Z. Makhacheva

A NEW PERSPECTIVE ON THE ANATOMY OF THE VITREOUS BODY

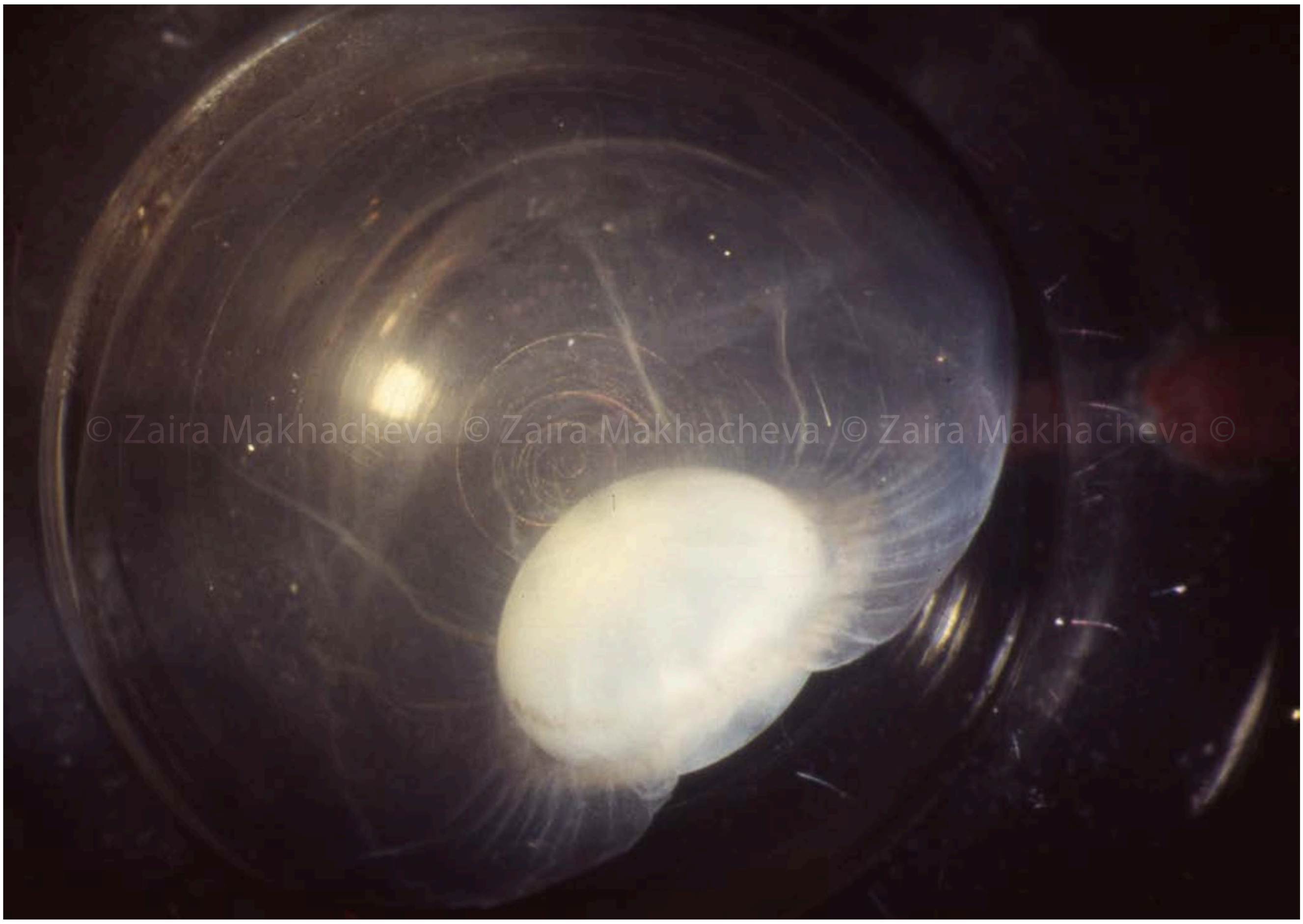
BACKGROUND

The unfixed vitreous body (VB) appears to be a transparent and structureless viscoelastic media of the eye. The use of various techniques on autopsy eyes, such as biomicroscopy (*G. Eisner*) and injection of coloured inks into the vitreous body (*J. Worst*) have made it possible to observe its complex structure, which could reveal its previously unknown functions.

By injecting dyes into both unfixed and formalin-fixed specimens *J. Worst* (1977) discovered and described pouch-like entities, which he named "cisterns". He classified cisterns into three groups in the antero-posterior direction: circulus cisternalis retrociliaris, circulus cisternalis equatorialis, and circulus cisternalis petaliformis.

The bursa premacularis was first described by *J. Worst* in 1975 as a pear-like pouch located in front of the macular area.

The cisterna preoptica is a small pouch located in front of the optic nerve head, in the area previously referred to as the prepapillary area of *Martegiani* (1814).



PREPARATION & EXAMINATION TECHNIQUES

The autopsy globes and the vitreous body specimens remain submerged in water during the entire process of preparation. A specimen holder made of polymethyl methacrylate (PMMA) is used for support.

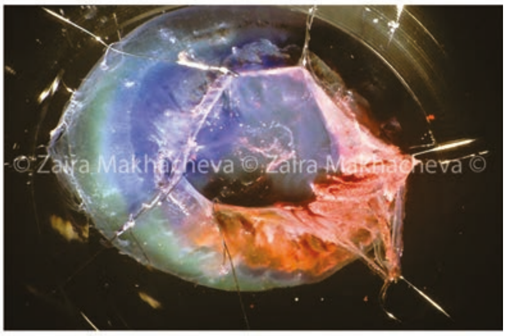
FLOWER technique (developed and named by *Z. Makhacheva*)

After marking the sclera to indicate the upper-lower and temporal-nasal segments of the autopsy eye, the sclera is cut with scissors between the four rectus muscles, stopping before the macular area and the optic nerve head. The resulting four petals are turned outwards and secured with stainless steel surgical thread to the PMMA specimen holder. The choroid and retina are also cut to form four petals.

