Phacoemulsification in Cataractous Eyes with Shallow Anterior Chamber

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Abstract:

There is a lack of consensus in the ophthalmological community if posterior vitreous tap with phacoemulsification in cataractous eyes with shallow anterior chamber is an optimal method to avoid intraoperative and postoperative complications as endothelial cell damage and IOP elevation.

Keywords: Phacoemulsification, shallow anterior chamber, Anterior chamber depth.

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Introduction:

Anterior chamber depth (ACD) is defined as the distance between corneal endothelium and anterior capsule of crystalline lens. ACD is a significant value to be assessed prior to any intraocular surgery.

Cataract surgeries with shallow anterior chamber are associated with higher risk of intra and postoperative complications as corneal endothelial damage and posterior capsular tear. ACD is also incorporated as an important parameter for recent generations of IOL-power calculation formulas **(1).**

<u>Clinical Assessment of anterior chamber depth</u>

The average depth of anterior chamber is about 3 mm. ACD can be roughly assessed by simple clinical methods. Smith's method can be used with the illumination tower angled temporally to observational microscope at 60º using a horizontal beam. The beam length is shortened resulting in two beams one focused on cornea and the other out of focus on anterior lens capsule, then slit is lengthened till obliteration of gap and the reading is multiplied by factor 1.4 **(2).**

Van Herick method is another clinical way for assessment of peripheral ACD and anterior chamber angle (ACA). Using slit-lamp, examiner compares between width of corneal beam and peripheral ACD that is known as dark area between corneal beam and beam reflected from iris after adjusting slit-beam at 60^{o} temporally. Anterior chamber angle is graded according to ration between corneal width and peripheral ACD. It is limited by that this method only assesses temporal AC angle and being sensitive to deviation by 10 degrees from perpendicular direction **(3).**

Table "1" Van Herick Grading **(4)**.

Width of the empty space (LACD*) as compared to the corneal thickness	van Herick Grade	Angle status
No black space observed	0	Closed
<1/4 Corneal thickness	1	Extremely narrow
1/4 of corneal thickness	2	Narrow
>1/4 to 1/2 of corneal thickness	3	Open
≥1 of corneal thickness	4	Wide open

*LACD = Limbal Anterior Chamber Depth.

Another clinical method for ACD estimation is split limbal technique. It is used for rough assessment of superior angle which is the narrowest and more liable to angle closure. Slit lamp light is used to provide illumination but observation is done by naked eye not using slit lamp eye pieces. Light falling on cornea and iris is observed and the angular separation between the two beams can be used for estimation of superior ACD.

The pen torch method is a rough simple method to assess ACD. Light is shined into the eye from the temporal canthus with the torch at the same plane of the eye. With adequate ACD, the whole iris can be illuminated. With Shallow ACD, the iris lies more forward blocking the light reducing amount of light illuminating the iris and AC Depth can be estimated depending on amount of iris illuminated. Grading ranges from Grade 1 in which less than 1/3 iris is illuminated to Grade 4 in which there is full iris illumination **(5)**.

Anterior Segment OCT for ACD Assessment

Anterior segment optical coherence tomography (AS-OCT) is a non-contact method for assessment of cornea and anterior segment including ACD and ACA. OCT produces 2 or 3 dimensional images by measuring the delay of echo time of light scattered back from tissues. It is dependent on low-coherence interferometry that uses a light source split into two beams with beam splitter into two arms, the reference arm in which light is reflected from mirror and the sample arm where light is back reflected from tissues.

Light reflected from tissues is scattered at interfaces as different tissue structures have different refractive indices. Both reflected light beams from both arms are combined at beam splitter and directed to the detector. Since it is low-coherence light, interference occurs only when the pathway between the two beams is within coherence length of the light source **(6)**.

Interference patterns are produced to construct an axial A-Scan at one point. The light beam moves to scan along a line of the tissue producing multiple A-scans. These A-scans are then combined together to form a two-dimensional image of the targeted tissue which is known as B-Scan. Multiple B-Scans at different sites can be combined to produce a three-dimensional image.

