Practical Manual of Vitreoretinal Surgery

Ahmed B. Sallam
Ferenc Kuhn
Giampaolo Gini
Ron A. Adelman
Editors

Springer

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Foreword

The topic of this book needs no introduction. Vitreous surgery has been at the forefront of ophthalmic procedures for more than 50 years. Retinal diseases are an important cause of ocular morbidity and visual impairment globally. Population-based studies have reported the prevalence of retinal disorders ranging from 5.35% to 21.02% at age 40 years and above. In developed countries, retinal diseases are the most common cause of irreversible blindness. Nevertheless, advances in surgical repair of retinal detachments, and macular diseases, including small-incision surgery, use of perfluorocarbon liquids, and silicone oil and gas tamponade, have made treatment very effective and visual recovery possible in many cases. Despite these advances, retinal diseases continue to be a leading public health issue that will grow in importance as the population increases and life expectancy is extended worldwide. Not to mention the prevalence of trauma in young males worldwide that frequently affects the retina and requires vitreoretinal surgery.

Many contributed to the development of vitreoretinal surgery, and the history of vitreoretinal surgery is beyond the scope of this "Foreword." However, I cannot avoid mentioning Robert Machemer, better known as the "Father of Modern Vitreoretinal surgery," who devised VISC (vitrectomy, infusion, suction, cutter) with Jean Marie Parel at Bascom Palmer in Miami, USA. After experimenting and succeeding in removing the egg albumin through the motorized instrument via 17-gauge ports, in order to improve the visibility, he later added a fiber optic light pipe for endoillumination. In 1970, he obtained good results in cases of vitreous hemorrhage and poor results in a case of proliferative vitreoretinopathy. Significant advances have taken place during the last 50+ years.

For these reasons, the appearance of this *Practical Manual of Vitreoretinal Surgery* edited by Drs. Ahmed Sallam, Ferenc Kuhn, Giampaolo Gini, and Ron Adelman to help ophthalmologists learn the newest techniques on vitreoretinal surgery is a wonderful gift to us all and our patients. The book has been beautifully illustrated and divided into 34 masterful chapters including important topics such as applied anatomy and physiology, preoperative evaluation of vitreoretinal surgery patients, vitreoretinal anesthesia, pars plana vitrectomy set up, vitreous substitutes, vitreous hemorrhage and opacities, retinal breaks and pneumatic retinopexy, pars plana vitrectomy for primary retinal detachment, scleral buckle surgery, giant retinal tear detachment, proliferative vitreoretinopathy detachment, retinoschisis, epiretinal membrane and vitreomacular traction, surgical management of lamellar macular hole, surgical management of macular holes, optic pit maculopathy, myopic traction maculopathy, diabetic delamination surgery, sickle cell retinopathy surgery, subretinal and suprachoroidal hemorrhage, uveoscleral effusion, choroidal patch graft, vitreoretinal surgery and pressure-dependent optic neuropathy, vitreoretinal surgery for anterior segment complications, vitreoretinal surgery in uveitis, vitreoretinal surgery in endophthalmitis, vitreoretinal surgery in trauma, vitreoretinal surgery in pediatrics, vitreoretinal surgery for ocular tumors, three-dimensional retina surgery, vitrectomy in the presence of corneal opacity, and cataract surgery and vitreoretinal surgery. With 177 color images, 123 videos, and 61 authors from 21 countries, this *Practical Manual of Vitreoretinal Surgery* is a must read for anyone interested in Vitreoretinal Surgery and helping our patients.

Contributors to this book are both educators and practitioners. There was no way for them to have developed these techniques and expertise except by performing them themselves. Their accumulated knowledge is the result of tremendous clinical and academic effort, and their expertise flows to the reader with the hope that individual lives will benefit. In bringing their work to press, Drs. Ahmed Sallam, Ferenc Kuhn, Giampaolo Gini, and Ron Adelman have done a great service to patients living with vitreoretinal diseases and to the doctors caring for them. Those who will read and study this *Practical Manual of Vitreoretinal Surgery* have already demonstrated that they care for their patients and that they want to learn. We now just need to move forward together to give our patients the gift of sight.

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Preface

We are pleased to present our book on retina surgery—*Practical Manual of Vitreoretinal Surgery*.

The purpose of this book is to impart clinical and surgical skills to retina surgeons and provide invaluable insights and recommendations from experienced practitioners in the field. Our aim is to deliver the fundamentals of retina surgery in a clear and practical manner, emphasizing efficient and straightforward approaches. By simplifying surgical procedures, we hope to instill confidence in new surgeons, minimize the risk of errors, and enhance the proficiency of experienced surgeons. One of our main focuses is to provide the easiest and "no faff about ways" for doing surgery. Throughout our journey, we have discovered that the saying "less is more" holds true for vitreoretinal surgery, and in many cases, it is indeed the best approach!