WINDOW technique (developed and named by *Z. Makhacheva*)

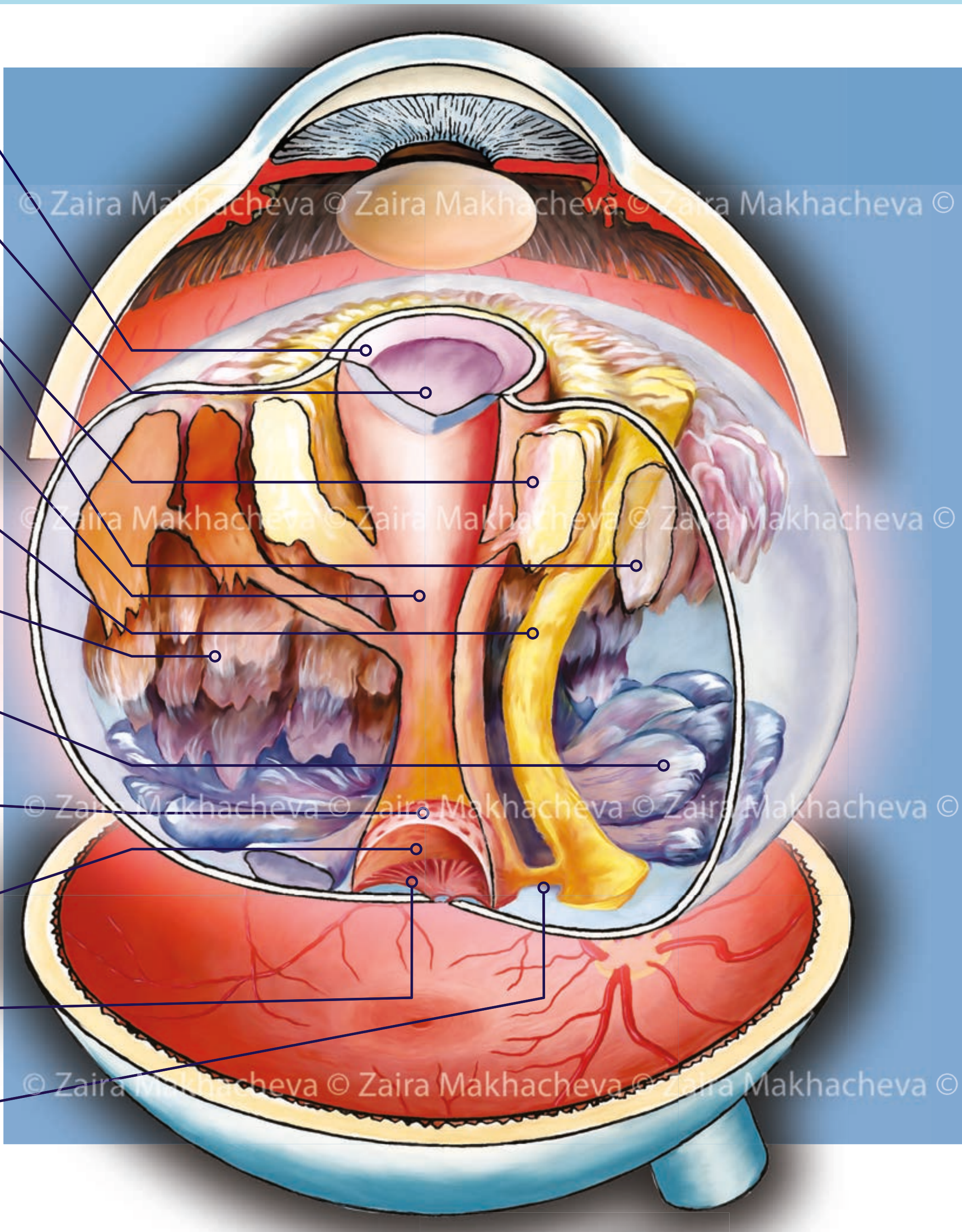
After marking the sclera to indicate the upper-lower and temporal-nasal segments of the autopsy eye, two longitudinal cuts are performed with scissors through the middle of the internal and lower rectus muscles; the macular area and the optic nerve head are spared. The longitudinal cuts are smoothly connected and the "window" comprising the lower-nasal segment of the sclera is removed. The underlying choroid and retina are excised in the shape of the scleral window.

TRAMPOLINE technique (developed and named by *J. Worst*)



This technique is used to examine the internal structure of the VB specimens, and more precisely the posterior and anterior vitreous. The vitreous specimen is hemmed with stainless steel surgical thread to an additional PMMA ring, which is mounted on the PMMA specimen holder. The PMMA ring can be detached and the specimen can be examined from both sides. The anterior approach, in which the dissection of the vitreous specimen is performed in the antero-posterior direction allows the examination of the bursa premacularis and prepapillary area in their integrity. The posterior approach, in which the dissection is conducted in the opposite direction allows for thorough examination of the anterior portions of the vitreous.

MODEL OF THE VITREOUS BODY ANATOMY
as to *Z. Makhacheva*



ligamentum hyaloideo-capsulare
Wieger (1883)

spatium retrolentalis
Berger (1887)

circulus cisternalis retrociliaris
Worst (1977)

canalis lentico-macularis
Makhacheva (1993)

canalis optico-ciliaris
Makhacheva (1993)

circulus cicternalis equatorialis
Worst (1977)

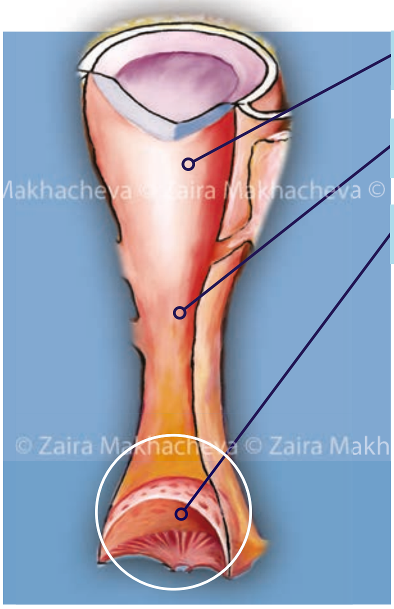
circulus cisternalis petaliformis
Worst (1977)

membrana cribrosa
Makhacheva (1993)

bursa premacularis
Worst (1975)

stratum spongiosum
Makhacheva (1993)

canaliculus communicans
Makhacheva (1993)



pars lenticularis

pars intermedia

pars macularis

pars ciliaris

pars intermedia

pars papillaris

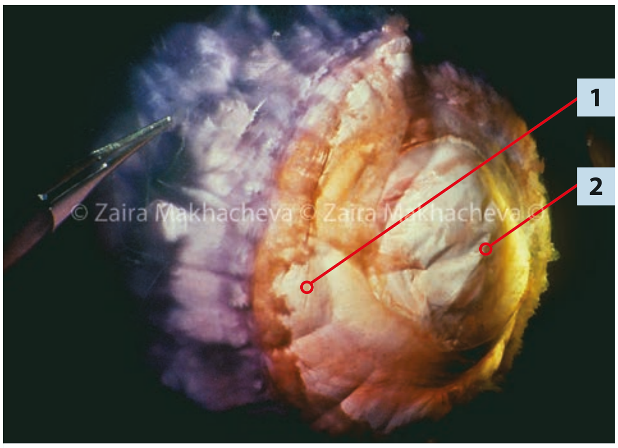
The following sections are based on my own studies in the Jan Worst Research Group in the Netherlands in 1993.