Time-domain OCT: uses a reference mirror that moves at constant speed. Interferences are produced from light reflected from tissues at various positions of reference mirror that moves to change the optical path of the reference beam to match beam returning from different tissue positions, so light echoes are detected sequentially at point detector. The necessity of a moving mirror in this OCT limits its scanning speed to a few thousand A-scans per second.

Spectral-domain OCT: uses an array of detectors with fixed reference mirror that analyzes all reflected light at same time. This increases the speed of scanning up to 100,000 A-Scans per second, improving the quality and resolution of images.

Swept-source OCT: uses swept-source laser of about 1050 nm wavelength. It depends on technology in which light wavelength is rapidly swept with high acquisition rates using a point detector. This results in higher scanning speeds up to 400,000 A-scans per second with axial resolution of 5 um **(7)**.

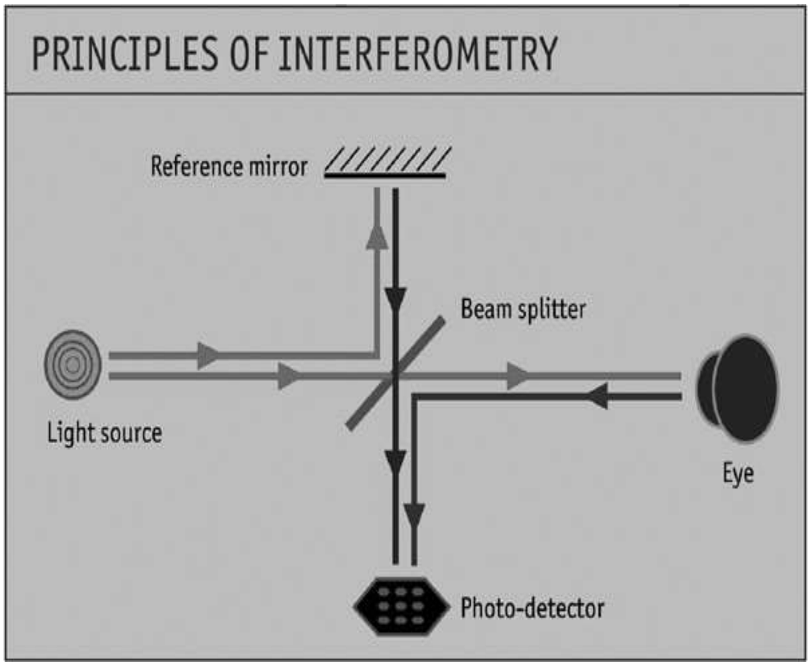
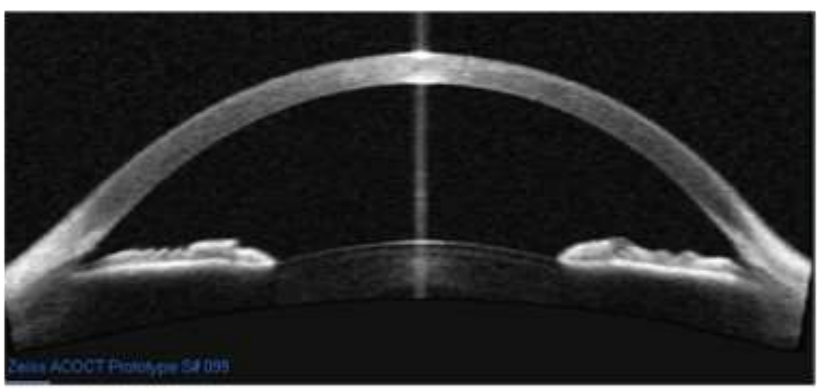


Figure "1" Principle of Interferometry in OCT **(8).**

Imaging the anterior segment is one of the scanning modalities of OCT. AS-OCT has some requirements different from that of posterior segment imaging. Anterior segment imaging needs to capture the full anterior segment, requiring larger scan depth and width that is used for posterior segment imaging. So, Longer wavelengths may be needed which is optically more accessible into anterior segment than posterior segment as they are attenuated by vitreous **(9)**.



Cross-sectional image of the anterior segment made by AS-OCT prototype (Carl Zeiss Meditec Inc.)

