importance in determining the choice of surgery.

- Vascular supply of the surrounding tissues.
- Stretchability of the lids.
- Availability of regional and distant tissue for reconstruction.
- Age of the wound.
- Previous treatment and prior history of radiation.

Repair of Anterior Lamellar Defects

- Small defects < 5mm in size heal well by secondary intention.
- Defects involving < 50% of the upper lid can be closed by a variety of local flaps. The flap is mobilized as skin-muscle flap. In patients with superficial defects, the orbicularis fibres are removed from the base of the defect prior to flap rotation. If excess tension is present along the line of closure, a skin graft must be used for reconstruction. The skin of opposite eyelid and post auricular area represents the best available source for skin grafts.

- Defects involving > 50% of the anterior lamella usually require a full thickness skin graft for reconstruction.

Full Thickness Defects Involving the Lid Margin

For the purpose of surgical repair, eyelid defects can be classified according to the defect size.

Young patient

- Small defect - 25-35%
- Medium - 35-50%
- Large - > 50%

Older patients / in lax lids

- Small defect - 35-45%
- Medium - 45-55%
- Large - > 65%

However, every case should be judged on individual basis and too much stress should not be placed on the size of defect for systemizing the type of repair. Lids vary in elasticity and tonicity and in some young patients, a small defect <20% may need additional procedures like lateral canthotomy.
Small Defect

1. Primary repair by direct suturing

Tarsal edges are fashioned to create vertically oriented ends extending till the full vertical height of the tarsal plate. The defect is then converted into a pentagon by excising a triangle from the ends of the defect. This forms a vertical pentagon with apex towards the corresponding fornix. The lid is repaired in layers with 3 vertical mattress sutures passed at the lid margin. The first suture is placed at the grey line, the deeper bite emerging 3mm below and behind the cut edge of the lid margin. The superficial bites are placed 1.5 mm behind and below the lid margin. 6-O Vicryl suture with a spatulated needle is the best option. Two more sutures are passed in front and behind the grey line to approximate the anterior ciliary margin and the sharp tarsal conjunctival margin posteriorly. The ends of posterior sutures are kept long and then engaged in the knot of the anterior suture to prevent the rubbing of cornea by suture ends. Vertical end of the tarsal conjunctival wound is sutured with 6-O Vicryl while the anterior skin orbicularis layer is sutured with a 6-O Silk suture. It is desirable to achieve a slight eversion and pouting of the ends of lid margin. This prevents the post operative lid notching. Excessive tension at wound if present can be relieved with lateral canthotomy and cantholysis of the respective crus of lateral canthal tendon. Lid margin sutures should not be removed before 14 days while skin sutures can be removed on 5th postoperative day.

This technique can be used for repair of traumatic lid lacerations, lid colobomas as well as defects created after tumor excision. It provides good lid stability and an excellent aesthetic appearance.

Medium Defects

The various surgical options available include:

1. Lateral canthotomy and cantholysis and direct suturing:

   Indicated for a lid defect too large for primary repair but involving less than half of the lid. This lid lengthening procedure is performed by doing a canthotomy to divide the lateral canthal tendon (LCT) superior and inferior crus. The lid to be reconstructed has the corresponding crus of the LCT cut at its insertion into the orbital rim after separating it from the conjunctiva and the orbicularis. The lid is advanced nasally and the defect closed by direct suturing as described above.

   This procedure has the advantage of preserving the contour of the lid and maintaining the continuity of the lash line. However there is some residual scalloping of the new lid margin at the lateral canthus and this procedure is not effective in closing defects involving more than half of the lid.

2. Tenzel semicircular flap technique:

   This is another lid lengthening procedure useful for closing both upper and lower lid moderate sized defect. A semicircular musculocutaneous flap is rotated from the lateral canthus and the defect is closed by direct suturing. The flap starts from the lateral canthus and extends in a semicircle to a diameter of 2 cms. For upper lid defects the semicircle extends inferiorly and for lower lid the semicircle extends superiorly above the lateral canthal angle. A cantholysis and canthotomy is done along with this procedure to facilitate rotation of the flap. Once the flap is rotated into place and sutured, the lateral canthus should be fixed adequately. Posterior surface of this skin muscle flap is covered by conjunctiva rotated from the inferior fornix.

   This procedure produces excellent cosmetic results. However, newly formed lateral part of the lid is devoid of cilia and absence of the rigid support of the tarsal plate in this area may cause lid notching.

   Other techniques for repair of medium defects include:

3. Tarsoconjunctival flap (Kollner) and Hewes-Beard modification of the tarsoconjunctival flap.


5. Mustarde’s pedicle rotation flap.
All these procedures are based on the principle that one of the lamella of the lid defect is closed by a sliding pedicle flap from the opposite lid or adjacent area. The defect of the other lamella is closed by a free graft. At times both the lamella may be closed by pedicle flap as for the Hewes tarsocconjunctival flap technique. Here a tarsocconjunctival flap is raised from the midportion of the upper lid and is left with its blood supply coming from the intact lateral portion. The flap is rotated into position in the lower lid defect and the anterior lamella is repaired with advancement skin flap from inferior aspect.

**Repair of large defects**

1. **Cutler Beard Bridge technique:**

The Cutler-Beard technique is used for reconstruction of full thickness eyelid defects involving more than half of the lid. Originally described for reconstruction of the upper lid, this technique can be used for reconstruction of the lower lid defect also, a procedure known as reverse Cutler-Beard. This procedure is done in two stages. In the first stage a full thickness tongue of the lower lid is brought under a bridge flap of the eyelid margin and sutured to the upper lid defect. The width of the flap is equal to the width of the defect measured with the temporal and the nasal lid margins brought together as closely as possible. The horizontal incision in the lower lid is made 4-5 mm below the lid margin to preserve the vascular supply and prevent ischemia of the remaining lower lid margin. Since this flap is devoid of tarsus, autogenous cartilage can be used to recreate the tarsal plate of the upper lid.

Separation of the flap is done 6-8 weeks later as second stage surgery. The flap is released by cutting in a convex down curve approximately 2 mm below the desired site of the upper lid margin. A thin strip of skin muscle is removed from this extra length of the flap leaving an extra fold of conjunctiva beneath the upper lid margin. This conjunctiva is rotated anteriorly to cover the lid margin so that the lid margin is now lined by mucous membrane rather than keratinized epithelium. The lower lid is also reformed by freshening and suturing the inferior margin of the bridge.

**Advantages of Cutler-Beard procedure:**

- Skin color and texture matches well.
- Good margin support present.
- Good results with less scarring.
Drawbacks:
- Two stage procedure.
- Absence of cilia in the reconstructed lid margin.
- Cannot be done in infants and young children, can give rise to stimulus deprivation amblyopia.

Complications:
- Necrosis of the lower lid bridge. Can be prevented by giving the lower lid skin incision at least 4-5 mm below the lid margin thus preserving the marginal arterial arcade.
- Corneal abrasion due to rubbing of the cornea by small skin hair. Covering the lid margin with the extra conjunctival flap can decrease this complication considerably.

2. Hughes tarsoconjunctival flaps for lower lid defects:

This technique is used to repair full thickness lower lid defects involving more than 50% of the lid. A flap of tarsoconjunctiva from the upper lid is used to reconstruct the posterior lamella of the lower lid. A horizontal incision is made on the upper tarsal plate approximately 4mm from the lid margin after everting the lid. The length of the incision is equal to the size of the lower lid defect needing repair. Vertical incisions are made from the edges of this horizontal line extending till the superior fornix. Dissection is carried out to raise a tarsoconjunctival flap which is mobilized and advanced to the lower lid defect and sutured to the conjunctival edge of the defect. The anterior lamella is reconstructed with skin muscle lamella advanced superiorly from the lower lid or by full thickness skin graft obtained from upper lid or post auricular area.

The separation of the flap is done 6-8 weeks later as second stage surgery. The procedure is same as done for Cutler-Beard technique and care should be taken to cover the newly formed lid margin with conjunctiva.

3. Mustarde’s upper lid reconstruction:

This procedure is especially useful for reconstructing shallow marginal defects of the upper lid. A full thickness marginal flap from the lower lid is rotated 180° and sutured to the defect in the upper lid in layers. The flap is attached to the lower lid by a pedicle of approximately 8mm width which provides vascular supply to the flap. The base of the flap is divided at 2-4 weeks time and the redundant flap is inserted into the upper lid defect. The lower lid marginal defect is closed by direct suturing. A canthotomy and canthlysis can be done if there is excessive tension at the suture line.

Advantages:
- This procedure has the advantage of providing a lash bearing lid margin and hence gives good cosmetic results.

Drawbacks:
- Two stage procedure.
- Irregularity of the lower lid margin.