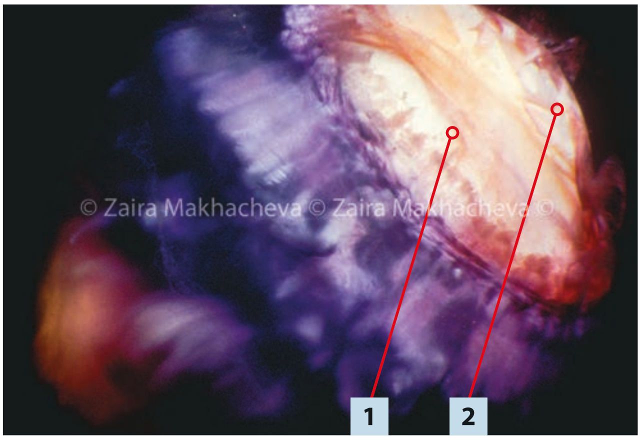
CISTERNAL SYSTEMS

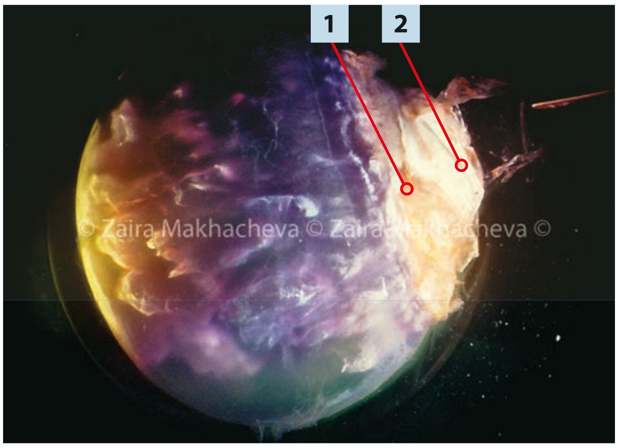
Retrociliary cisterns look like cylindrical pouches and communicate with one another. They form a ring in the projection of the ciliary body. When dye is injected, they gradually fill, acquiring the shape of a doughnut.

On the periphery, the ring of the retrociliary cisterns is attached to a dense matter, which constitutes the outer, solid part of the vitreous body. The retrociliary cisterns in their ring shape lie on the somewhat concave surface of this solid supporting substance. Equatorial and petaliform cisterns are embedded within the solid matter and surround the central VB cone, which incorporates the VB canals.

Dissecting the VB with the trampoline technique, one can see the systems of cisterns arranged in tiers relative to the central axis, and thus one can reach the posterior pole of the VB, which represents the most important formations in both anatomical and functional terms: the bursa premacularis and cisterna preoptica. These formations are surrounded by a dense matter that is usually referred to as the VB cortex. From the outside, the bursa premacularis and the cisterna preoptica themselves are covered with a thin layer of the posterior hyaloid membrane.

