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Applied Anatomy of the Eye in Cataract Surgery

– Sérgio Canabrava –

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01

APPLIED ANATOMY OF THE EYE IN CATARACT SURGERY

1. INTRODUCTION

The idea of the chapter is to show essential points in anatomy that the surgeon can apply in cataract surgery. Enjoy it!

2. APPLIED CORNEAL ANATOMY

Here, the critical point for cataract surgery is the endothelium.

Endothelium

The endothelium is composed of a single layer of cuboid cells, intimately adherent to the Descemet's membrane through hemidesmosomes. Its primary function are: a barrier to the aqueous humor, metabolic, maintenance of the corneal deturgescence state, and transparency.

Basal endothelial density at birth (Sherrand, Novakovic, Speedwell, 1987) is around 6000 cells/mm2 and diminishes by 26% in the first year of life. Another loss of ±26% happens in the following years and then it stabilizes. The minimum number of cells to maintain the corneal deturgescence state is unknown. However, corneas with less than 500 cells/mm2 are at risk of developing corneal edema. The increase in cell size (polymegathism) and variance in their shape (polymorphism) correlate to the reduction of the endothelial cells' bility to keep a deturgescence state.

Obs.: *The American Academy of Ophthalmology reports that corneas with density ranging from 500 to 1000 cells/mm^2 display high risk of decompensation at any surgical trauma; those with density between 1000 and 2000 cells/mm^2 have lower risk, but are susceptible to decompensation with time.*

Attention corneal decompensation – Sérgio's Canabrava Recommendations

Polymegathism (larger cells), pleomorphism (variability in size and shape of cells), and dark areas of endothelial cell loss (guttae), < 1.500 cells in dense cataract, < 1.000 cells in normal cataract

Corneal thickness, specular microscopy and endothelial function

The corneal thickness measurement indirectly reflects endothelial function. The average corneal central thickness is around 500µm, and the peripheral is higher, usually around 650-700µm. Due to normal diurnal variation, the cornea is thicker in the morning due to the diminished evaporation of the lacrimal film and the reduction in endothelial metabolic activity. Patients with endothelial injury report blurry vision in the morning, improving throughout the day. An example is a patient with Fuchs syndrome.

A damage to the endothelium can lead to different outcomes, from alterations in size and shape to the loss or irreversible alteration to the cells' cytoskeleton. Stress can be metabolic (hypoxia, hyperglycemia), toxic (drugs, preservatives), mechanic (trauma or surgery), or alterations in pH and osmolarity. Viscoelastic material protects the endothelium against intra-operatory manipulation trauma, pharmacological agents and intracameral flow turbu- lence during cataract surgery.

Specular Microscopy

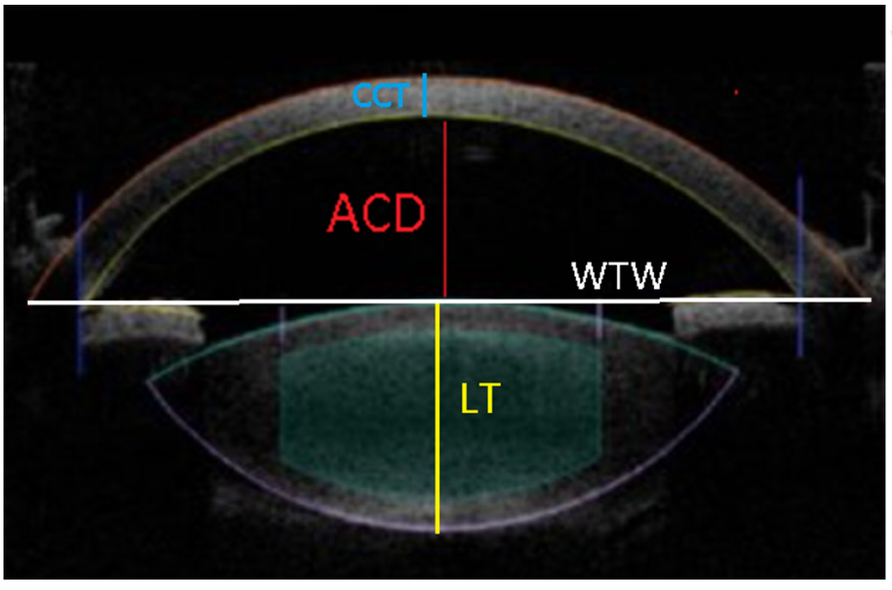
Specular microscopy permits an evaluation of the morphology and density of the endothelial cells. However, if the corneal edema is severe, confocal microscopy might be needed since it allows visualization of corneal layers even in the presence of edema or opacification. During the first month after cataract surgery, the number of endothelial cells diminishes and increases in pleomorphism, since they spread to compensate for the loss of cells during surgery.