Figure "2" Anterior segment OCT **(10)**.

AS-OCT can be used to measure ACD by measuring the axial distance from inner corneal surface to anterior lens surface. Using AS-OCT, one study showed that ACD increases over early years of life to reach a peak by the end of second decade then decreases slowly till 80 years and also showed that ACD is reduced by 30 um for each 1 diopter of accommodation.

AS-OCT can also be implemented into assessment of AC angle, and it is considered to be a valuable tool for quantitative analysis of AC angle. Various parameters can be recorded at angle with AS-OCT capture:

1- Angle opening distance (AOD): the length of the line drawn from point on the endothelial surface 500 um (AOD 500) or 750 um (AOD 750) anterior to scleral spur to the iris surface perpendicular to corneal endothelium.
2- Trabecular-iris angle (TIA): the angle formed by the apex at iris recess with two arms, one passing through a point on the trabecular meshwork 500 um (TIA 500) or 750 um (TIA 750) anterior to scleral spur, and the other arm passing through a point on the iris perpendicularly opposite to the previous one.
3- Angle recess area (ARA): triangular area bounded by corneal endothelium, anterior iris surface and line drawn from corneal endothelium to anterior iris surface lying 500 um (ARA 500) or 750 um (ARA 750) anterior to the scleral spur.
4- Trabecular iris surface area (TISA): trapezoidal area bounded by inner corneoscleral wall, anterior iris surface, AOD 500 or 750 and line drawn from scleral spur perpendicular to inner scleral wall to the opposing iris. It is more accurate than ARA because it excludes non-filtering region behind the scleral spur **(11)**.

Radhakrishnan et al., estimated a cut-off value to consider an occludable angle "less than 10 degrees" which are 191 um for AOD 500, 0.11 mm^2 for TISA 500 and 0.17 mm^2 for TISA 750 **(12)**.

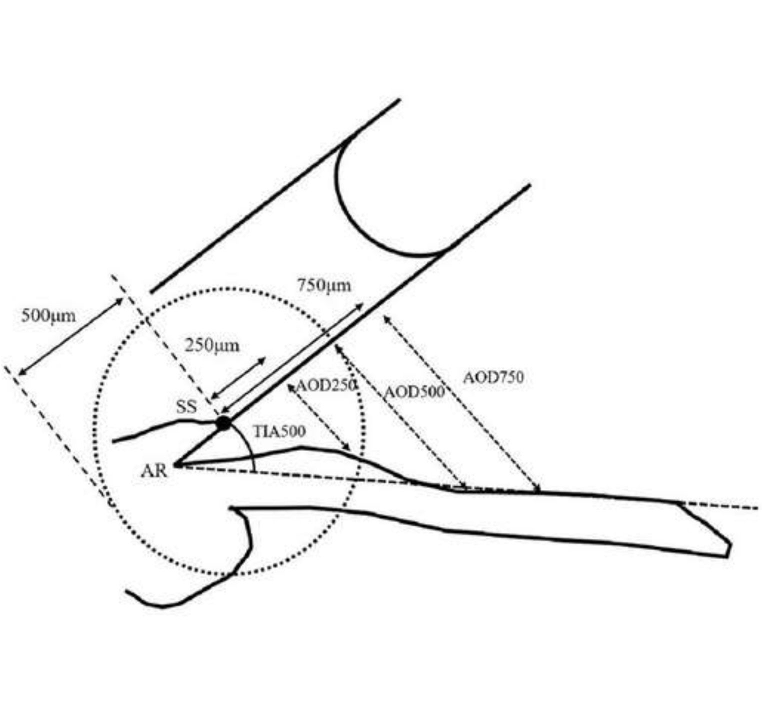


Figure "3" AS-OCT Parameters of AC angle (SS, Scleral spur; AR, Angle recess) **(13)**.

Scheimpflug Camera for ACD Assessment

Scheimpflug imaging is another valuable tool for assessment of corneal thickness and anterior chamber depth. It is based on Scheimpflug principle in which image of oblique objects can be captured with high depth of focus by having film plane, objective plane, and picture plane to intersect in one point **(14).**

Scheimpflug imaging devices can generate a three-dimensional image of the anterior segment by incorporating ultraviolet-free blue light source of 475 nm wavelength and two cameras.