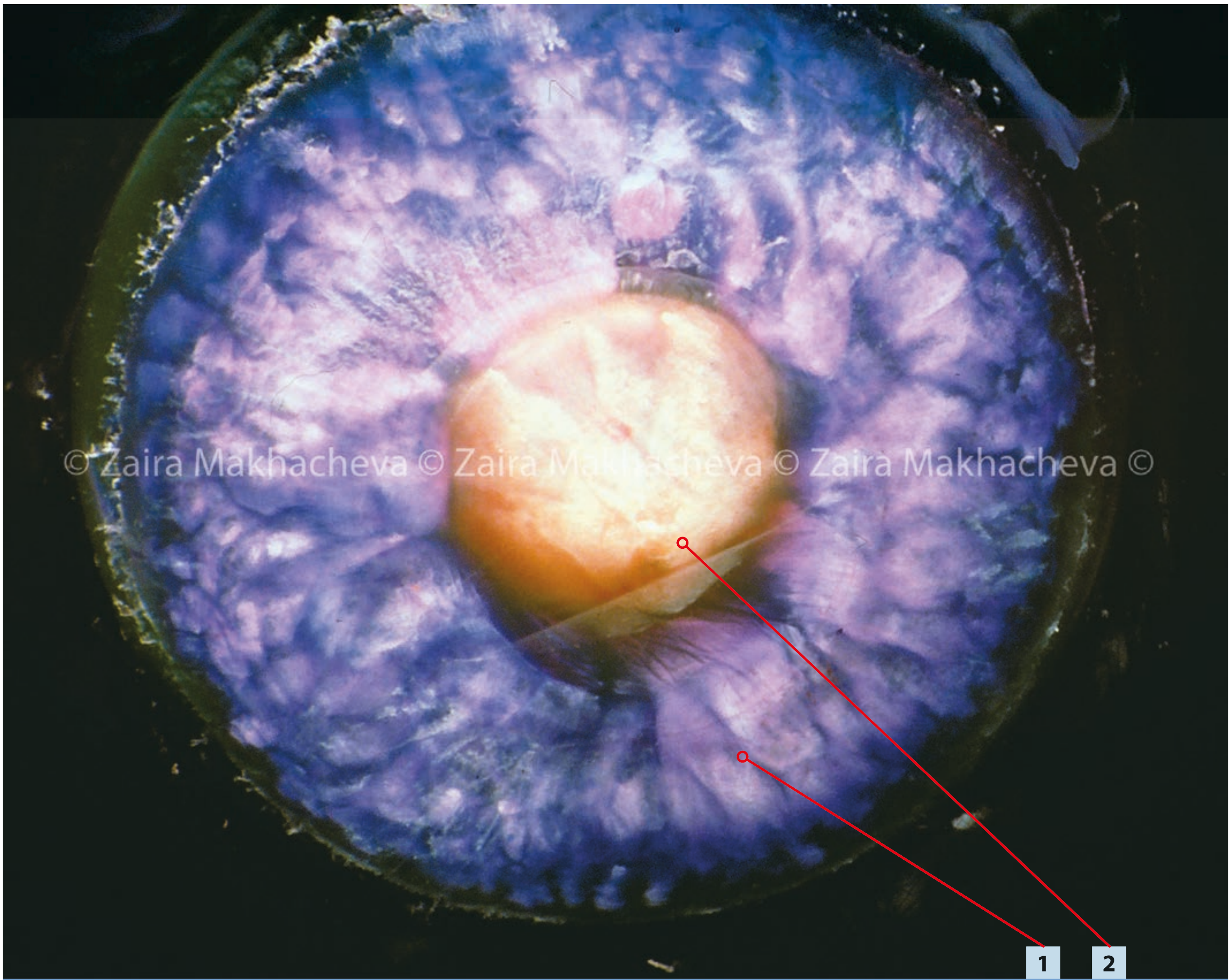






1. circulus cisternalis retrociliaris

2. pars lenticularis canalis lentico-macularis



1. circulus cisternalis retrociliaris

2. pars lenticularis canalis lentico-macularis

The structural anatomical differences of the two constituent components of the VB, i.e. the cisterns with the canals and the dense vitreous casing enclosing them, can be demonstrated in semi-macroscopical studies by a blunt separation of the retrociliary ring of the cisterns from the solid base they lie on.

In the very center of the ring of the retrociliary cisterns, is the lenticular part (pars lenticularis) of the lentico-macular canal, first described and named by *Z. Makhacheva* in 1993 as canalis lentico-macularis.

There is a **spatium retrolentalis *Berger*** (1887) between the posterior capsule of the lens and the anterior vitreous. It is outlined on the periphery by the **ligamentum hyaloideo-capsulare *Wieger*** (1883). In this space, lies the opening of the central canal of the vitreous body.

Thus, the vitreous body looks like a ball with truncated surfaces. The anterior surface has a larger diameter of the truncated area and a somewhat concave shape; retrociliary cisterns are situated upon it. In the very center of the anterior surface, surrounded by a ring of retrociliary cisterns, there is a central cone that contains the VB canals. Equatorial and petaliform cisterns surrounding the central cone are embedded in the thick cortical casing. I noted a consistent asymmetry in the distribution of cisterns: there are much more of them on the temporal side than on the nasal side. At the posterior pole, the cortical substance becomes thinner and is practically absent in the area of the bursa premacularis and the prepapillary part of the optico-ciliary canal.

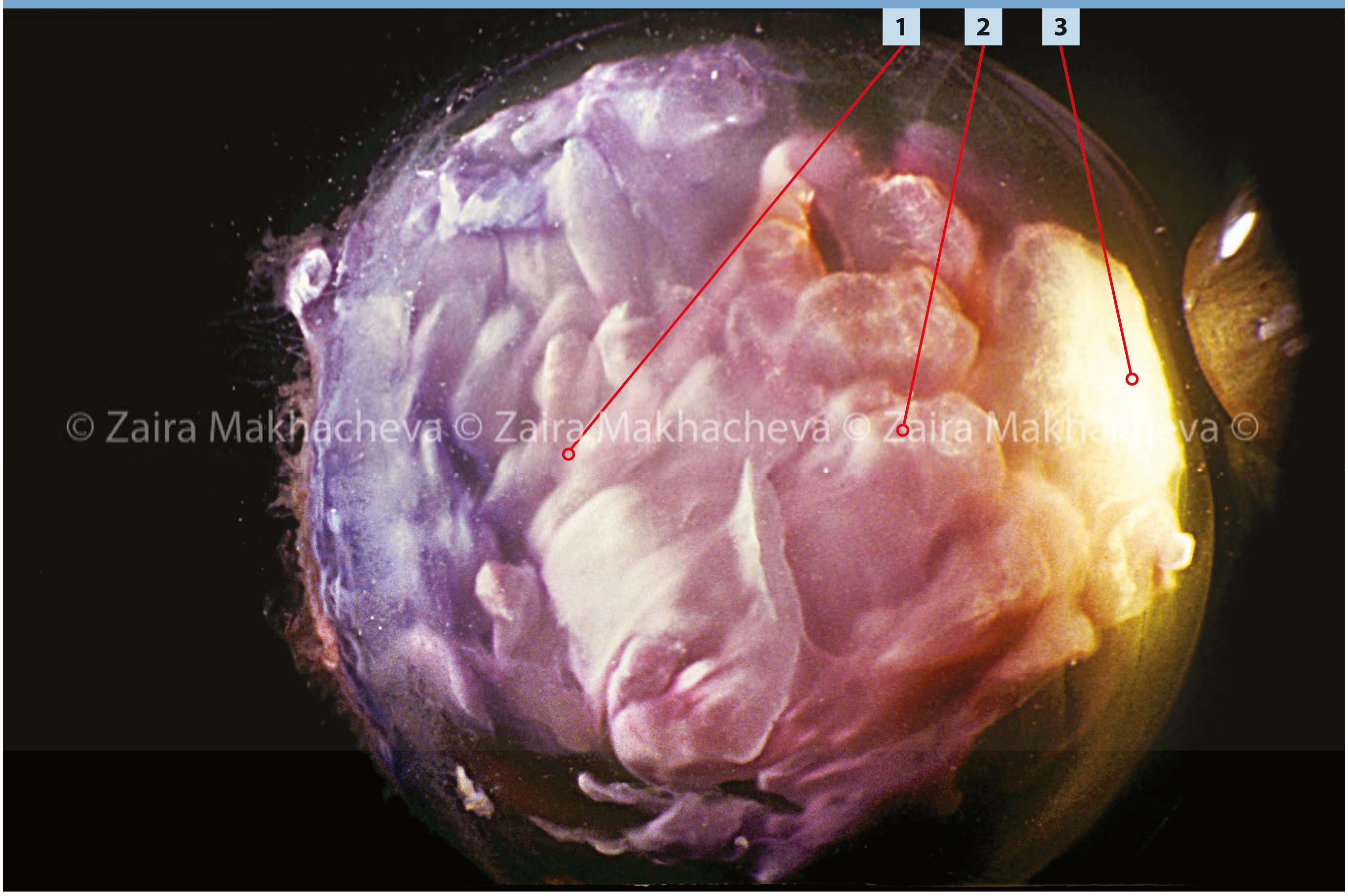
The bursa premacularis, which constitutes the pars macularis of the canalis lentico-macularis *Makhacheva*, looks like a horizontal oval from the perspective of the retina, the average size of which is 6 mm x 5 mm.