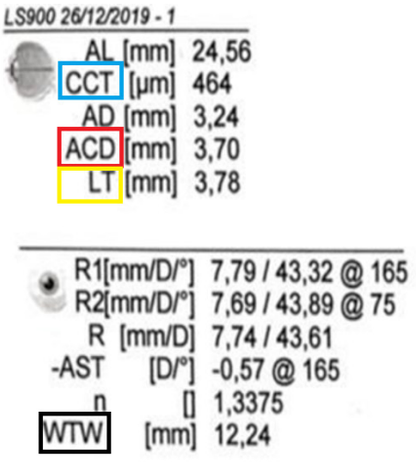
Anatomic considerations on the implant of anterior chamber intraocular lens

The angle-fixated anterior chamber intraocular lens can have its haptics positioned more anteriorly leading to direct contact with peripheral corneal endothelium. It can lead to the death of endothelial cells, which do not multiply. Consequent migration of central cells to the periphery, to maintain endothelial integrity, might cause a reduction in endothelial cell count towards critical levels to the maintenance of endothelial function.

3. APPLIED ANATOMY OF THE ANTERIOR CHAMBER (AC)

Cataract surgery involves the anterior chamber, which is filled by the aqueous humor produced in the ciliary body. The anterior chamber communicates with the posterior chamber through the pupillary opening and accommodates the aqueous humor drainage system. It displays an average depth according to researched references chart below. Depth diminishes 0.01 mm per year, and increases 0.06 mm per increase of myopia diopter. After crystalline lens extraction, the AC deepens to around 4.5 mm.





- **ACD (Anterior Chamber Diameter)** = distance between the corneal endothelium to the anterior lens capsule
- **WTW (White to withe diameter)** = distance between sclera sides
- **LT (Lens thickness)** = Cristallyne diameter
- **CCT (Central Cornea Thickness)** = Cornea thickness

Anterior chamber depth in practice!

According to "Anterior ocular segment study with the Scheimpflug rotational camera in refractive surgery candidates"

Myopia – ACD: 3,19 ± 0,28 mm
Hyperopia – ACD: 2,76 ± 0,38 mm

In practice, the surgeon should be careful with eyes with an AC **shallower than 2.6 or deeper than 3.5.**

Cataract surgery in the deeper anterior chamber or high myopia

- Floppy and large capsular bag and zonular weakness in some cases
- Anterior chamber depth fluctuations
- Lens-iris diaphragm retropulsion syndrome - LIDRS (360 degrees of irido-capsular contact leading to reverse pupillary block, pupil dilation, and pain). We will discuss it on the challenging cases chapter.

Cataract surgery in the shallower anterior chamber or high hyperopia

- Iris prolapses
- Phaco tip near to endothelium producing corneal edema
- Preoperatively administering mannitol may deepen the anterior chamber
- Highly retentive viscoelastic can be advantageous for maintaining space
- In extremely shallow, a small pars plana vitrectomy (PPV) is a great option.
- it can be very difficult to control the capsulorhexis
- increased risk of developing aqueous misdirection postoperatively.