One camera is fixed to monitor fixation for automatic correction of any motion and measure pupil and a second rotating scheimpflug camera to provide up to 50 cross-sectional images on angle from zero to 180^{o} in a single scan, capturing up to 25000 elevation points in two seconds. This system allows imaging from anterior corneal surface to posterior lens surface **(15)**.

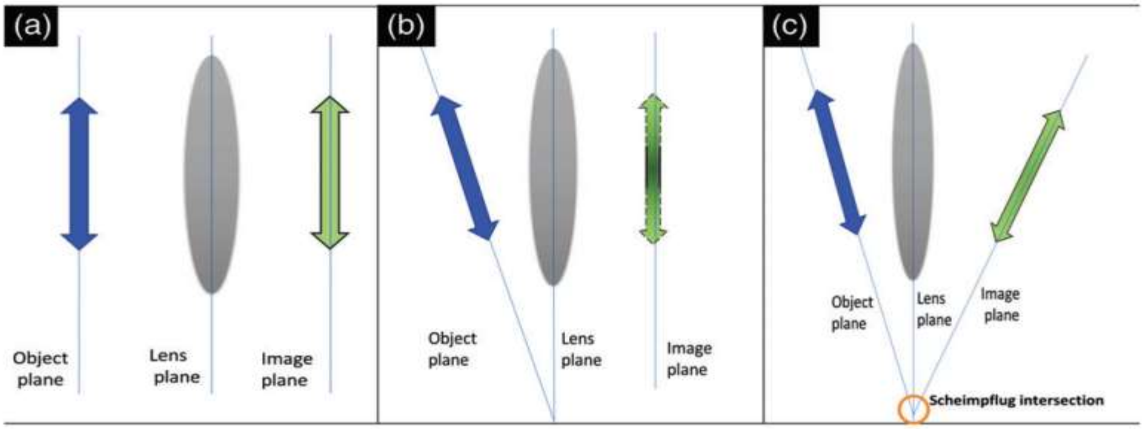


Figure "4" Scheimpflug Principle **(16).**

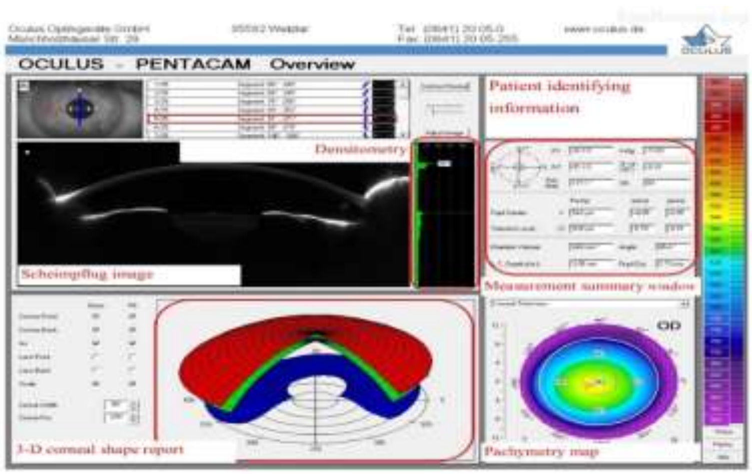


Figure "5" Pentacam Overview **(17).**

Scheimpflug-based machines have a three-dimensional chamber analyzer that helps to assess AC parameters. It can also be helpful to surgeons for accurate implantation of phakic IOL. Lens density can be assessed using these cameras by rather a built-in lens density module or exporting scheimpflug images to image analysis software **(18)**.

<u>PCI Biometer for ACD Assessment</u>

Partial coherence interferometry (PCI) biometers used for IOL power calculation can be used for ACD measurement. While this system uses PCI for axial length measurement as discussed before, ACD is assessed by non-PCI method using slit-beam photographic method in which a light beam passes through anterior segment at 33^{o} to visual axis and ACD is measured automatically using a 33-degree tangent and a constant.