When viewed from the retina, the pars papillaris of the canalis optico-ciliaris *Makhacheva* has the shape of a vertical oval, the dimensions of which are 3 mm x 4 mm. The walls of the pars papillaris are attached to the optic nerve head along its edges.

1. circulus cisternalis equatorialis

2. circulus cisternalis petaliformis

3. pars macularis canalis lentico-macularis

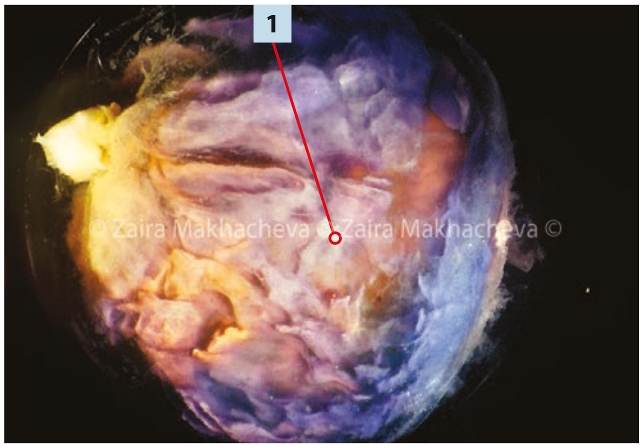


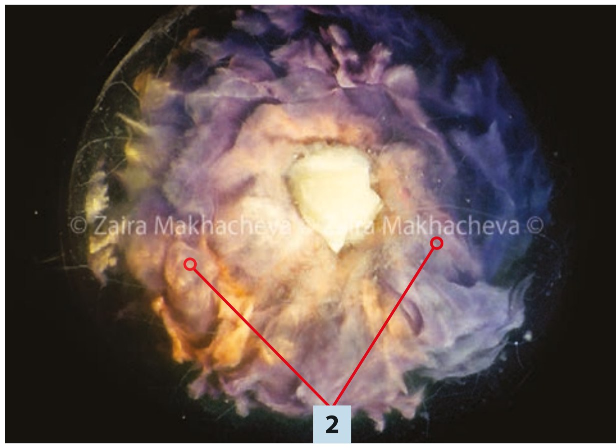
In my opinion, the name ‘prepapillary space’ is more accurate than ‘cisterna preoptica’, since it is not a separate entity like the bursa premacularis, but only a local expansion of the canal.

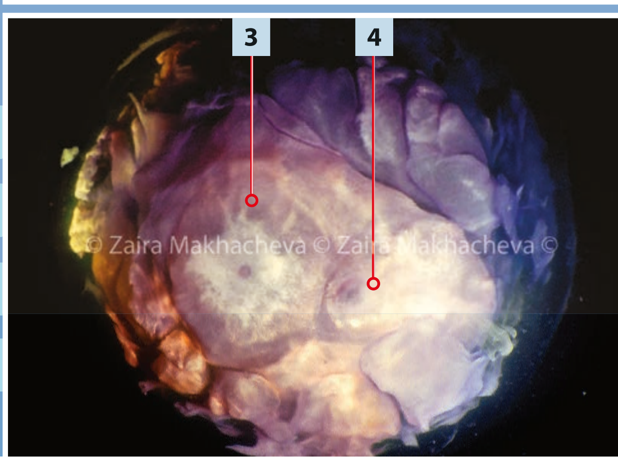
The prepapillary space is separated from the optic nerve head by a thin membrane, in which there are openings for the passage of the retinal vessels. It is possible that these openings serve as the intravitreal fluid outflow channels into the perivascular spaces of the optic nerve.

There is a **canaliculus communicans *Makhacheva*** between the bursa premacularis and the prepapillary part of the canalis optico-ciliaris *Makhacheva*.

This anatomical connection between the prepapillary space and the bursa premacularis indicates their functional interaction and explains the involvement of both the macular area and the optic nerve, which is observed in clinical practice.







1. circulus cisternalis equatorialis

2. circulus cisternalis petaliformis

3. pars macularis canalis lentico-macularis

4. pars papillaris canalis optico-ciliaris

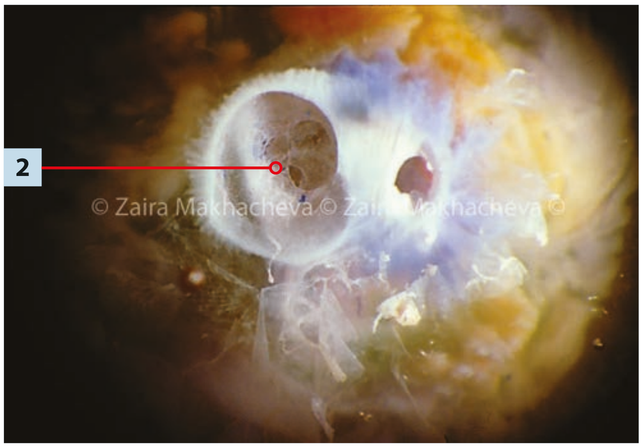
BURSA PREMACULARIS

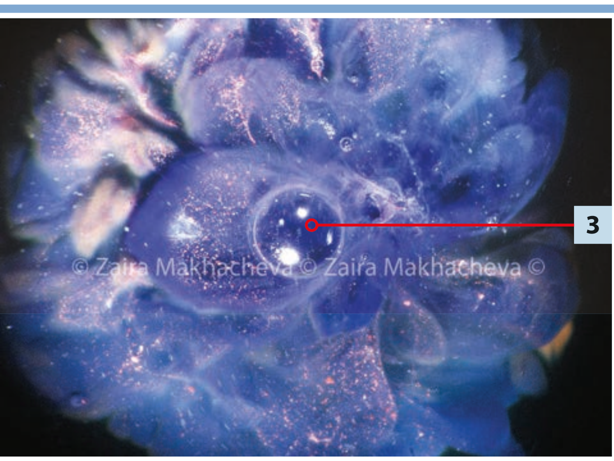
The bursa premacularis is a closed cup-shaped pouch. In this area, the vitreous cortex is thinning and is practically absent in the region corresponding to the central fovea. This explains the extreme vulnerability of the perifoveal part of the vitreous body, the damage of which causes the prolapse of the internal vitreal structures.