Grafts in lid reconstruction

Free grafts are often needed for large lid defects which cannot be closed by direct suturing or advancement flaps.

For anterior lamella of the lid full thickness skin grafts taken from ipsilateral or contralateral upper lid is the best match. If enough upper lid skin is not available as in young patients, full thickness skin grafts can be taken from post auricular region, inner upper arm, supraclavicular region and nasolabial fold.

For posterior lamella, tarsoconjunctival free graft is the best option. Other options include nasal mucoperichondrium, hard palate mucoperichondrium, buccal mucosa, auricular cartilage and autogenous fascia lata.

The above was a short synopsis and overview of the basic principles of eyelid reconstruction which can be used to give excellent functional and cosmetic results to the patient, as practiced by the authors. Individual variations in technique may be present. Meticulous dissection and reconstruction of the eyelids, laying stress on the anatomical layers of the eyelids is the key to a successful outcome.

References and suggested readings:
Trabeculectomy with Releasable Sutures

Kirti Singh MD, FRCS, Pooja Jain MS, Shikha Jain

The basic mechanism of all glaucoma filtering procedures is the creation of a fistula (opening), at the limbus, which allows aqueous humor to drain freely from the anterior chamber, thereby circumventing the pathologic obstruction to outflow. The aqueous flows directly or indirectly into subconjunctival spaces and is then removed by one or more routes.1

Full thickness or free filtering surgeries were the initial type of surgeries to be performed and rapidly went into disrepute because of unregulated outflow of aqueous leading to hypotony with its tragic consequences. This led to the second type of surgery, the more controlled “partial thickness” scleral flap surgery pioneered by Sugar in 1961 and later on by Corrylos in 1967.2 However Cairns is the ophthalmologist whose name is frequently associated with trabeculectomy, because of his innovative modification of Sugar’s procedure and current trabeculectomy is what he did in 1968. Cairns, and subsequently Watson in 1970 reported successful trabeculectomies using a one half-thickness flap, hinged posteriorly in the sclera or anteriorly in the limbus.3,4 The intent was to remove the trabeculum (the suggested site for resistance to outflow). The external flap was sutured tightly to prevent any excessive filtration. Unlike with the earlier full thickness fistulas, there was lower incidence of complications like hypotony, anterior chamber shallowing, choroidal detachement, cataract, hypotonous maculopathy, blood aqueous barrier breakdown (with potential for increased healing response and failure by scarring) aqueous misdirection, and suprachoroidal hemorrhage. However, the resulting guarded aqueous outflow prevents the profound and long lasting reduction of IOP typically attained by full thickness filtration procedures.1

Why is there a need for releasable sutures?

The resistance to bulk flow of aqueous is largely determined by the apposition of the flap to the underlying sclera adjacent to the sclerostomy which in turn is determined by the suture position and tension. If the scleral flap is poorly constructed or too loose, trans sclerostomy flow will be too great, which will commonly result in hypotony. If the scleral flap is too tight, the IOP will be too high, which places the patient at risk from sudden loss of remaining field if the glaucoma is advanced (“snuff out”) or further ganglion cell loss and resultant worsening of glaucomatous optic neuropathy. Manipulation of the suture tension could therefore alter the flow beneath the flap and also the IOP.5

Simmons in the 1970s developed a tamponade technique using a plastic device called the glaucoma shell which prevented the problems of early hypotony and promoted the development of a diffuse filtering bleb with very low resultant intraocular pressures.6 The other modifications developed were laser suture lysis or bleb massage in the region of scleral flap to reduce the raised IOP in the immediate postoperative period. Laser suturolysis was introduced to lyse the sutures holding the scleral flap during the first few days or weeks after surgery, thus allowing better aqueous runoff and preventing early hypotony.7 The technique of laser suturolysis was first described by Lieberman with a Goldmann goniolens.8 Hoskins and Migliazzo reported a new design for a lens to facilitate the procedure.9 Both mildly compress the conjunctiva to expose the underlying sutures. More recently new lenses have been designed to facilitate the procedure.10,11 However laser suturolysis has some disadvantages, it requires access to Argon laser, the cost and availability of which is a major limiting factor in India. It also requires a Hoskin’s or equivalent lens, which enables compression of the filtration area during the procedure.12 Manipulating the operated area so soon after surgery caries the inherent risk of infection, flap dehiscence and wound leak, not to mention extreme patient discomfort and trepidation. Additionally, sutures can be obscured by hemorrhage, overlying edema or a thick Tenon capsule precluding suture release when it is most needed. In addition, complications of laser suture lysis such as conjunctival burns, conjunctival flap leak, hypotonous maculopathy, malignant glaucoma, iris incarceration and hyphema have been reported.7,13,15

These and other disadvantages, led to the use of releasable sutures which were introduced by Schaffer et al16, but popularized by Cohen and Osher.17 The use of releasable sutures minimized the incidence of shallow anterior chamber and hypotony in the early postoperative period12,18,19. Once the wound and anterior chamber stabilize, the sutures are released to enhance the outflow of aqueous humor. The resultant situation, resembling a full thickness surgery, would ensure good bleb function and provide lower long term IOP15,12,18,21. In a nutshell it
combines the benefits of partial thickness filtration surgery by allowing a formed anterior chamber in the immediate post operative period along with those of full thickness filtration surgery by allowing a freer flow of aqueous and consequently lower intraocular pressures (IOP) once the sutures are removed in the later post operative period. The other alternative of using antifibrotic agents like Mitomycin C to achieve lower IOP carries the hazards of drug toxicity, thinner, fragile, vascular, unhealthy blebs. Consequently literature witnessed a flurry of techniques where surgeons competed with each other to devise their own methods of tying sutures, which could be manipulated, and aqueous flow titrated.

Does it work?

Thomas et al in their retrospective review of 154 trabeculectomies with releasable sutures noted that the immediate reduction in IOP was significant (mean 7.5.7 mm Hg; p<0.01) when the suture was released during the first three postoperative weeks. Seventy percent of eyes had a reduction in IOP more than 5 mm Hg if released within the first week compared to 20% after the third week. Jacob et al in their prospective study observed a highly significant drop of 9.1 mm Hg p<0.001, post suture release. In another prospective study by Raina et al 55% reduction in IOP was noted on day 1 in group with releasable sutures and the final IOP at 12 months was 16.9 ± 1.2 mm Hg in the group without releasable sutures and 15 ± 1 mm Hg in the group with the releasable sutures.

Many authors have speculated about the possibility of dangerous elevation in IOP with the tight closure of scleral flap with releasable sutures. However this fear has never been substantiated. The assurance that the suture can be released in the postoperative period allows the surgeon to secure the scleral flap higher than usual thus minimizing hypotony and if high IOP is found in the postoperative period one or more suture may be released to allow improved filtration, which is not possible with permanent sutures.

Regarding the amount of astigmatism induced, study by Hornova J showed that the postoperative astigmatism increased by +2.8 D on the 1st day which declined to +2 D by 1st month, and during 6 – 12 months it only makes +0.25 D difference.

A popular technique

Various releasable sutures techniques have been described. Wilson described a mattress type scleral type suture, which was externalized with the knot on the cornea. Postoperatively, the suture could be cut or removed. Shin fashioned a scleral flap suture utilizing a releasable knot, which was passed through the conjunctival bleb. This technique risked subsequent wound leakage. The technique described by Cohen allows ready access to the
suture which can be easily removed postoperatively at the slit lamp. 

Johnsone et al.25 and Hsu et al.26 have also described modifications in this technique.

The technique described by Cohen and Osher17 and modified by Kolker et al.18 in 1994 is described below. A limbus based conjunctival flap is raised approximately 8 to 10 mm from the limbus. The dissection is carried to the limbal zone. Superficial bleeding vessels over the site of the intended scleral flap are cauterized lightly. A triangular scleral flap measuring 4 x 4 mm and of one-half scleral thickness is dissected up to the limbal zone. A 3 x 1 mm internal sclerotomy opening in the anterior chamber is made just anterior to the scleral spur. A peripheral iridectomy is made slightly wider than the opening of the sclerostomy.

The needle of a 10-0 nylon suture is passed first into the intact sclera posterior to the scleral flap and then brought out anteriorly through the scleral flap. This suture is then passed through the base of the scleral flap, beneath the conjunctival flap insertion, through partial thickness cornea 1 to 2 mm from the limbus, and then out on to the epithelial surface of the cornea. A peripheral iridectomy is made slightly wider than the opening of the sclerostomy.