Canabrava's Protocol for ACD

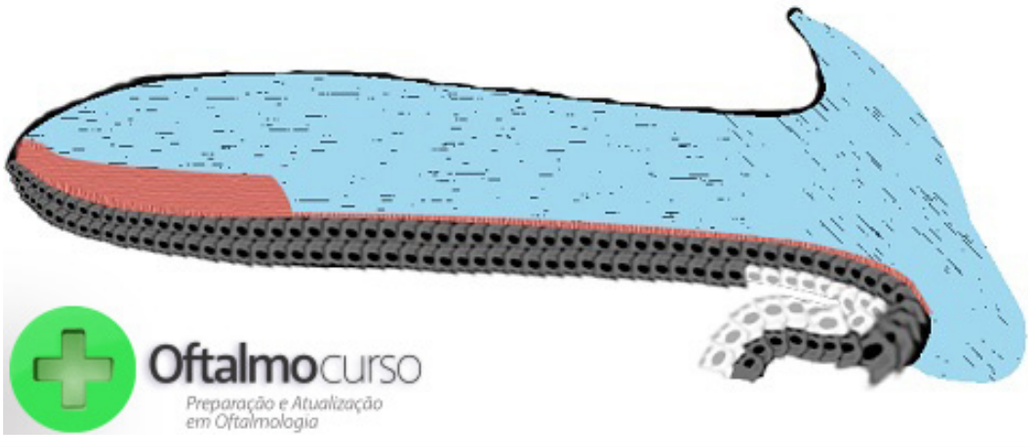
- ACD < 2,5 mm = preoperatively administering mannitol
- ACD > 3,5 mm = Phacoemulsification with BSS bottle between 50 – 70 cmH_2O
- Small pars plana vitrectomy (PPV) = shallow anterior chamber with iris prolapse or not possible to insert the instruments inside de eye

Papers about high myopia

The main issue in high myopia (-15.00 to -30.00 D) is the high incidence of retinal detachment, which is around 8% within 3 years of phacoemulsification in myopic eyes, compared with 0.4% to 1.2% in the general population. Thus, you must be careful during the prolonged postoperative period by performing retinal mapping.

4. THE IRIS

The iris is the most anterior portion of the uveal tract. It is between the two refractive structures of the eye: the cornea and the crystalline lens. It separates the anterior chamber from the posterior one. Its base is intimately connected to the ciliary body, and the iris's root represents the angle recess's beginning. Its diameter is ± 12 mm, and its circumference averages 38 mm. The iris is thicker in the collarette (0.6 mm) and thinner in its root (0.5 mm).



Note that the posterior portion of the iris is composed of its epithelium. When an intraocular lens is positioned in the ciliary sulcus, it can touch this region, causing pigmentary dispersion or uveitis. This dispersed pigment can obstruct the camerular sinus causing glaucoma.

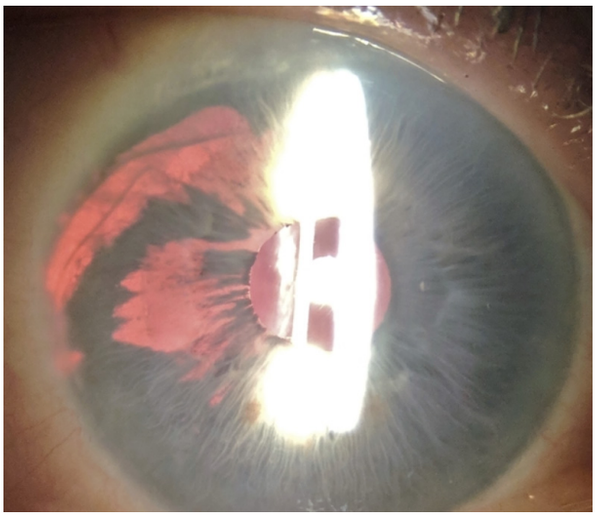
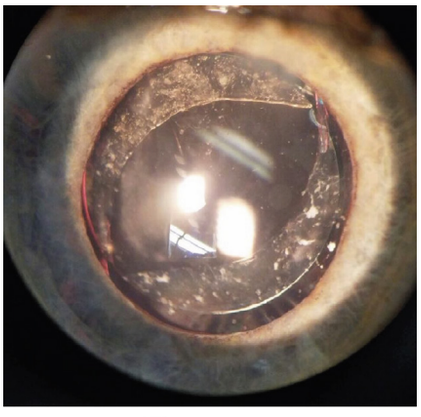
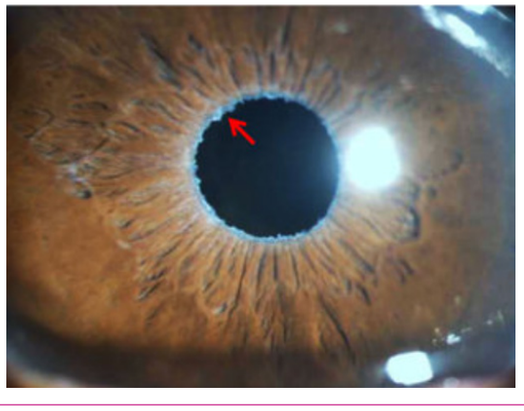