I was the first to discover that the bursa premacularis has an anterior wall, which is an intravitreal membrane with numerous holes, giving it a sieve-like appearance. I named this new anatomical structure **membrana cribrosa *Makhacheva*.**

The posterior wall of the bursa premacularis is formed by a thin membrane, which has a spongy layer on the vitreal side (**stratum spongiosum *Makhacheva***). There is no such layer in the central part of the posterior wall corresponding to the fovea of the retina. The spongy substance is easily removed from the surface of the posterior wall of the bursa premacularis via a transvitreal approach.

The posterior wall of the bursa premacularis is connected to the internal limiting membrane (ILM) by a circular hyaloideo-macular ligament (*J. Worst*), similar to the ligamentum hyaloideo-capsulare *Wieger*. Similar to the retrolental space, there is a slit-like subbursal space between the posterior wall of the bursa premacularis and the retina. The subbursal space is filled with transparent fluid.

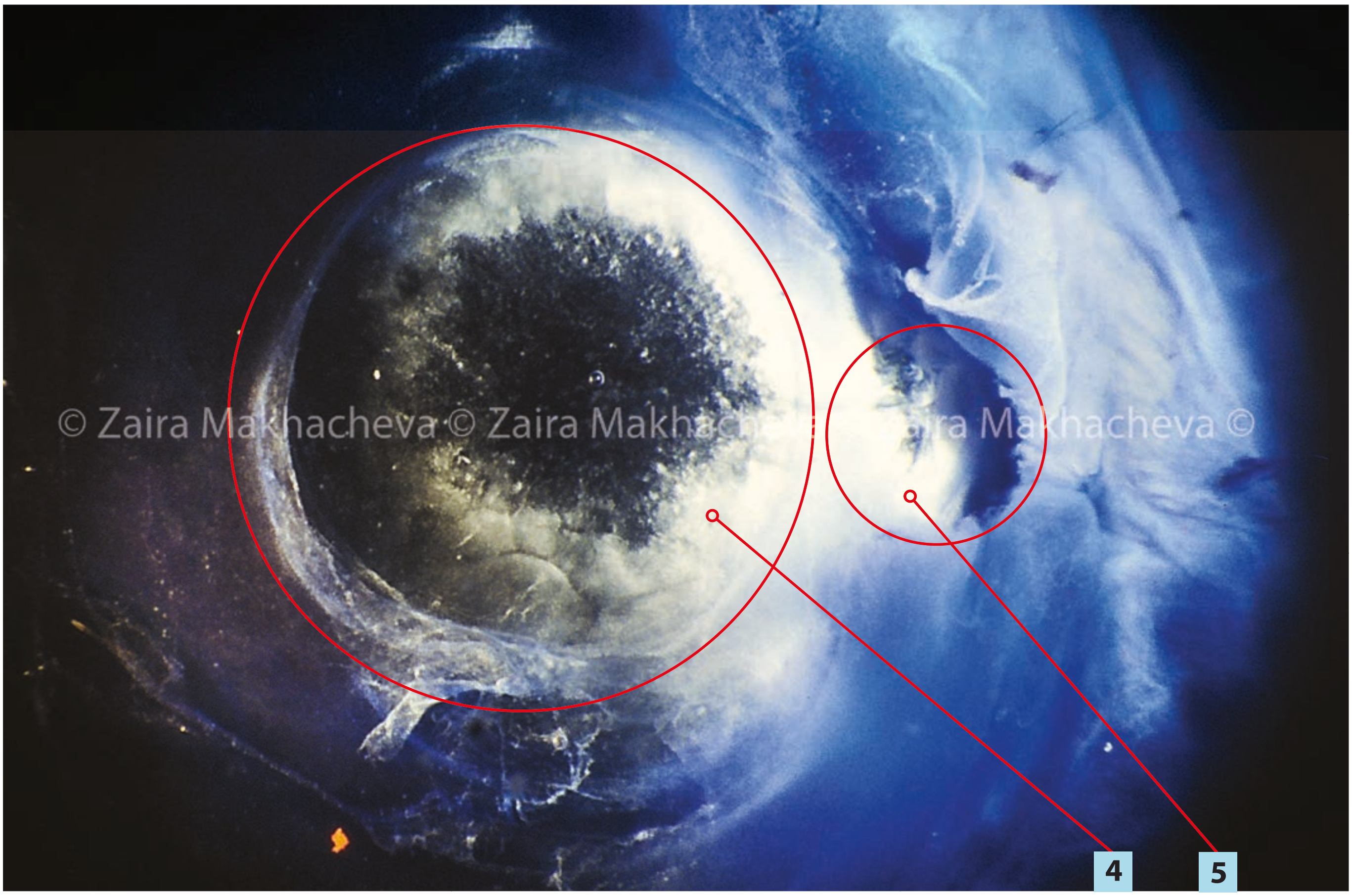




1. stratum spongiosum bursae premacularis

2. membrana cribrosa bursae premacularis

3. air bubble in the bursa premacularis



4. pars macularis canalis lentico-macularis

5. pars papillaris canalis optico-ciliaris

6. leakage of the dye from #4 and #5 respectively

CANALS

The bursa premacularis and the prepapillary space are connected to the anterior parts of the vitreous body by means of canals.

I came to the conclusion, based on my research, that the central canal (so called canalis *Cloquet*) connects the retrolental space directly to the bursa premacularis, and not to the optic nerve disc, as is commonly believed (*Duke-Elder,* 1961).