Regarding release of sutures, these are removed with the patient under topical anaesthesia and seated at the slit lamp by pulling the exteriorized corneal loop with a suture holding forceps. The sutures are released one at a time, within 10-14 days. Suture removal usually produces an immediate increase in filtration with enlargement of the filtering bleb and a fall in IOP. Suture removal after 2-3 weeks has little effect on bleb appearance or IOP. However, in cases of trabeculectomy with antifibrotics, suture removal may be delayed until 2-3 weeks after surgery so as to reduce the development of hypotony.

Is it totally safe?

Very minimal complications have been reported with the use of releasable sutures. In a retrospective study by Kolker et al., in six (4.1%) eyes, the anterior chamber shallowed following suture removal. There were no cases of flat anterior chamber following suture removal, and surgical reformation of the anterior chamber was not required. Thomas et al., in their retrospective review of 154 trabeculectomies did not observe any case of shallow anterior chamber after suture release. In prospective study by Raina and coauthors, the overall incidence of hypotony and shallow anterior chamber was reduced significantly with use of releasable sutures (20% and 7% respectively) while the incidence was higher without the use of these sutures (53% and 33% respectively). No cases of hypotony maculopathy, choroidal detachment, hyphema or peripheral anterior synechiae were noted.

One frequent complication is windshield wiper keratopathy, which occurs due to rubbing of suture on cornea with the movement of lids. This is a distinctive wedge shaped keratopathy that resembles the pattern left on a car windshield by the wiper blade and occurs with or without the use of antimetabolites. Although this keratopathy resolves with release or trimming of the suture, there is a potential for infection and techniques have been described to avoid this complication. Finally, as
a track remains when the suture is trimmed, there is always the risk of **bleb infection**. Other complications reported are epithelial abrasion and subconjunctival bleed following the release of releasable sutures.12

So we conclude that releasable scleral flap sutures is an effective way at no extra cost or instrumentation in reducing the incidence of hypotony and shallow anterior chamber after trabeculectomy, thus taking care of the short term complications and maximizing the long term bleb score and lowering the IOP. The technique is effective even when a cataract extraction is added to trabeculectomy. Use of releasable scleral flap sutures therefore is an important development towards outpatient trabeculectomy in this era of day care eye surgery.

**References**

5. Wells AP, Bunce C, Khaw PT. Flap and suture manipulation after trabeculectomy with adjustable sutures: Titration of flow and IOP in GFS.
Retinal photocoagulation basically involves thermally damaging the abnormal tissues in retina to produce their destruction or inducing adhesions. In this article we will basically discuss the practical & basic techniques of photocoagulation in various retinal disorders and the proper settings of laser parameters to produce the desired effect and minimize the side effects of laser application. Before we discuss these aspects, it is important to know the fundamentals of retinal photocoagulation.

Photocoagulation (PHC) is produced by laser light absorption by ocular pigments (melanin & hemoglobin) to raise the temperature of ocular tissue causing denaturation (coagulation) of proteins. Absorption can occur directly in the tissue to be photocoagulated or indirectly by the neighboring tissues from which heat is then transferred to the tissue of interest.

Various parameters of photocoagulation (PHC)

i) **Power** (its unit is milliwatts or mW)- power needed varies with host of other parameters-
   a) Spot size- Larger spot size needs larger power to cause similar photocoagulation effect e.g. with 100ì spot size, just 100 mW power might suffice while if spot size is increased to 200ì, power required would be greater, say 200 mW to cause similar photocoagulation effect.
   b) Duration of exposure- Larger exposure time means (normally 0.1 sec is used for average setting) less power required.
   c) Clarity of media- hazier media e.g. due to cataract or vitreous hemorrhage means more power required.
   d) Pigmentation (melanin) of patient’s fundus- Pigmented eyes need less power than Caucasian eyes. Moreover within patient’s own fundus, pigmentation varies requiring variable power for different areas. Macular region has maximum melanin pigment and hence absorbs greater energy than surrounding paramacular regions.
   
   ii) **Spot size**- Already mentioned. Simple rule of thumb in FD-YAG (Frequency Doubled) or Argon green laser with exposure time set at 0.1 sec is to use same number of milli Watts power as the spot size in microns (i.e. for 100ì spot size at 0.1 sec exposure time, 100 mW is the average power required; practically however as the machines get older, it needs higher power to cause similar effect). Larger spot sizes destroy greater retinal thickness. In the ‘parfocal’ system of focusing laser beam (now this is the one mostly used; instead of older ‘defocusing’ system), small spots have smaller depth of focus. Hence it is very important to maintain proper focus when smaller spots are used.

   iii) **Exposure time**- Longer exposure increases the influence of thermal conduction in tissue causing the lesion to spread in size & the region of damage gets less well defined. Shorter exposures are more useful if the patient frequently moves his eyes while lasering.

   iv) **Wavelength (colour) used**- Wavelengths most commonly used are Green as in Frequency-Doubled YAG (FD-YAG with 532 nm) & Argon green (515 nm), Infrared in Diode (810 nm). Now rarely used are krypton red (647 nm), krypton yellow (568 nm). Argon blue (480 nm) is no more used.

How does wavelength matter?

   a) Peak absorption of macular xanthophyll is at 460 nm; hence 480 nm (Argon blue) is no more used as it’ll be greatly absorbed by xanthophylls. 532 nm (FD-YAG) is better than 515 nm (Argon-green) in being less absorbed by xanthophylls.

   b) Absorption by Hemoglobin (Hb) & Melanin- Peak absorption by oxyHb is at 542 nm & that of melanin is at 550 nm hence FD-YAG laser has greater absorption by these pigments than of Argon green. 532 nm of FD-YAG is closer to 542 & 550 than 515 nm of Ar green.

   c) Penetration through ocular tissues-
      ➢ Diode infrared penetrates better through blood hence PRP is possible even through mild vitreous hemorrhage.
      ➢ Longer (e.g. infrared) wavelengths penetrate deeper into retina producing less visible burn, more pain, more of outer retinal & choroidal injury; thus the CNVM may be better treated through overlying hemorrhage than with shorter wavelengths.
      ➢ Longer wavelengths are thus less scattered (e.g. Krypton red & Diode infrared) and are not absorbed by blood.

Before we start with individual diseases, it is desirable to discuss the general lesion treatment strategies which will then be applied to individual retinal disorders.
General lesion treatment techniques

1. **Microaneurysms**
   - Focal laser treatment is generally given
   - Start with 100μ spot size, 0.1 sec exposure time and 100 mw power
   - End point of laser is immediate blanching of micros (especially if it is larger one), although re-redening results after minutes. In small micros, surrounding RPE will lightly blanch rather than micros itself.
   - Over-treatment can rupture Bruch’s, thereby exciting secondary CNVM formation or excessive scarring of RPE.

2. **Macular edema**
   - Focal treatment is given as above if localized edema is there due to microaneurysm, while grid laser is given for diffuse macular edema.
   - Initial parameters setting is similar to that used for focal treatment. Try a test spot in a non-critical paramacular area.
   - 100μ burns are placed 1 burn width apart (keep inter-burn distance actually at 1½ to 2 burns width as thermal effect slowly spreads so that final inter-burn distance achieved is one burn width only) applied in a grid pattern. Macular grid may have to be modified i.e. extended peripherally to include all adjoining thickened areas.
   - Endpoint is slight whitening of retina. Power required varies with the macular thickness; power required is more for more thickened areas.
   - **Retreatment** - Revaluate the patient every 4 weeks. If after 8-12 weeks, there are areas of thickening (i.e. edema) still present; give a little touching to all leaking areas (repeat FFA is done before this) upto 250 microns from the foveal centre.
   - 50μ spot size is generally not used as there are more chances of choroidal rupture.

   **Subthreshold macular grid laser** - This is a relatively new concept in which micropulse (i.e. duration of 0.1millisecond), subthreshold (i.e. clinically invisible laser spots) diode laser burns (wave length of 810 nm) have been shown to be effective in macular edema. Theoretically thermal damage remains confined to RPE level (anteroposterior thermal diffusion is decreased with decrease in exposure time to 0.1millisecond instead of conventional 0.1 sec). Underlying choriocapillaris and overlying photoreceptors thus escape the damage, thereby reducing the number of parfoveal scotomas. However placing spots without seeing is technically difficult.