However, ACD measured using PCI biometer incorporates also central corneal thickness, producing longer ACD reading than other devices. But this can be bypassed by taking two measures, one is the automatically measured ACD and the second is the true ACD which is calculated as automatically measured ACD minus Central corneal thickness **(19)**.

Ultrasound bio-microscopy (UBM) for ACD Assessment

UBM is a high-resolution ultrasound device that can be used for photographing details of anterior segment structures. UBM uses high frequencies in the range of 50 – 100 megahertz for high quality and resolution of anterior segment imaging. It can also be involved in imaging ocular adnexa, conjunctiva, and sclera.

Ultrasound waves are generated from the transducer and reflected from tissue of interest after which the signal is amplified depending on the depth from which the wave is reflected that is known as time-gain compensation. Then after signal processing, data is converted to be digital for display on computer screen.

For imaging, Patient is positioned in supine position and eyecup is placed after topical anesthesia to separate eyelids that is later filled with viscous fluid as methylcellulose 1-2.5% or normal saline **(20)**. UBM ultrasound waves have higher frequency with short focal length that are associated with higher resolution up to 30 um axial resolution and 50 um lateral resolution but with low tissue penetration, about 4 – 5 mm depth.

The transducer has a white line that indicates the direction of linear movement of the transducer. There are three types of scan:

1- Radial (Longitudinal) Scan: in which transducer white line perpendicular to the limbus aimed towards the pupil. This can visualize corneoscleral junction, angle, iris, and ciliary body.

2- Transverse Scan: in which transducer white line is parallel to the limbus aimed to upper or nasal direction. This can visualize a section of cornea and iris and the probe need to be moved posteriorly to get more peripheral structures as peripheral iris, ciliary body processes and ora serrata.

3- Axial Scan: in which transducer is placed over the cornea with the white line aimed upper for vertical axial scan or nasal for transverse axial scan. This can visualize anterior segment structures from anterior to posterior and helpful to assess anterior chamber depth.

The anterior chamber on UBM is defined as the echo-free area between the cornea and the iris. So, Central ACD can be measured as the distance between the posterior surface of the cornea to the anterior lens capsule at the center of pupillary plane. ACD also can be measured at any area by a point from corneal endothelial surface to anterior surface of iris or lens that can be helpful to have an anterior chamber profile that may be useful later in different issues **(21)**.

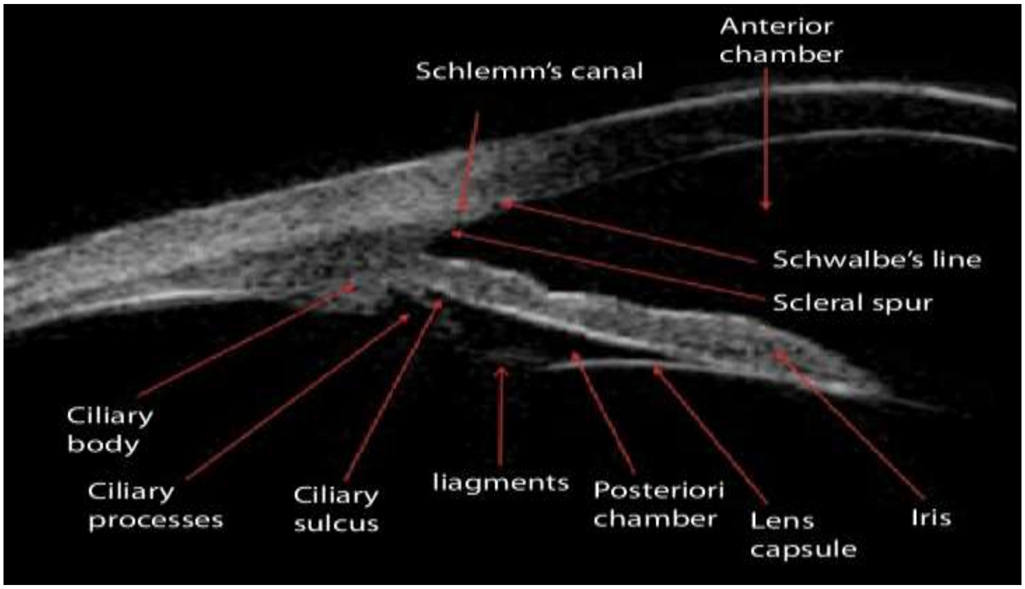


Figure "6" UBM image of anterior chamber angle **(22)**.