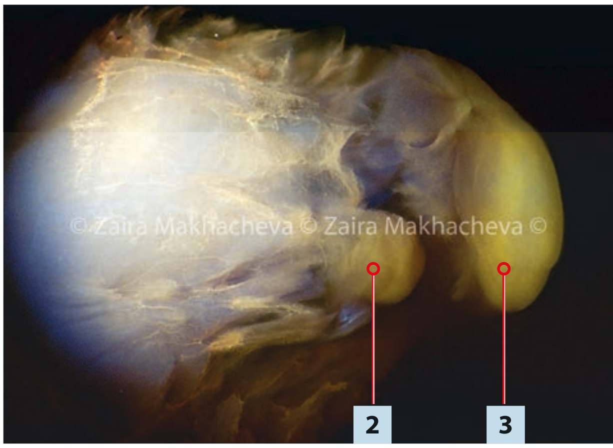
The dye from the central canal gets into the bursa premacularis and then reaches the prepapillary space through the canaliculus communicans *Makhacheva.* The latter connects the two canal systems of the vitreous body. Along with the central canal, which more accurately should be called the **canalis lentico-macularis *Makhacheva***, there is another canal connecting the prepapillary space with the retrociliary cisterns, presumably in the upper-nasal segment. I named this canal: **canalis optico-ciliaris *Makhacheva*.**

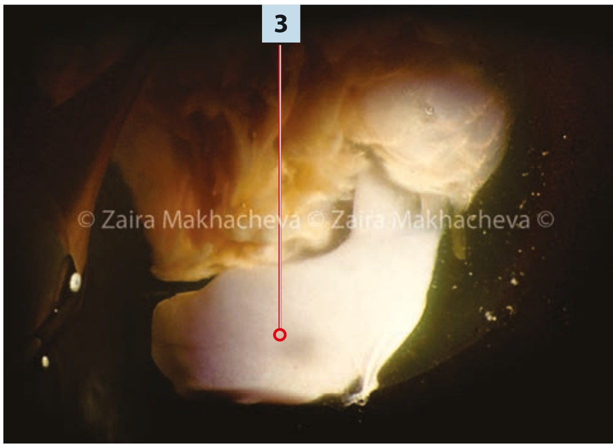
Canalis lentico-macularis:

1. pars lenticularis

2. pars intermedia

3. pars macularis





Canalis lentico-macularis:

1. pars lenticularis

2. pars intermedia

3. pars macularis

Canalis lentico-macularis is connected to the branched system of cisterns that surround it, and reminds me of a tree with abundant foliage. Anastomoses of the canalis optico-ciliaris are not as extensive and are limited to a small area of the retrociliary cisterns near the orifice of the canal.

I hypothesize that the intravitreal canals play a role in the transport and exchange of nutrients and by-products by directing the flow of the liquids, as well as in maintaining the metabolic and hydrodynamic balance between the anterior and posterior segments of the eye.

The existence of a canal connecting the retrociliary cisterns with the prepapillary space can elucidate the pathogenesis of glaucoma.

The direct connection between the retrolental area and the bursa premacularis explains the occurrence of complicated cataracts in involutional and inflammatory macular conditions, as well as the complications in the posterior pole of the eye after lens removal and glaucoma surgery.

I identified thin tubular structures on the inner walls of the central canal and on the anterior surface of the retrociliary cisterns. I speculate that they might play a role in the circulation of vitreous fluids. Further studies using SEM and transmission electron microscopy are necessary.

The central and optico-ciliary canals are characterized not only by anatomical autonomy, but also by biochemical specificity.

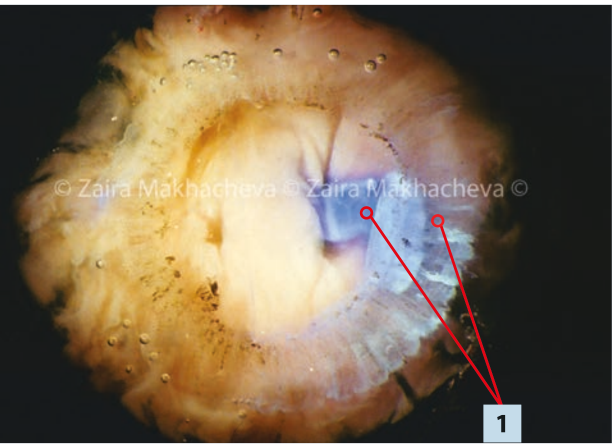
I observed something peculiar while performing a dissection on an autopsy eye of a female who died from a massive subarachnoid hemorrhage (Terson syndrome).

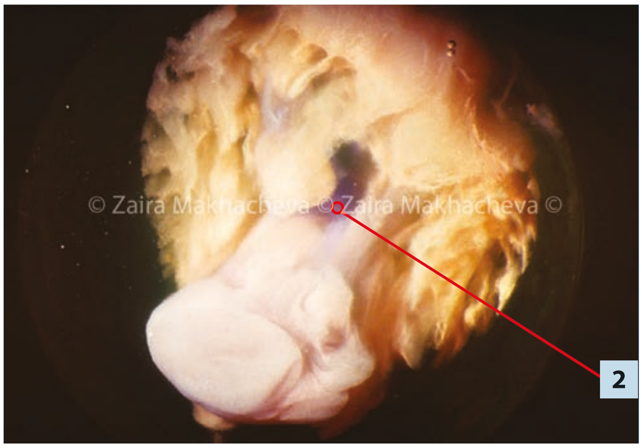
It came to my attention that both VB canals were filled with blood; however, the blood in the central canal was in a liquid state and could be traced to the retrolental space, while in the optico-ciliary canal and the prepapillary space, the blood was clotted.

I am assuming that the central canal and bursa premacularis might contain some common anticoagulant properties, which indicate both their integrity and the presence of a mechanism for the rapid drainage from the structures that are critical for the projection of the image onto the retina. In the optico-ciliary canal, which does not follow the visual axis, the presence of such an anticoagulant mechanism would not only be useless, but also harmful, since the optic nerve vessels can often be a source of an intraocular hemorrhage.

The canals are connected by means of the canaliculus communicans *Makhacheva*, which I was able to trace during a retrograde cannulation of the prepapillary space and the bursa premacularis.