3. **Panretinal photocoagulation (PRP)**
   - On an average 200-250μ spot size with exposure time of 0.1 second and power of 200-300 mw is used.
   - Wide angled indirect lens is more desirable as this makes the process easier and quicker (e.g. Mainster wide-field ‘125°’ or Ultrafield, Volk quadraspheic with 130° field or Volk superquad XL) than 3-mirror lens.
   - If patient also needs macular grid, it should be done first followed by first sitting of PRP after 2 weeks. However if PRP is urgently required as in cases of high risk. PDR; first sitting of PRP may be given, starting first in the nasal quadrant to avoid increasing the macular edema.
   - Laser burns first start as oval ring around temporal retinal vascular arcades and about 1 disc diameter around optic disc (except temporal to disc).
   - Inferior areas are treated first (as it might otherwise get obscured by any future vitreous bleed). Burns are applied up to the equator.
   - Moderate intensity burns are used (grayish white & not dense white). Equidistant spots are preferred.
   - Avoid major retinal vessels, any old laser spots, chorioretinal scars, retinal hemorrhages, vortex veins, giving haphazardly placed spots etc. while applying laser spots.
   - PRP is done in 3-4 sittings with a gap of 2-7 days between 2 sittings.
   - PRP is done under topical anesthesia. If larger spots say 500 microns are used, laser application becomes more painful and may even need retro or peribulbar injection of lignocaine. PRP with Diode infrared laser is also quiet painful and it may need retro or peribulbar block.
   - With 200-250μ, the number of spots required is generally 2500 to 3500 with approximately 800-1000 spots given in each sitting. Only approx. 1500-2000 spots are required with 500μ spot size which is practically never used.
   - Interburn distance should be approximately 1½ to 2 burns width.
   - Posterior pole scatter or mild scatter laser treatment is no more recommended by various studies.
   - Avoid overzealous laser treatment particularly in periphery as it can result in choroidal effusion and consequent angle closure glaucoma due to forward rotation of ciliary body. If it occurs, treat it by topical steroids, antiglaucoma medication or even PI may be required.
   - Repeat FFA is done at 3 months after PRP completion to see adequacy of treatment.
   - For persistent neovascularisation, PRP strengthening or fill-in treatment is given. NVE areas may be treated directly if these are still present and are away from the macula. Use 100μ spot size to fill in the gaps between
the 2 laser spots. Avoid the previous laser spots. PRP is also extended beyond equator and is also moved slightly inside the temporal vascular arcade.

**Possible complications of PRP**-

i) Macular edema with decrease in vision. This especially happens if patients have some pre-existing edema (hence complete the macular grid first followed by PRP after 2-3 weeks) or perifoveal capillary non-perfusion. This loss may recover in a month time or may sometimes persist.

ii) Increased IOP especially if treatment is heavy. Angle shallowing may result due to ciliary body forward rotation as described earlier. If can usually be managed easily & conservatively.

iii) Mydriasis due to sphincteric damage if pupil was not well dilated or due to damage to nerves in uveal tract. It is usually permanent.

iv) Paralysis of accommodation- usually temporary.

v) Choroidal detachment and exudative RD-especially if treatment is heavy. It is usually transient.

vi) Choroidal hemorrhage and Bruch’s rupture with subsequent CNVM can occur with heavy burns.

vii) Vitreous hemorrhage may result due to regression of NVEs with subsequent contraction of glial tissue.

viii) Inadvertent foveal burn- may result in permanent loss of central acuity.

ix) Extension of extrafoveal retinal traction to involve fovea. Avoid heavy treatment in or near areas of vitreoretinal traction.

### 4. Choroidal Neovascular Membrane (CNVM)

- CNVM can be treated by conventional laser, photodynamic therapy (PDT-photosensitizer dye e.g. Verteporfin is used with the application of diode red laser of 690nm) and transpupillary therapy (TTT-Diode infrared laser of 810 nm is used with long duration of 60 sec).

- In conventional laser, green wavelength (e.g. FD-YAG at 532 nm or Argon green at 515 nm or red wavelength of krypton) is used for treating CNVM. Blue wavelength is now not available and is not recommended.

- Conventional laser suffices for an extrafoveal classic CNVM.

- Choice of laser varies with type of CNVM (whether classic i.e. well defined leak on early angiograms or/and occult), location of CNVM (Subfoveal, juxtafoveal i.e. 0-199µ from foveal center or extrafoveal i.e. beyond 200µ from the centre).

- Higher level of power is basically required. Test burn with 200µ spot size and 0.2 to 0.5 second duration and initial power of 250 mw is first placed at the outer perimeter of the lesion. End point is uniform white burn. Use short duration burns for patients who move the eyes too much or one may have to give peri/retrolbulbar block.

- Perimeter of CNVM is then treated with confluent burns extending 100µ all around the leak or bleed or pigment.

- Angiogram should be placed before the ophthalmologist (either on nearby computer screen or projected behind the patient) & it should not be older than 96 hours (preferably less than 48 hours old).

- Subfoveal & juxtafoveal lesions whether classic or occult are now no more treated by conventional laser. Instead PDT & TTT are now the preferred treatments for these.

- Any recurrent CNVM is treated similarly except that laser treatment is also extended into the previous laser scar.

- Macular photocoagulation study did not show any beneficial effect of Krypton red over Argon green laser. Moreover no visible wavelength has been shown to have any significant advantage over the other wavelengths.

### Areas to be avoided while treating CNVM-

- i) Don’t treat over any major retinal vessel overlying CNVM, rather straddle it

- ii) Don’t treat within 100-200µ of optic nerve margin.

- iii) Spare at least 1½ clock hours of papillomacular bundle i.e. area temporal to disc.

- iv) Subfoveal & juxtafoveal lesions are now preferably treated with non-conventional laser treatment viz. PDT & TTT.

### Follow-ups after laser for CNVM-

- i) Patient is warned to report immediately if any drop in vision, distortion or increase in scotoma occurs.

- ii) First follow up is at 2-3 weeks, when besides visual acuity & fundus biomicroscopy, FFA is repeated to look for persistence or recurrence of CNVM (FFA done earlier than this may be difficult to evaluate because of the swelling & leakage caused by treatment itself).

- iii) Similar repeat examinations are done after another 3 weeks followed by every 3 months for a year and thereafter every 6 months up to 2 years of treatment after which recurrences are unusual, when only clinical examination (without FFA) may suffice.

- Fundus biomicroscopy alone on follow ups can easily miss recurrent CNVM hence regular FFAs are must upto 2 years as stated earlier.
Higher rate of recurrence exists in presence of following risk factors (i) hypertension (ii) cigarette smoking (iii) poorly pigmented CNVM that takes laser poorly.

**Photodynamic therapy (PDT)** - PDT and TTT selectively destroy the CNVM without affecting the overlying photoreceptors/neurosensory retina. These are actually not the photocoagulation treatments. PDT involves injection of photosensitizer dye followed by exposure to non-thermal laser which causes release of nascent oxygen to selectively destroy actively dividing CNVM vessels. For PDT with Verteporfin (Visudyne), diode red laser (690 nm wavelength) is used with long exposure time of 83 sec.

**Transpupillary Thermotherapy (TTT)** - Diode infrared (810 nm) laser is used producing intralesional rise of temperature by 4-8°C to cause free radicals’ release producing intravascular thrombosis & damage. 300-600 mW power is used only once for 60 seconds with spot size of 1.5 to 4.5 mm.

5. **Retinal tears & detachment**
   - Laser spots of about 200-250 microns, 0.1sec duration with starting power of about 200-250 mw is applied all around the tear on the attached retina. Spots are placed half burn width apart (spots become almost confluent with spread of laser burn).
   - Three rows of laser burns are applied all around.
   - If tear is too anterior, laser treatment is carried up to the ora. While for treating small detachments, spots are placed at the ora also as the detachment has already usually reached the ora. Treatment is then supplemented by cryopexy.
   - Maximum attachment strength is achieved in about 2 weeks of laser treatment.
   - Any of the available wide angle laser contact lens (e.g. Mainster Wide-field or Volk’s Quadraspheric or 3-mirror lens) may be used as discussed previously that allows peripheral retina to be seen & treated with ease.
   - Laser photocoagulation burns for retinal tears or hole can be placed much more accurately without damage to conjunctiva, choroid or sclera. There is no release of RPE cells into the vitreous unlike cryopexy (these RPE cells can cause macular pucker or PVR in case detachment ensues).

6. **Retinal arterial macroaneurysms (RAM)**
   - These consist of saccular or fusiform dilatation of major retinal arterioles usually within first 3 orders of bifurcation. They usually regress spontaneously following a benign course. Thus asymptomatic macroaneurysms without any leakage (in form of threatened or already caused macular edema or exudates) are just observed. RAM that has already bled; undergoes resolution thereafter on its own without any treatment.
   - Laser treatment can be direct or indirect. Usually both are combined together. In the direct treatment, RAM is photoagulated directly by long (0.2 to 0.5 sec with 250μ spot size) & mild burns (150-200 mw) to cause light gray burn. Small spots with high energy and short exposure are quiet dangerous. Avoid occlusion of associated branch retinal artery.
   - In indirect treatment, scatter spots are applied around RAM as RAMs are frequently supposed to be due to old veno-occlusive disease with surrounding capillary telangiectasia.