<u>Risks regarding phacoemulsification in shallow anterior chamber</u>

Generally, any cataract surgery can be associated with intraoperative complications such as endothelial cell damage and posterior capsular rupture with vitreous loss. Phacoemulsification with shallow anterior chamber carries higher risk of these complications due to narrow area making intraocular structures more liable to surgical damage **(23).**

Intraoperative complications that have high incidence with cataract surgery in shallow anterior chamber are extension of capsulorrhexis, corneal injury causing endothelial loss and descemet's membrane detachment, and positive vitreous pressure with frequent iris prolapses, zonular dialysis, posterior capsular rupture with vitreous prolapse that may deteriorate to suprachoroidal hemorrhage.

Postoperative complications that are more likely to be seen are postoperative increased IOP, choroidal effusion, macular edema, and malignant glaucoma **(24)**.

<u>Specific considerations with intraoperative manipulation</u>

1) Deep-set eye:

These eyes tend to be associated with orbital structure that may render phacoemulsification surgeries more challenging. Eyes are deeply set within orbit with prominent superior orbital rims and associated orbital fat atrophy. A Temporal approach may be used to achieve feasible surgical steps and appropriate eye exposure. Also, Anterior placement of the incisions in the form of clear corneal incisions is more preferable than scleral incisions.

If tolerable by the patient, extension of the neck may be helpful to help for better exposure of the limbal area **(25)**.

2) Volume Reduction:

Intravenous osmotic agents like mannitol could be used before cataract surgery as a method to decrease positive vitreous pressure. Mannitol works by increasing tonicity of plasma to draw water out of vitreous into vascular spaces to be excreted by kidney. Mannitol also has an effect on central osmoreceptors in the hypothalamus that have a lowering effect on aqueous production. Therefore, Mannitol causes vitreous dehydration decreasing positive pressure resulting in increased anterior chamber depth **(26).**

3) Anesthesia & Position:

General anesthesia with endotracheal intubation and paralytics use may cause relaxation of extraocular muscles resulting in reduced vitreous pressure. Also. Inhaled agents include smooth muscle relaxants that help in reduction of orbital volume by reduction of central venous pressure.

Another advantage to general anesthesia in cataract surgeries with shallow anterior chamber is the associated reduction in systolic blood pressure decreasing the risk of suprachoroidal hemorrhage that may occur in such eyes if associated with preoperative elevated IOP.

Reverse Trendelenburg position is preferred due to gravity effect that reduces venous pressure resulting in reduction of orbital and choroidal volume **(27).**

4) Maintaining deep anterior chamber:

Various methods are suitable to achieve comfortable anterior chamber depth for easy intraocular surgery, these methods include:

- Frequent instillation of highly cohesive ophthalmic viscoelastic into anterior chamber. This helps in maintaining acceptable anterior chamber depth and flattening of convex anterior lens surface to facilitate capsulorrhexis and reduce risk of capsulorrhexis radialization.
- Anterior chamber maintainer is fixed at side-port to keep stable depth of anterior chamber.
- Passive needle aspiration of some liquified vitreous using 23 to 26-Gauge needle, but some risk may occur due to possibility of vitreous traction.
- Vitreous tap has been described using the 20-Gauge Vitrectomy system, but this technique requires conjunctival peritomy with suturing of sclerotomy and conjunctiva and there is a risk of vitreous prolapse through the large 20G sclerotomy. Implementation of 23G or 25G system is associated with smaller size of sclerotomies, safer maneuvers and no need for suturing **(28).**

<u>**Limited Vitrectomy for Anterior Segment Surgery**</u>

Vitrectomy is considered to be a valuable tool within the hands of anterior segment surgeons. It is helpful to manage several complications that may be encountered during surgery as:

1) <u>Positive vitreous pressure or malignant glaucoma:</u> anterior vitrectomy using pars plana approach can be effective in such situations. A small amount of vitreous is removed to help

deepening of the anterior chamber rendering anterior surgery more feasible and improves aqueous passage and outflow in cases with malignant glaucoma.