Image from Retina Bank. Never implant a one-piece lens in the ciliary sulcus. It may cause Pigment Dispersion Syndrome like in this image because the posterior portion of the iris is composed of its epithelium



3-piece IOLs are recommended for implant in case of posterior capsule rupture with preservation of support (capsulorhexis integrates). In such cases, the optical zone must be captured in the capsulorhexis, keeping the haptics in the ciliary sulcus. It avoids the optic zone touch in the posterior iris endothelium.

Pseudoexfoliation syndrome and the iris



If you observe fibrillar white flaky deposits on the pupillary border in a patient with pseudoexfoliation syndrome you will need an iris hook or an iris expander ring. These patients have poor pupillary dilation.

5. APPLIED ANATOMY OF THE CRYSTALLINE LENS

Surgically, the crystalline lens can be divided into four zones with different characteristics: the **capsular bag, the superficial cortex, the epinucleus and the nucleus**.

The capsular bag

The capsular bag receives the insertion of the zonular fibers in its periphery (anterior and posterior) and the equator, being cleared in the central area (6-6.5mm).

That's why a capsulorhexis longer than 6-6.5mm tends to run to the zonula and escape peripherally

The capsule is thicker in its anterior pole (15.5 µm) than its posterior pole (2.8-4.0 µm) or the equator (Finchman, 1937). Along aging, the anterior thickness grows, and, in the posterior pole, there is slight variation (Fisher, 1969).

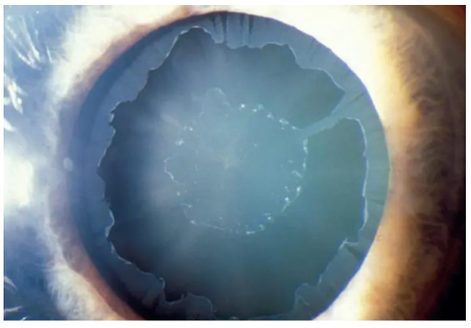
Due to its high elasticity, it can distend up to 1.66 times before rupturing.
Obs: That is why, many times, the surgeon might perform some movements that distend the capsule such as the insertion of IOLs while not rupturing the capsule.

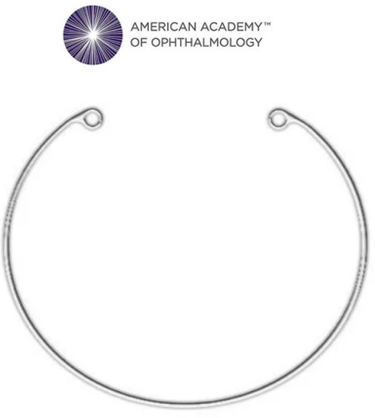
The **equatorial diameter** of the crystalline lens ranges from 5 to 6.5mm at birth and 9-10mm by the 2nd decade of life, varying little in size after this age. It is essential to decide the Capsular Tension Ring Size in patients with disinsertion zonule. But we can use a simple rule to estimate which CTR insert in the bag.

Axial length x CTR

Axial length	CTR size
< 24 mm	12 – 10 mm
24 – 28 mm	13 – 11 mm
> 28 mm	14 – 12 mm
* Note that the CTR boxes show 2 numbers. For example, 12 - 10 mm. The 12 mm represents the size of the CTR outside the capsular bag and the 10 mm is the size inside the capsular bag.	