**Laser indirect ophthalmoscopy (LIO)**

LIO has limited but definite role in retinal photoagulation. It is not recommended for PHC around macular region. With LIO, treatment strategies are similar; however only available wavelengths are Diode infrared and Green lasers (FD-YAG & Argon).

Spot size can’t be adjusted in LIO per se. Only one particular size is available with any brand. However the spot size can be varied by varying focusing lens. High dioptre lens produces larger spot size.

Some of the indications for LIO are -
   i) To treat peripheral retina in gas filled eyes (e.g. after VR surgery or pneumatic retinopexy).
   ii) Ideal for treating babies with Retinopathy of prematurity.
   iii) Peripheral retina can be well treated to complete or strengthen the PRP even in hazy media with cataracts or mild vitreous hemorrhage (Diode infrared wavelength is especially useful).

After we have discussed the different photoagulation strategies in general; we will now discuss it as applied to individual diseases. Only differences from these general strategies or special points will be discussed here.

1. **Preproliferative/ Proliferative Diabetic Retinopathy (PPDR/PDR)**

   Treatment of choice is PRP in cases with DRS-High Risk Characteristics (HRC-PDR) e.g. Severe NVD, mild NVD & NVE with vitreous/ preretinal hemorrhage.

   While other indications for doing PRP may be considered relative, still most ophthalmologists would do PRP in these non-HRC PDR & Severe NDPR i.e. PPDR cases in clinical practice-
   i) Rubeosis with/without NVG.
   ii) Extensive capillary non-perfusion (CNP) areas on FFA.
   iii) Other eye lost due to complications related to PDR.
   iv) NVE even without hemorrhage in juvenile diabetics.
v) Pregnant patients.
vii) Patients unlikely to follow up regularly on long term basis.

PRP as described earlier is done and also followed up similarly.

2. *Diabetic macular edema (DME)*

It is treated as already described under the headings of microaneurysms & macular edema (q.v.). DME is treated if clinically significant macular edema (CSME) is present as defined by ETDRS. Grossly it includes macular thickening within FAZ (central 500μi) or hard exudate within FAZ with surrounding thickening or thickening larger than 1 disc diameter area involving central 1 disc diameter of macula. Visual acuity is not the criterion as it may still be 6/6 in patients with CSME.

Non significant macular edema (non CSME) may also require treatment if patient is due for cataract surgery, patient is unable to follow up and in a patient who has suffered damage in vision in other eye because of CSME.

3. *Central Retinal Venous Occlusion (CRVO)*

- Treatment of choice is pan-retinal photocoagulation (PRP), which is actually required only in a few selected cases as described below and as per CRVO study recommendations.
- Aim is not to improve or stabilize the visual acuity as this has not been possible by any means, but to prevent the dreaded complication of secondary neovascular glaucoma (NVG) and a painful blind eye.
- To start with, patient is followed up every month for initial 6 months and carefully looked for neovascularisation of iris (NVI) or angle (NVA) (For this, do gonioscopy regularly). First FFA is done only after hemorrhages clear up significantly (usually after 3-6 months) to allow for capillary non-perfusion (CNP) areas to be evaluated (more than 10 disc diameter areas is considered as a sign of significant ischemia).
- Prophylactic PRP in CRVO has no role (except in those who can’t follow up). PRP is done only after NVI/NVA appears. PRP is done as described already under general lesion treatment strategies (q.v.).
- Photocoagulation attempt to create retino-choroidal anastomosis by intentionally rupturing Bruch’s membrane with small, high-intensity laser burns has not found favour with the majority of the clinicians.
- During PRP, the retinal areas with an overlying blood readily take up laser while higher power is required for edematous areas.
- CRVO study did not recommend any laser treatment for macular edema; since angiographically, macular grid laser does improve the macular leakage but causes no visual gain.

- Hemispheric retinal venous occlusion (HRVO) is managed similar to CRVO except that photocoagulation is limited to the affected retinal half only.

4. *Branch retinal venous occlusion (BRVO)*

- Photocoagulation for this disease is given in the form of scatter treatment or treatment for macular edema.
- As per BRVO study, Scatter (sectoral) treatment is only given if retinal neovascularisation develops (as also confirmed on angiography, which is done only after 3-4 months to allow for clearing of hemorrhages).
- Scatter laser parameters are same as those described in PRP section (q.v.); however laser is confined only to the involved quadrant.
- Modified macular grid laser is recommended for macular edema reducing vision to 6/12 or less but with adequate macular perfusion. Burns extend from edge of FAZ (i.e. leaving central 500μ) upto 2 disc diameters i.e. till retinal temporal vascular arcade.
- Repeat FFA is done only after 2-3 months & if it still shows any leakage, treatment may be supplemented as already described (q.v.).

5. *Retinopathy of Prematurity (ROP)*

- Photocoagulation (PHC) with laser indirect ophthalmoscope (LIO) is now preferred to ablate peripheral avascular retina.
- PHC is as effective as cryotherapy in preventing vasoproliferation and is generally preferred over cryo.
- Its advantages are that it can be done under topical anaesthesia with minimal postop reaction in form of periorbital edema & discomfort and can be easily applied in zone-1 and posterior zone-2.
- PHC burns are given on the entire avascular retinal areas anterior to the ridge (neovascular tissue or vascularised retina is NOT to be treated).
- Theoretically, Diode infrared laser may be preferable because it allows treatment even through a persistent tunica vasculosa lentis without damaging or coagulating these vessels.

6. *Eales' disease*

- Treatment of choice for neovascularisation is photocoagulation.
- Scatter laser is done for all non-perfused areas and for junction of perfused & non-perfused areas.
- Peripheral retinal neovascularisation (NV) in Eales’ is treated as in any other similar disease e.g. Sarcoidosis & Sickle-cell retinopathy. Flat NV is first surrounded
by moderate intensity spots of 200μ followed by its direct treatment with confluent laser burns. In addition milder burns are also applied one burn width apart in ischemic areas (local scatter); this helps indirectly in regressing the neovascularisation. Generalised PRP (scatter) is generally not advisable over non-ischemic areas unlike diabetic retinopathy as disease has more of localized picture in Eales’ disease.

- For elevated neovascularisation, local treatment and local scatter might rarely help; sometimes direct feeder arteriole treatment (Never directly treat venule first) can help in regression of NV. For this, use 250μ spots with 0.2 to 0.3 sec duration with power sufficient enough to segmentate the arteriolar blood column. After this treat the venule.

- Simultaneous active retinal vasculitis might be coexisting in another retinal quadrant which needs cover of systemic steroids.

7. **Wet ARMD**
   See section on CNVM.

8. **Peripheral retinal angiomas /von-Hippel’s disease (Capillary hemangioma)**

   - A small asymptomatic peripheral lesion may be just kept under observation.
   - Larger, multiple or symptomatic lesions need treatment in form of laser photocoagulation or cryotherapy.
   - Angiomas can be treated by direct treatment over angioma (especially if small upto 1DD) or by feeder arteriolar treatment or by combined approach in one or multiple laser session treatments.
   - Moderately intense, long duration confluent laser burns are generally required. Multiple sessions may be required to completely obliterate the lesion. Too intense treatment in one session can result in subretinal or vitreous bleed or aggravation of macular edema.

   - For angiomas of 1-2 DD size, feeder vessel treatment should be attempted which is then supplemented by direct treatment in next laser session. Feeder vessel treatment has already been described under section on Eales’ disease. Still larger angiomas should not be photocoagulated as they are better treated by cryotherapy.

9. **Central serous retinopathy (CSR or ICSC)**

   - Photocoagulation is attempted in very few special situations in view of self resolving nature of disease. Laser therapy does not give any better long term prognosis; instead the potential complications of PHC (secondary CNVM, possible foveal damage) may occur.
   - Laser treatment does cause the faster resolution but does not give better long term visual prognosis or reduced recurrence rate.

   - Hence indications for treatment include non-resolving CSR (in more than 3-6 months), occupational needs (as in certain professionals) for binocularity, bilateral disease where one eye may be treated or if there are long standing RPE changes.

   - Prerequisite for laser therapy is well defined leak which is at least 500μ away from the centre.

   - If any doubt exists about any underlying CNVM, repeat FFA should be done after about 3 weeks when leak of CNVM might have increased while reverse will be the case with CSR.

   - Procedure-100μ, 0.1sec duration and light 4-5 confluent laser burns (100-200 mW) are applied over the leakage site (direct treatment). Indirect laser treatment at the edge of detachment has also been described but this has higher recurrence chances of the disease and is now not recommended.
Advances in IOL technology have been striving to replace the natural lens completely. The crystalline lens has several functions which include optical, anatomical and accommodative. However, the most difficult function to simulate is accommodation.