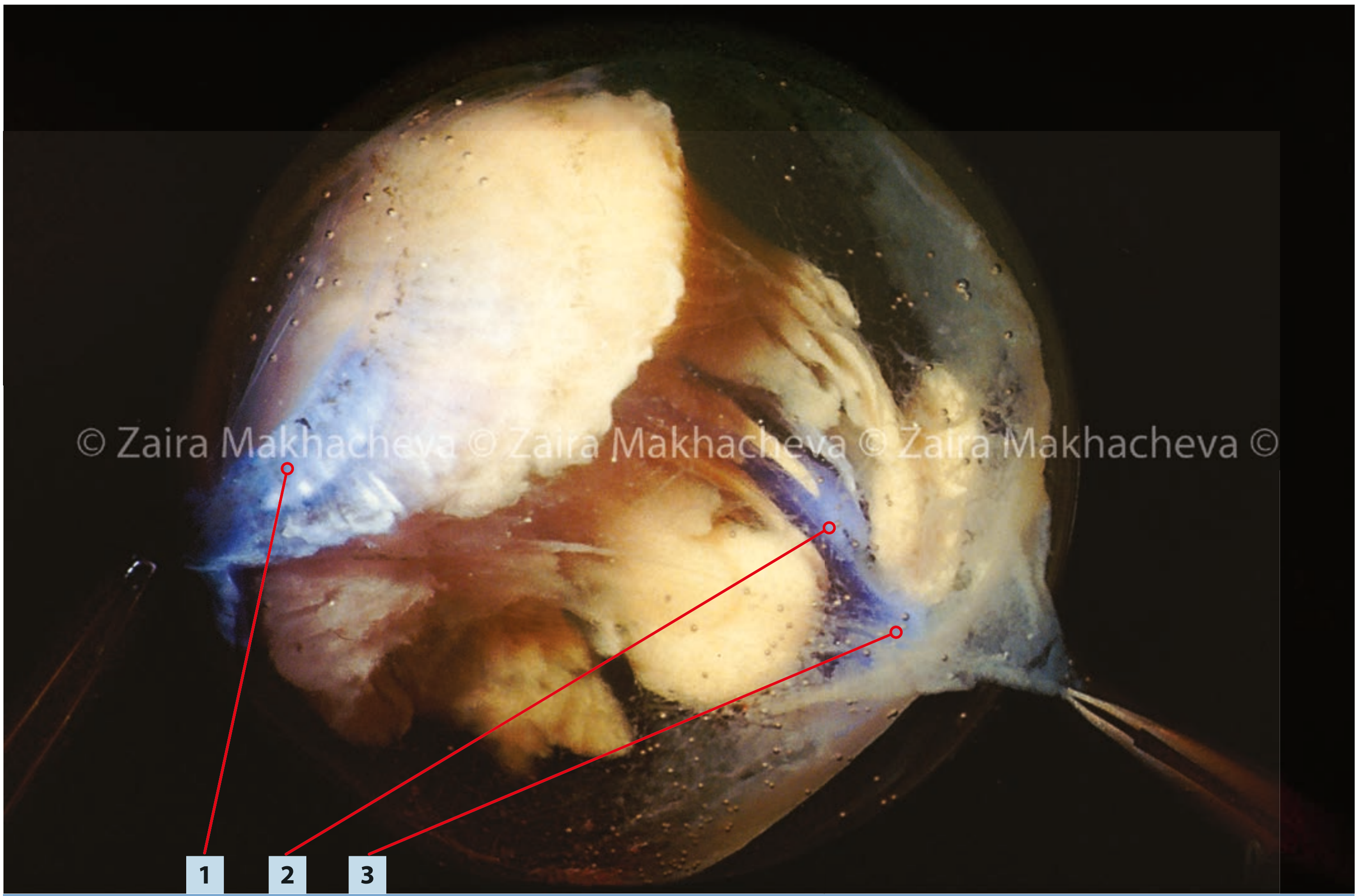
I noted that when a dye is injected into the prepapillary space, the contrast agent fills the canalis optico-ciliaris, and then reaches the bursa premacularis and the canalis lentico-macularis through the





Canalis optico-ciliaris:

1. **pars ciliaris**
2. **pars intermedia**
3. **pars papillaris**



Canalis optico-ciliaris:

1. pars ciliaris

2. pars intermedia

3. pars papillaris

canaliculus communicans. With retrograde cannulation of the bursa premacularis, the dye first fills the canalis lentico-macularis, then penetrates the prepapillary space through the canaliculus communicans and much later, with additional ink injection, penetrates into the canalis optico-ciliaris. This made me suggest the presence of a valve or mechanism that makes the retrograde filling of the canalis optico-ciliaris from the bursa premacularis somehow difficult. It is possible that this mechanism provides a unidirectional movement of fluid, and damage to this mechanism can contribute to the onset of glaucoma.

Undoubtedly, the vitreous body is a highly organized apparatus that performs important physiological functions including hydrodynamic balance and intraocular homeostasis, which are crucial for the ultimate visual functions.

Dr. Zaira Makhacheva
A New Perspective on the Anatomy of the Vitreous Body. - Moscow, 2006. - 16 p.with illustrations.

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A New Perspective on the Anatomy of the Vitreous Body by Z. Makhacheva, MD, Ph.D. presents the highlights of her research on the vitreous body anatomy conducted at the Jan Worst Research Group (Haren, the Netherlands) in 1993.

By pioneering a new topographo-anatomical approach for studying the vitreous body anatomy in fresh autopsy eyes and by developing original preparation techniques, Dr. Zaira Makhacheva was able to discover new vitreal structures and clarify misconceptions, thus advancing the knowledge of the vitreous body anatomy and its role in physiological and pathological conditions.

The critical structural elements of the vitreous body are pictured by the author in the Model of the Vitreous Body Anatomy, as well as in the unique and explicit pictures of the vitreous body specimens. These depictions makes it obvious that the vitreous body has a more complex organization and function than previously thought.

This new perspective on the vitreous body anatomy is a valuable resource for researchers and practical ophthalmologists.

Zaira Makhacheva

INCOGNITO BODY

Anatomy of the Vitreous Body

Full version in three parts:
1. Preparation & Examination Techniques
2. Anatomy of the Vitreous Body
3. Vitreous Body in Pathological Conditions

Language: Russian
Length: 60 minutes

The artistic filming offers a unique approach to viewing the vitreous body of the human eye. The preparation techniques developed by the author present an innovative topographo-anatomical approach for the study of the anatomy of the vitreous body.

The original discoveries depicted force the reevaluation of the role of the vitreous body in the physiological and pathological functions of the eye.

The CD can be ordered at: zmakhacheva@yahoo.ca

Dr. Zaira Makhacheva
MD, Ph.D., Professor

Dr. Zaira Makhacheva completed her Residency in Ophthalmology, Ph.D. program, and Doctoral studies at the leading Russian research centre *Eye Microsurgery*, under the mentorship of the prominent ophthalmologist Dr. Svyatoslav Fedorov.

In 1985, she completed her Ph.D. thesis on the benefits of an early vitrectomy intervention through her research into the hemodynamics and acid-base balance in patients with proliferative diabetic retinopathy pre- and post-surgery.

Her Doctoral thesis was dedicated to multidisciplinary research of the vitreous body. The pioneer studies involving its anatomy were performed at the Jan Worst Research Group in Haren, the Netherlands.

Z. Makhacheva is the author of more than 100 scientific papers, patents, educational manuals, and video films. Her primary research areas are anatomy, biochemistry, and physiology of the vitreous body.