Pseudoexfoliation Syndrome and the capsular bag





If you observe fibrillar white flaky deposits on the anterior lens capsule you need to think in pseudoexfoliation syndrome and zonular dialysis and phacodonesis because the fibrillar material deposits in the zonular.

Sérgio's Canabrava Protocol: Always insert Capsular Tension Ring (CTR)

Crystalline lens epithelium

Crystalline lens epithelium is formed by a single layer of cuboid cells distributed at the anterior side of the crystalline lens (under the capsule) and directed towards the equator. There are around ± 500.000 cells in a mature crystalline lens (Young, 1991) with a central density of 5000/mm^2 in men and 5781/mm^2 in women (Gugenmoos-Holzmann *et. al.*, 1989) increasing as we move towards the periphery.

The critical point to discuss here is that these cells are responsible for causing posterior capsule opacification and capsular contraction syndrome. Some references recommend polishing the anterior capsule while others do not.

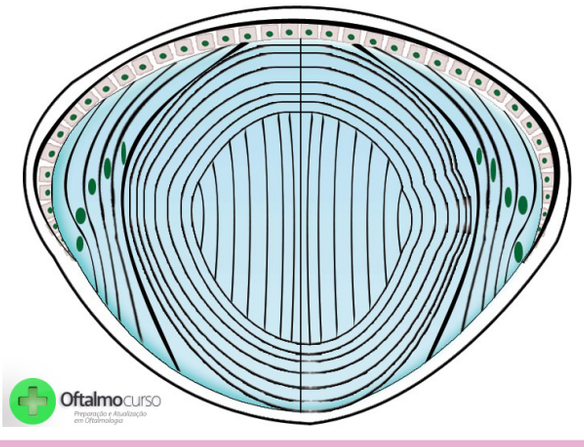


Image illustrating how the anterior surface of the crystalline lens is less convex than the posterior one. Also, observe the anterior cuboid epithelium only under the anterior capsule as well as the formation of the crystalline fibers from the equatorial region.

The cortex

The cortex is a thin, soft layer, immediately underneath the capsule and enveloping the epinucleus. It consists of secondary fibers continuously formed after sexual maturation. It is easily aspirated from the capsular bag during cataract surgery. Practically, it is what the surgeon aspirates with the I/A (irrigation/aspiration).

The epinucleus

The epinucleus is a crystalline lens layer that envelops the nucleus. It is hard to aspirate during cataract surgery, demanding a larger cannula for this step. It can be more easily handled with the tip of the phacoemulsifier.

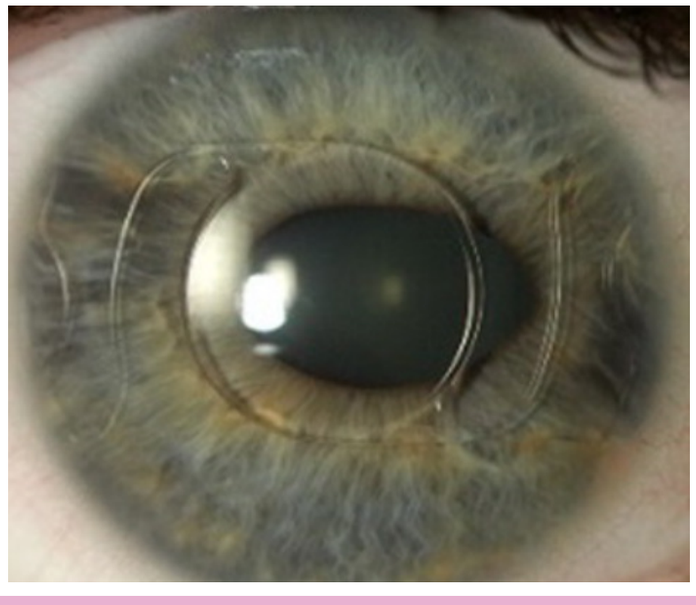
6. APPLIED ANATOMY OF THE SCLERA

For surgical practice, it is necessary to know that the **long posterior ciliary arteries are located on the 180º axis (3 and 6 o'clock) of the sclera** and, therefore, it is important to avoid such region in cases of scleral fixation.