Following IOL implantation, the zonules adjacent to the tip of the loops are over relaxed. Further contraction of ciliary muscle cannot relax them more i.e. the primary position of lens is over accommodation.

Multifocal IOLs were developed to provide functional ‘pseudoaccomodation’. Visual disturbances like night vision problems like night driving, halos and glare have been reported in 25% of multifocal IOLs as compared to 3-9% of monofocal IOLs.

The promise of spectacle independence whether by multifocal or accommodative IOLs should be preceded by careful patient selection. Attributes of a good patient include:

1. Patients motivated to be free of spectacles both for near and distance
2. A young patient with normal fellow eye
3. A patient requiring B/L IOL implantation motivated for similar (multifocal/accommodative) lens implantation in both the eyes.

Poor patient characteristics include:

1. patients with unrealistic expectations
2. patients with excessive complaints about spectacle and contact lenses
3. patients not tolerant to monovision
4. patients whose lifestyle or occupation involves night driving
5. patients happy wearing glasses

But on the hindsight, multifocal IOLs can provide a solution for only a selected patient population. The optimal solution would involve use of an artificial lens in which the refractive power can vary in a controlled manner.

The loss of accommodation is mutifactorial and involves age related changes in most elements of the lenticular system. There are many possible approaches to the development of an optical system which would change its refractive power, such as a lens filled with a solution that can change its refractive index in response to application of a local electric field or a set of lenses capable of changing the distance between them when an external force is applied. There have been numerous attempts at lens refilling using injectable semi-fluidic materials and inflating intracapsular balloons with fluidic substances. However the results have been controversial and inconclusive.

The anterior movement of the IOL during the effort for accommodation has been reported. The forward movement occurs due to increased vitreous pressure which arises following ciliary muscle contraction which redistributes the mass posteriorly impinging on the anterior vitreous. An increased vitreous pressure is associated with a reduction in anterior chamber pressure which causes a pressure differential which induces an anterior movement of the pseudophakos.

Near function is ascribed to the anterior displacement of lens and the accommodative change varies with the power of the implanted lens. Roughly, the IOL movement of 0.6mm causes 1D of accommodation at the spectacle plane. The change in the power is proportional to the linear excursion of the lens and the power of the lens is described as below:

\[ \Delta D_c = \frac{(D_m / 13)}{\Delta s} \]

where \( \Delta D_c \) is the conjugate change in power, \( D_m \) is the power of IOL, and \( \Delta s \) is the change in position of IOL in mm.

The lens designs which exploit this anterior movement are AT 45 Crystalens and ICU intraocular lens.

AT 45 Crystalens (figure 1) got FDA approval in 2003. It is a modified silicon plate haptic lens. It has a hinge at the junction of its haptic and optic and T shaped polyamide haptics at the end of the plates. The lens is 11.5mm from loop tip to loop tip and the length as measured from the ends of the plate haptics is 10.5mm. The lens has a biconvex optic that is 4.5mm in diameter.

Fig.1: AT 45 Crystalens
This lens was reported to result in excellent uncorrected distance and near visual acuity. However, this study was not randomized and had no internal control group. Using laser interferometry with identical measurement protocol, pilocarpine caused a small backward movement of the CrystaLens. Such backward movement should result in slight disaccommodation and therefore should be counterproductive for an accommodating IOL.

The small optic diameter 4.5mm has not yet been reported to cause dysphotopsias. Even though CrystaLens has a sharp optic edge, there is a junction phenomenon with PCO ingrowth behind the IOL optic along the haptic plates. Therefore the incidence of PCO is predicted to be higher than the current conventional open loop IOLs. There is no published data on PCO with this lens to our knowledge.

The 1CU intraocular lens (Human optics AG Erlanger, Germany) is a one piece, three dimensional, foldable, acrylic IOL. The optic is 5.5mm and the IOL has a diameter of 9.8mm. The modified haptics are intended to allow anterior movement of the lens optic upon contraction of the ciliary muscle. 1CU is a deformable three dimensional IOL that mimics the properties of human crystalline lens to some extent.

Using laser interferometry, pilocarpine induced ciliary muscle contraction caused a forward movement of 1CU IOL of 0.314mm compared to randomized control group which showed no IOL movement. The estimated accommodative effect, calculated from IOL movement data with ray tracing was less than 0.5D in a little more than half the eyes examined.

There have been a number of reported cases of ‘infolding’ of 1CU haptics in front of the optic underneath the capsulorhexis and such documented cases of haptic subluxation had to undergo explantation because of hyperopic shift or astigmatism induced by the tilt.

Concerning PCO, absence of effective sharp edge at the junction zone of the four haptics poses as an ineffective barrier and along with the hydrophilic material results in greater PCO as compared to current sharp edge open loop IOLs.

Another accommodative IOL concept is the Dual optic accommodating IOLs. They are not yet approved in Europe or in United states. The dual optic lenses such as Synchrony (Visiogen, Irvine, Calif.) [figure 2] have the following features:

**Advantages**

1. Allows more accommodation than the single optic IOLs, with less lens movement
2. Contrast or glare problems do not develop, unlike the multifocal IOLs.

**Disadvantages:**

1. Possibility of interlenticular opacification in between the two optics
2. Not as predictable as the multifocals in terms of visual outcome

The Synchrony IOL is a silicone lens with two optics joined by a spring mechanism. The anterior high powered plus optic, 5.5mm in diameter and a complementary minus power optic work together to produce an accommodative effort of more than +2.75D. The optics diverge or are compressed together according to movements of the capsular bag. On accommodation, the distance between the lenses expands resulting in a more plus powered lens.

Another model, designed by Bausch and Lomb (Rochester NY) is the Sarfarazi Elliptical IOL (figure 3) which is yet to begin clinical trials in humans.
Third type, are the deformable accommodative IOLs. The Medennium Smart IOL (Irvine, Calif.) is a thermodynamic, hydrophobic acrylic IOL designed to completely fill the capsular bag. At room temperature, it is convertible to a thin rod that can be inserted into the eye through a small incision. Under the influence of body temperature, it reconstitutes its original power (figure 4).

Nulens (Herzeliya, Israel) is still in animal studies. It is based on the principle of compressible polymer between fixed plates so that on accommodative effort there is bulge in the polymer through an aperture in the anterior fixed plate (figure 5).

The Power vision IOL redistributes peripheral fluid centrally on accommodation increasing the plus power of the optic (figure 6).

The current accommodating IOLs might be expected to provide superior image quality compared to multifocal lenses, since competing retinal images are avoided.

Burrato et al studied the visual results of AT-45 lens and the 1 CU lens in 108 eyes and found uncorrected distance VA of 20/30 or better in 84.6% of the bilaterally implanted 1 CU patients and in 73.6% of AT 45 patients one year following surgery. Uncorrected near VA of J1 or better was achieved in 42% of 1 CU patients and 36.8% of AT-45 patients. He concluded that the 1 CU IOL appears clinically to provide slightly better uncorrected distance and distance-corrected near VA than VA than the AT-45 lens.

Macsai et al retrospectively studied the Crystallens with the multifocal IOL and found that the uncorrected monocular near vision was significantly better in the Crystallens group than the multifocal group with 90% and 15%, respectively reading J3 or better postoperatively. Measures of accommodation were significantly higher in Crystallens patients than in the multifocal IOL patients (dynamic retinoscopy 2.42+/−0.39 D versus 0.91+/−0.24 D (p<0.01); monocular defocus 1.74+/−0.48 D versus 0.75 +/-0.25D(p<0.01) and monocular near point of accommodation 9.5+/−3.1 inches versus 34.7+/−9.8 inches(p<0.01)).

The unpredictability in terms of amplitude of accommodation, incidence rates of PCO and long term centration are issues which need to be settled before the accommodative IOLs gain widespread popularity. Thus a truly complete and ideal IOL is still amiss.

Bibliography


Vitreoretinal surgery has relied heavily on technological advances to advance the field. In particular, the introduction of new viewing technologies and significant improvements over established techniques have allowed this ophthalmic subspecialty to develop at an accelerated rate. The latest viewing systems allow truly remarkable views of the retina, where the surgeon can appreciate nearly the entirety of the fundus with clarity. Improved illumination systems allow flexibility in lighting all or parts of the retina, and enhanced lens design and optics permit the surgeon to work on one part of the retina while making sure that his/her manipulations do not cause retinal breaks at the retinal periphery.

Optics of Vitreoretinal Lenses

The corneal contact lenses used during vitreous surgery helps in excellent visualisation of the fundus. To maintain a clear view of the posterior vitreous, the contact lens must neutralise the refractive power of the cornea, permit visualisation of vitreoretinal pathology, allow corneal contact on rotation of the globe, and eliminate the accumulation of blood or air bubbles between the contact lens and the cornea, thereby enabling the surgeon to focus the operating microscope onto the fundus.