2) Vitreous loss after posterior capsular tear during cataract surgery or after ocular trauma: a common event that may occur during cataract surgery with following increased risk of macular edema, anterior segment inflammation, increased IOP and retinal traction. Sufficient anterior vitrectomy is of great benefit in these cases to reduce the risk of these complications and allow safe completion of surgery with IOL implantation in many cases.

3) Pediatric Cataract: soft nucleus with pediatric cataractous lenses can be easily extracted by vitreous cutter and posterior capsulotomy can be done if needed **(29)**.

In cases of vitreous loss or intended posterior capsulotomy, anterior vitrectomy can be achieved either via anterior limbal approach or pars plana approach. The anterior approach depends on bimanual introduction of irrigation and vitrector through limbal side ports with the aim to remove any vitreous prolapsed into the anterior segment and preserve the vitreous structure as much as possible. Intracameral injection of triamcinolone acetonide is usually used for particulate staining of any prolapsed vitreous in addition to its postoperative anti-inflammatory effect. During Limbal anterior vitrectomy, it is better to introduce the vitrector through a paracentesis port rather than the main corneal wound as main corneal wound will not be completely filled by the vitrector and may cause vitreous flow around it. Also, it is advisable to avoid moving into the vitreous with the vitrector without cutting as vitreous may flow into the port when foot switch position is just at irrigation position and cause vitreous traction. Vitrectomy mode that is used during anterior vitrectomy is better to be irrigation / cutting / aspiration mode to avoid any traction on the vitreous without cutting **(30).**

Anterior vitrectomy should start from farthest point away from site of prolapse with cutting and progressing backward towards the posterior segment to reduce any tractional risks and OVD may be used to push vitreous away from incisional wounds for more feasible removal. A High cutting rate with sufficient irrigation and low vacuum is done to remove vitreous and maintain AC Stability.

If any residual cortex is present and an attempt is made to remove these residuals, this can be easily applied using the vitrector with lowering the cut rate to have some time enough for cortex engagement to the vitrector port to be aspirated. A Pars plana approach is another approach that can be also considered with the advantage of simple accessibility to vitreous at site of prolapse with little risk of vitreoretinal traction. The Vitrector is introduced through a sclerotomy that is made 3.5 mm posterior to the limbus using 20 or 23-Gauge (G) microvitreoretinal (MVR) blade. The cutter should be visualized before starting to cut, posterior to site of capsular defect. The cutter is held at this site for some minutes to allow vitreous to move posteriorly. Pars plana anterior vitrectomy for vitreous prolapse is considered to be completed by noticing stopping of posterior capsular motion and disappearance of triamcinolone-stained particles at the site of vitreous prolapse, then the vitrector can be removed with active cutting till getting out of the eye to avoid any inadvertent traction. The sclerotomy is then sutured and any residual vitreous in the anterior segment is removed using the limbal approach and OVD is applied as needed to prevent recurrent vitreous prolapse **(31)**.

Anterior vitrectomy can also be achieved using co-axial anterior vitrectors in which both irrigation and cutting are both achieved using a single probe. This approach has some disadvantages as irrigation port is near cutting port which may cause turbulent flow and vitreous hydration at the site of capsular tear, which may cause tear enlargement **(32)**.

In cases of positive vitreous pressure, crowded AC or risk of aqueous misdirection, the elevated vitreous pressure can render anterior segment surgery at high risk of complications as posterior capsular tear, frequent iris prolapses and endothelial damage. Dry limited pars plana vitrectomy can be incorporated in such cases to increase working space in these eyes and reduce risk of these complications. This approach can be done using single port 23G sclerotomy with tapping of small amount of vitreous.

Dry limited vitrectomy in crowded eyes can be very helpful to achieve adequate AC depth for anterior segment surgery, more significant reduction of postoperative IOP and lowering the risk of malignant glaucoma **(33)**.

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