Another relevant point concerns the sclera of **highly myopic** patients and patients with **Marfan syndrome**. In general, these patients have a thinner sclera, which can produce a more hypotonic eye during surgery. Thus, these are patients for that we do not recommend undergoing surgery at the beginning of the surgeon's learning curve.

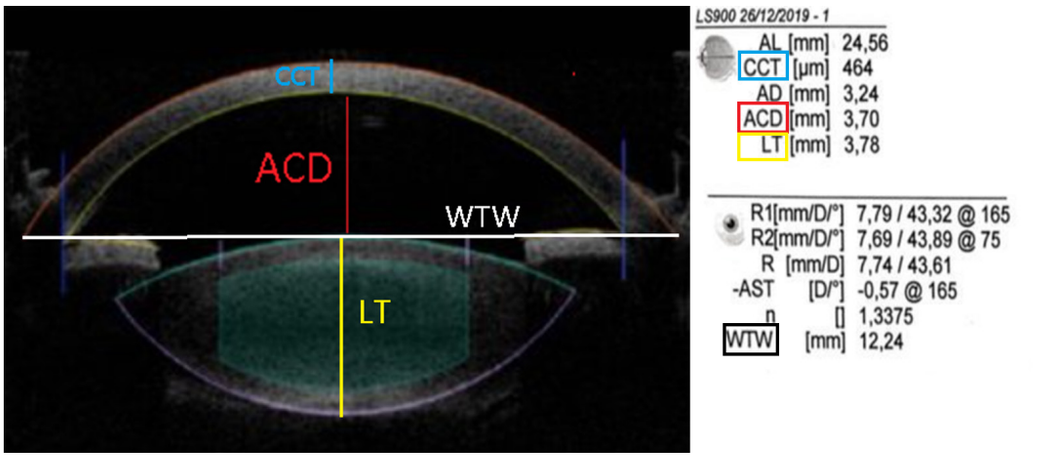
The **white-white diameter** of the sclera is essential in two points:

1- For insertion of Open Loop anterior chamber IOL for aphakia. If the IOL is too large, it may extrude from the eye, or if it is too small, it may rotate in the anterior chamber.



Open Loop IOL implanted

2. For the insertion of iris expander rings. As most rings have an internal diameter of 6.3 to 6.5 mm and an external diameter of between 9 to 9.5 mm, insertion is complicated in eyes with

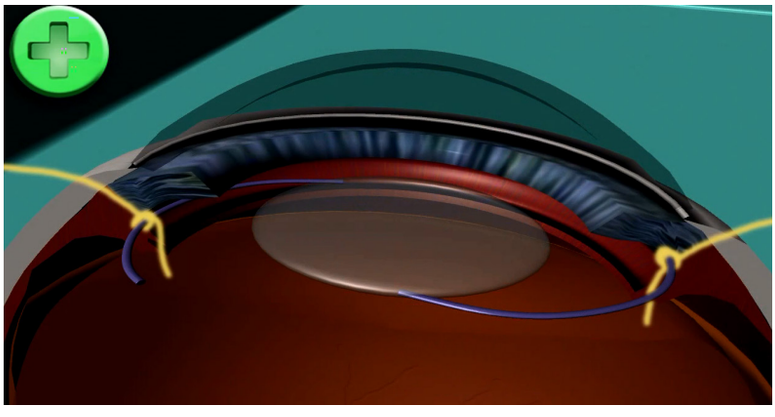


Withe-Withe diameter measure by lenstar.

7. APPLIED ANATOMY OF THE POSTERIOR CHAMBER

Single Piece Foldable Intraocular lens implanted in the sulcus has the setback of the direct contact between the implant and the uveal tract, which can lead to complications such as erosion and chronic inflammation. Pigmentary dispersion and glaucoma might also occur if the contact is between the posterior portion of the iris and the haptics of the lens.

Scleral fixation might be required if there is no posterior and anterior capsular support, and the IOL haptics ideally should be located in the ciliary sulcus. It is wise to avoid suturing the fixation in the vertical and horizontal axis since the long posterior ciliary arteries and the nerves penetrate the ciliary body at 3 and 9 o'clock and the anterior ciliary arteries at 3, 6, 9, and 12 o'clock. **Hence, the fixation is safer when the needles pass approximately 1.5 to 2.0 mm posterior to the surgical limbus in the oblique meridians. It is also recommended to reduce the power of the IOL by 0.5 dp.**



Illustrative image of the location of the IOL in the ciliary sulcus after scleral fixation.