Types of Lenses

Various contact lens systems exist. Plano-concave lenses provide a non-magnified view of the posterior pole. These lenses require a host of supplemental lenses (i.e., prismatic lenses, biconcave lenses) to view the entire fundus in stages during vitreous surgery. The panoramic wide-angle fundus viewing system provides enhanced visualisation of the peripheral fundus during surgery. Though the wide-angle system has the advantage of a larger field of view, resolution and stereopsis of the lenses are compromised.

Often higher magnification for precise surgical manoeuvres, such as removal of epiretinal or subretinal membranes around the macula, drainage of intraretinal or subretinal blood or exudates, or internal limiting membrane peeling for macular hole surgery, is required. Magnifying contact lenses are suitable for these procedures. These lenses either require a sutured lens ring or the presence of an assistant to hold the irrigating handheld lens system for stability.

Wide-field systems have been developed over the past decade and allow panoramic intra-operative views of the retina. Such systems are grounded on binocular indirect ophthalmoscopy principles, originally developed through the use of high plus biconvex lenses. The lenses are incorporated directly as an attachment to the operating microscope. However they produce an inverted image. A major technological advancement that now allows binocular indirect ophthalmo-microscopes (BIOMs) has been introduced. In essence, a re-inverter erects the inverted image of a wide-angle observation system while maintaining stereopsis.

Two types of wide-field systems are available for vitreoretinal surgery: the non-contact systems or contact systems.

A new self-retaining contact lens system with footplates for vitreous surgery has evolved which has many advantages over existing lens systems.

1. Ocular Landers Wide Field Vitrectomy Lens

The lens has a dioptric power of 155D. It produces a wide angle inverted image, allowing a panoramic viewing of far peripheral retina. It provides a clear image in fluid or gas filled eye. The lens can also be used in eyes with hazy ocular media or a small pupil. A tall sutured lens ring is required to stabilize the lens (Fig: 1).

2. Ocular Landers Equatorial II Vitrectomy Lens

The lens has a dioptric power of 91D. It is a wide angle lens, used for procedures from the posterior pole to the equator. The lens provides greater magnification and detail than Landers Wide Field (Fig: 2).

3. Ocular Woldoff High Magnification Vitrectomy Lens

A 66D lens, is ideal for wide angle viewing of the posterior pole. Its wide field provides stereopsis well beyond the area seen by a conventional flat lens. The high magnification and resolution create very precise depth perception. It provides an excellent image for delicate work around the macula such as macular hole surgery or peeling of epiretinal membranes from the macula (Fig: 3).

4. Ocular Landers Non-Autoclavable Wide Field Vitrectomy Lens

A single-piece, 155D lens designed for clinical situations where autoclaving is either not available or not desired. This lens is excellent for panoramic viewing of the far
All wide angle inverting vitrectomy lenses (Fig: 7).

Included in this set are: Ocular surgical viewing system cases, Rubber adjustment knob, Screw driver, slotted, 3/16”

5. **Ocular Landers Non-Autoclavable Equatorial Vitrectomy Lens**

This is a single-piece 91D lens designed for clinical situations where autoclaving is either not available or not desired. It is excellent for delicate membrane peeling around the optic nerve and off of the major vascular arcades. It also provides an excellent image for delicate work around the macula such as macular hole surgery or peeling of epiretinal membranes from the macula (Fig: 5).

6. **Ocular Woloff Non-Autoclavable High Magnification Vitrectomy Lens**

A single-piece, 66D lens, ideal for wide angle viewing of the posterior pole. Its wide field provides stereopsis well beyond the area seen by a conventional flat lens. The high magnification and resolution create very precise depth perception. It provides an excellent image for delicate work around the macula such as macular hole surgery or peeling of epiretinal membranes from the macula (Fig: 6).

7. **Ocular Inverter Vitrectomy System - LEICA**

This lens is designed to work with all Leica (Wild) microscopes. It is easy to operate with steam sterilizable knob. There is no light loss in upright mode and no image shift when switching between upright and inverting modes. The optics is crystal clear and is compatible with all wide angle inverting vitrectomy lenses (Fig: 7).

Included in this set are: Ocular surgical viewing system cases, Rubber adjustment knob, Screw driver, slotted, 3/16”

8. **Ocular Inverter Vitrectomy System - ZEISS**

This is designed to work with all Zeiss, Zeiss type (Topcon, Moeller, etc.) microscopes. It is easy to operate with steam sterilizable knob. No light is lost in upright mode and virtually there is no image shift when switching between upright and inverting modes. It is compatible with all wide angle inverting vitrectomy lenses (Fig: 8).

Included in this set are: Ocular surgical viewing system cases, Rubber adjustment knob, Screw driver, slotted, 3/16”

9. **Ocular Vitrectomy Lens Handle**

It is designed to be used with the Wide Field and Equatorial lens, and the handle provides additional stability to the lens while sitting in the ring during a procedure (Fig: 9).

10. **Ocular Landers Four Post Vitrectomy Lens Ring**

Two sutures placed over one post on each side hold this ring on the eye. Either post can be selected to center the ring over the patient’s pupil (Fig: 10).

11. **Ocular Peyman-Wessels-Landers 132D Upright Vitrectomy Lens**

The 132D imaging optic gives a very wide, non-contact view of the fundus and vitreous. A microscope with an inverter is not required. Unlike conventional wide angle lenses, the image of this lens is upright to simplify vitre-
12. Ocular 132D Upright Vitrectomy Lens Holder

Ring holder for the Peyman-Wessels-Landers 132D Upright Vitrectomy Lens. Includes two adjustable links that snap onto the end of the slotted arm of the Surgical Viewing System (Fig: 12).

13. Ocular 132D Indirect Vitrectomy Lens

This is designed to be used with the Ocular Landers Wide Angle Surgical Viewing System (OSVS). It attaches to the OSVS using the Ocular 132D Upright Vitrectomy Lens Holder (OUV-H132-2). Designed to allow a clear view in the fluid or air filled eye (Fig: 11).

14. Ocular Landers Wide Angle Surgical Viewing System

This is a non-contact vitrectomy system designed with a flexible arm for positioning wide angle lenses which easily swings in and out of the surgical field. The OSVS [clamps] attaches to the wrist rest or surgical bed, freeing the surgeon’s hands and the assistant to perform tasks other than holding a lens. When used with an Upright Vitrectomy Lens, the system allows the surgeon to work in the vitreous with an upright, non-reversed image under panoramic conditions. This system also includes a lens holder and lens case and either an OUV 132-2 or OIV 132 Vitrectomy Lens (Fig: 14).

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Table 1: Features of Ocular Landers Wide Field Vitrectomy Lens

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<th>Lens Height</th>
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<td>11.8mm</td>
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<td>146°</td>
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Table 2: Features of Ocular Landers Equatorial II Vitrectomy Lens

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Table 3: Features of Ocular Woldoff High Magnification Vitrectomy Lens

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Table 4: Features of Ocular Landers Non-autoclavable Wide Field Vitrectomy Lens

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Table 5: Features of Ocular Landers Non-autoclavable Equatorial Vitrectomy Lens

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Table 6: Features of Ocular Woldoff Non-autoclavable High Magnification Vitrectomy Lens

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<tr>
<th>Image Mag.</th>
<th>Lens Height</th>
<th>Static FOV</th>
<th>Dynamic FOV</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9x</td>
<td>13.6mm</td>
<td>57°</td>
<td>100°</td>
</tr>
</tbody>
</table>

Table 7: Features of Ocular Peyman-wessels-landers 132d Upright Vitrectomy Lens

<table>
<thead>
<tr>
<th>Image Mag.</th>
<th>Static FOV</th>
<th>Dynamic FOV</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.45x</td>
<td>100°</td>
<td>135°</td>
</tr>
</tbody>
</table>

Table 8: Features of Ocular 132d Indirect Vitrectomy Lens

<table>
<thead>
<tr>
<th>Image Mag.</th>
<th>Static FOV</th>
<th>Dynamic FOV</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.45x</td>
<td>99°</td>
<td>135°</td>
</tr>
</tbody>
</table>
15. **Biconcave Disposable Vitrectomy Lens**

The 83D biconcave lens facilitates viewing the fundus in an air-filled vitreous cavity in phakic and pseudophakic eyes. The lens has high resolution PMMA optics with a silicone flange for stability. Ocular Disposable Vitrectomy Lenses are designed to be used once. The silicone flange replaces the need for a suture-down ring (Fig: 15).

16. **Flat Disposable Vitrectomy Lens**

The plano anterior surface affords a 36° field of view of the central posterior pole and vitreous in phakic and pseudophakic eyes. This lens is ideal for photography. It consists of high resolution PMMA optics with a silicone flange for stability. Ocular Disposable Vitrectomy Lenses are designed to be used once (Fig: 16).

17. **Magnifying Disposable Vitrectomy Lens**

This lens helps in detailed examination and minute surgical manipulation of retinal membranes in phakic and pseudophakic eyes. The lens is made up of high resolution PMMA optics with a silicone flange for stability (Fig: 17).

18. **Wide Field Disposable Vitrectomy Lens**

The concave anterior surface facilitates a 48° field of view when visualizing the central posterior pole and vitreous in phakic and pseudophakic eyes. Composed of high resolution PMMA optics with a silicone flange for stability (Fig: 18).

19. **30° Prism Disposable Vitrectomy Lens**

This disposable vitrectomy lens provides visualization of the posterior peripheral fundus and vitreous beyond the equator with minimal distortion in phakic, aphakic and pseudophakic eyes. This also has high resolution PMMA optics with a silicone flange for stability (Fig: 19).

20. **Ocular Landers Four Post Vitrectomy Lens Ring**

Two sutures are placed over one post on each side to hold this ring on the eye (Fig: 20).

21. **Landers Irrigating Notched Lens Ring**

Irrigation version of notched ring (Fig: 21).

22. **Landers Irrigating Lens Ring**

This ring features an irrigation port. Sutures secure the two struts to the sclera which allows blood to be irrigated away and keeps the cornea moist (Fig: 22).

23. **Landers Silicone Lens Ring**

This silicone ring can be used with any Landers System lens. It allows the surgeon to change lens positions to obtain the optimum viewing angle. It is useful when using a prismatic lens for peripheral vitrectomy procedures (Fig: 23).

24. **Tano Vitrectomy Lens Ring**

This ring, with four upright tabs for suturing, requires only one circumferential suture. The features of this lens ring are, easy positioning, adjustment and removal without cutting or removing the suture (Fig: 24).

25. **Ocular Machemer Plus**

The Machemer Flat Lens is provided with a silicone flange. This combination is for observation or surgery of the central retina and vitreous when the use of a suture down ring is not desired (Fig: 25).

26. **Ocular Landers 50° Prism**

Ocular Landers 50° Prism allows visualization for vitrectomy and endophotocoagulation procedures in the
This is used to visualize structures deep in the vitreous cavity or on retinal membranes. Plano anterior surface affords a 36° static field of view of the central posterior pole and vitreous in phakic and pseudophakic eyes. Very lightweight and can be used to tilt or indent the eye during surgery (Fig: 29).

27. Ocular Hexagonal Vitrectomy Lens (Ohve)

Ergonomically designed hexagonal infusion handle makes these lenses easy to hold and manipulate. Unique ring design keeps infusion cannula out of the surgical field even at steep tilt angles. The lens is available in four styles, Flat, Biconcave, Magnifying and Wide Field (Fig: 27).

28. Ocular Landers Biconcave Vitrectomy Lens

This lens is designed for vitreoretinal surgery in air filled phakic or pseudophakic eyes. The lens has a power of 83D (Fig: 28).

29. Ocular Flat Vitrectomy Lens

far peripheral retina in phakic and pseudophakic eyes (Fig: 26).

Table 10: Features of Ocular Landers Biconcave Vitrectomy Lens

<table>
<thead>
<tr>
<th>Corneal diam.</th>
<th>Image Mag.</th>
<th>Static FOV</th>
</tr>
</thead>
<tbody>
<tr>
<td>9mm</td>
<td>0.8x</td>
<td>24°</td>
</tr>
</tbody>
</table>

Table 11: Features of Ocular Flat Vitrectomy Lens

<table>
<thead>
<tr>
<th>Corneal diam.</th>
<th>Image Mag.</th>
<th>Static FOV</th>
</tr>
</thead>
<tbody>
<tr>
<td>10mm</td>
<td>1.02x</td>
<td>36°</td>
</tr>
</tbody>
</table>

Table 12: Features of Ocular Peyman III Wide Field Vitrectomy Lens

<table>
<thead>
<tr>
<th>Corneal diam.</th>
<th>Image Mag.</th>
<th>Static FOV</th>
</tr>
</thead>
<tbody>
<tr>
<td>12mm</td>
<td>0.49x</td>
<td>48°</td>
</tr>
</tbody>
</table>

Table 13: Features of Ocular Peyman-green Fluid Cell Vitrectomy Lens

<table>
<thead>
<tr>
<th>Corneal diam.</th>
<th>Image Mag.</th>
<th>Static FOV</th>
</tr>
</thead>
<tbody>
<tr>
<td>12mm</td>
<td>1.02x</td>
<td>36°</td>
</tr>
</tbody>
</table>

Table 14: Features of Ocular Machemer Magnifying Vitrectomy Lens

<table>
<thead>
<tr>
<th>Corneal diam.</th>
<th>Image Mag.</th>
<th>Static FOV</th>
</tr>
</thead>
<tbody>
<tr>
<td>10mm</td>
<td>1.47x</td>
<td>30°</td>
</tr>
</tbody>
</table>

30. Ocular Peyman III Wide Field Vitrectomy Lens

A 60D anterior surface lens used for wide angle viewing in phakic and pseudophakic eyes. It allows visualization of the peripheral fundus for endo-photocoagulation in fluid or air filled vitreous (Fig: 30).

31. Ocular Peyman-Green Fluid Cell Vitrectomy Lens

The lens has a plano anterior surface. Balanced salt solution or methylcellulose added to the top of the lens
Newer Development of Lenses in Vitreoretinal Surgery by Volk:

Table 15: Newer Lenses From Volk

<table>
<thead>
<tr>
<th>Serial no.</th>
<th>LENS Specification</th>
<th>APPLICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Fig 33</td>
<td>Super Macula 77° Field of View 1.03x Magnification</td>
<td>Submacular surgery treatment of macular holes</td>
</tr>
<tr>
<td>2. Fig 34</td>
<td>Central Retinal Excellent 77° Field of View 1.03x Magnification</td>
<td>Diabetic vitrectomy Membrane peeling to the equator</td>
</tr>
<tr>
<td>3. Fig 35</td>
<td>MiniQuad ® XL Ideal lens for small pupil fundus viewing with the operating microscope</td>
<td>Management of dislocated lenses</td>
</tr>
<tr>
<td>4. Fig 36</td>
<td>MiniQuad Widest field of view, allowing visualization of virtually the entire retina including the ora serrata.</td>
<td>Retinal detachment surgery, treating giant retinal tears, anterior proliferative vitreoretinopathy</td>
</tr>
<tr>
<td>5. Fig 37</td>
<td>MiniQuad ® SSV Self Stabilizing Vitreoretinal procedures</td>
<td></td>
</tr>
<tr>
<td>6. Fig 38</td>
<td>Fundus SSV Lenses Self Stabilizing Vitreoretinal procedures</td>
<td></td>
</tr>
<tr>
<td>7. Fig 39</td>
<td>DynaView 156 130° Field of View .39x Magnification</td>
<td>Retinopathy of prematurity surgery</td>
</tr>
<tr>
<td>8. Fig 40</td>
<td>Fundus SSV 30° Field of View 1.0x Magnification</td>
<td>Submacular surgery</td>
</tr>
<tr>
<td>9. Fig 41</td>
<td>clariVit Wide Angle 110/132° Field of View 0.39x Magnification</td>
<td>Retinal detachment surgery, treating retinal tears, Diagnosis and treatment of anterior proliferative vitreoretinopathy</td>
</tr>
<tr>
<td>10. Fig 42</td>
<td>clariVit Central Mag 80/96° Field of View 0.72x Magnification</td>
<td>Detailed visualization to the equatorial regions, Vitrectomy in diabetics, Membrane peeling extending to the equator.</td>
</tr>
</tbody>
</table>

creates a wider field of view through a meniscus lens effect (Fig: 31).

32. Ocular Machemer Magnifying Vitrectomy Lens

This lens provides with high magnification for delicate macular surgery, in phakic, pseudophakic as well as aphakic patients (Fig: 32).

Conclusion

In vitreoretinal surgery resolution of the image and
the stability of the lens are concerns with all lenses used. Further developments in equipment optics, refinement of re-inverter systems and improvements in illuminators will continue to enhance intra-operative wide-angle, panoramic viewing of the retina. Such technologies are exciting tools that herald a new era in vitreoretinal surgery.

This article was written keeping in mind for surgeons pursuing Vitreoretinal surgery as a sub-speciality in the long run as well as for postgraduate students who need to have knowledge about the various lenses used in vitreoretinal surgery.

Suggested Reading