8. THE VITREOUS BODY

The vitreous humor is a gel that fills 4/5 of the ocular globe. It is posteriorly in contact with the retina and, anteriorly with the ciliary body, the zonula and the crystalline lens. During aging, the structure of the vitreous body modifies with the progressive diminishing of the density in the central area while keeping the high density in the periphery.

The patellar fossa accommodates the crystalline lens and separates itself from the vitreous body in Berger's space. In its margins, the vitreous body adheres to the crystalline lens' posterior bag through a ring-shaped area of around 8-9 mm diameter: the hyaloideocapsular ligament of Wieger, which also receives the insertion of the hyaloidal portion of the zonule. This adhesion is strong in young adults. However, it diminishes with age, especially after the 6th decade of living.

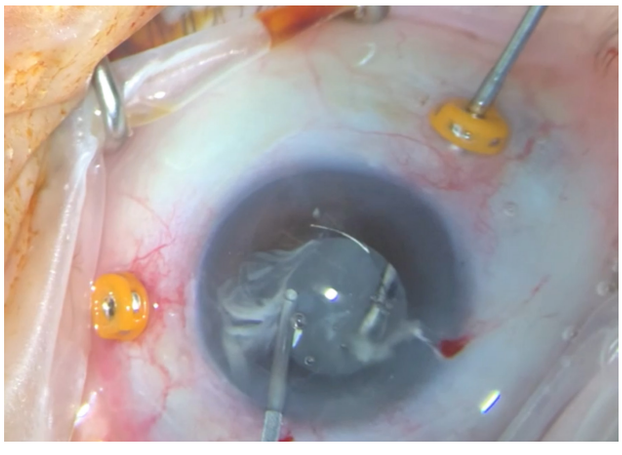
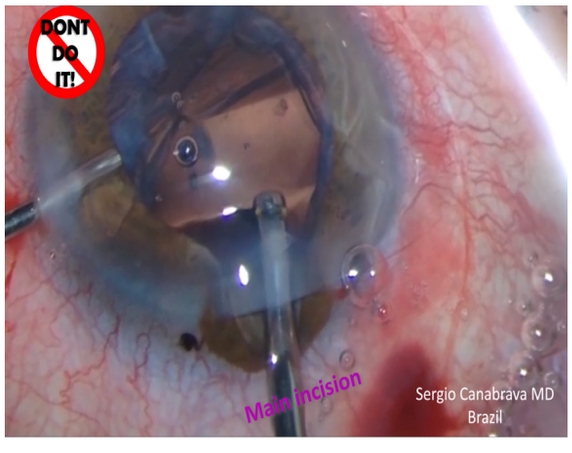
The Cloquet's hyaloid canal, 1-2 mm wide, runs from the posterior portion of the Berger's space, through a tortuous course, to the Marte- giani area in front of the optic disc. This canal represents the site of the primary vitreous body, and a condensation of the vitreous humor forms the fetal hyaloid artery and its walls.

Post-surgical vitreous alterations

Eye floaters are a frequent clinical symptom after cataract surgery, mainly due to alterations in the physicochemical properties of the vitreous body, which leads to synchysis (liquefaction), collapse (syneresis) and a partial or total displacement of the vitreous body from the retina. Hence, this information must be disclosed to the patient before the surgical procedure.

Applied anatomy of the vitreous

You may use triamcinolone acetate to identify any remaining prolapsed vitreous. Thus visualizing the endpoint of removal allows incisions to seal and avoids postoperative traction.

Correct approach	Wrong aproach
	
A pars plana incision technique 3.5 mm back from the limbus is well worth learning. A pars plana vitrectomy is the most effective method for amputating any vitreous that has exited the incision at the pupillary margin. This technique obviates the need to create traction with Weck-Cel sponges or by sweeping the incision while vitreous is present, which causes intraoperative traction.	The approach to the pars plana could cause intraoperative traction