In these 34 chapters, we have endeavored to cover all aspects of retina surgery, spanning preoperative care, surgical planning, intraoperative techniques, and postoperative management. We delved into the most frequently encountered conditions, such as primary retinal detachment and macular hole, as well as the most complex surgery, including advanced diabetic surgery and pediatric retinal surgery. Each chapter presents a step-by-step methodology for various techniques, accompanied by valuable pearls of wisdom and clinical scenarios to help guide clinical decisions. Additionally, we provide insights into the latest technologies and advancements in retina surgery, including surgical endoscopy and 3D surgery.

We hope this book serves as a convenient guide and indispensable resource for new retina surgeons as they learn the basics of the field, as well as an aid for experienced surgeons who are looking for new tips and tricks to refine their surgical skills and make their surgery both "smoother" and "slicker!" We hope that it will serve as a helpful companion to all readers throughout their journey in retina surgery.

We have asked the most experienced and knowledgeable retina surgeons from all over the world to write the book chapters, but we also paid attention to editing the book to avoid the inclusion of contradicting statements. We would like to express our greatest appreciation to each author who contributed to this book. Their effort, time, and dedication made it possible for this book to reach publication, and we owe

them a great debt of gratitude. We are privileged to have had the opportunity to collaborate with these distinguished scholars and outstanding teachers.

Our heartfelt thanks extend to the professional team at Springer for their invaluable assistance and guidance in bringing this book to fruition.

Surgical techniques continually evolve as various surgeons adapt and refine them over time. In this book, the editors and contributors share the techniques that have proven effective in their hands. Due to space constraints and the frequently unclear origins of many technical modifications in surgical techniques, which are traditionally passed from one surgeon to another, this book is lightly referenced. We acknowledge our teachers, innovators, and thought leaders for teaching us vitreoretinal surgery and sharing their knowledge. Without them, this book would not have been possible.

We are truly excited about the prospect of sharing our knowledge and experience with the readers, and we hope that, like us, you will continue to enjoy the fascinating world of retina surgery.

Sincerely,

Little Rock, AR, USA — Ahmed B. Sallam
Birmingham, AL, USA — Ferenc Kuhn
Worthing, West Sussex, UK — Giampaolo Gini
New Haven, CT, USA — Ron A. Adelman

Preface

Books, like people, have different destinies. Many eventually end up making a beautiful display of themselves in a book case only to be used as an occasional reference. This book is certainly not one of them. It is a practical compendium born from the experience of thousands of hours spent in the operating theater by some of the best surgeons in the world. The book covers all major vitreoretinal scenarios. Each chapter aims to give simple guidelines to address even the more complex issues. This is done in an easy-to-read, straight-to-the-point format, which is meant to prevent the surgeon from getting into trouble or getting him/her out of it as best and as quickly as possible. We as Editors believe this book should be a faithful, everyday companion to have in the doctor's debriefing room. Something to rely on as well as something which will stimulate further discussion. If one day we should venture into an operating theater and find a copy of the book with its pages wrinkled, dog-eared, and perhaps having a few coffee stains here and there, we will know we have been successful.

President of the European VitreoRetinal Society Giampaolo Gini

Acknowledgments

I have nurtured the idea of editing a manual on vitreoretinal surgery for a long time. While there exist numerous outstanding textbooks on the subject, to the best of my knowledge, there is currently no contemporary book that serves as a concise and handy manual that presents the information in a concise and practical manner, making it easily accessible for practitioners.

It was during one of the European Vitreoretinal Society Meetings 2 years ago that I had the opportunity to discuss the idea with my esteemed colleagues and dear friends, Drs. Ferenc Kuhn, Giampaolo Gini, and Ron Adelman. Their enthusiasm and eagerness to collaborate on this project were evident from the start. Bringing this project to fruition required extensive planning and a tremendous amount of teamwork.

I am indebted to all the contributing authors for generously sharing their knowledge, insights, and expertise, as well as for providing us with their invaluable videos and photographs.

Additionally, I would like to express my gratitude to the publisher, Springer, for their professional guidance throughout the entire process.

The assistance provided by my exceptional residents and fellows, particularly Drs. Riley Sanders and Zia Siddiqui, deserves special recognition. Their invaluable contributions in editing the videos and offering excellent suggestions for the writing played an instrumental role in shaping this manual.

Last but certainly not least, I want to extend my heartfelt thanks to my beloved wife, Sherin, and my children (and young friends), Abdel, Farida, and Amina. Their constant love, encouragement, and understanding have been the cornerstone of my journey. I am deeply grateful for their unwavering support, which allowed me the necessary time and space to dedicate myself to the creation of this book.

Ahmed B. Sallam

Contents

Applied Anatomy for the Vitreoretinal Surgeon

Abdelrahman M. Elhusseiny, Yousef Ahmed Fouad, Ahmed M. Alkaliby, and Ahmed M. Habib

This chapter discusses the surgical anatomy of the eye that is relevant to the vitreoretinal surgeon.

1 Important Definitions and Numbers

- Average anteroposterior diameter of the eye: 24 mm.
- Average horizontal diameter of the eye: 24 mm.
- Average vertical diameter of the eye: 23 mm.
- Average volume of the adult eye: 7 ml.
- Average volume of the vitreous cavity: 5 ml.

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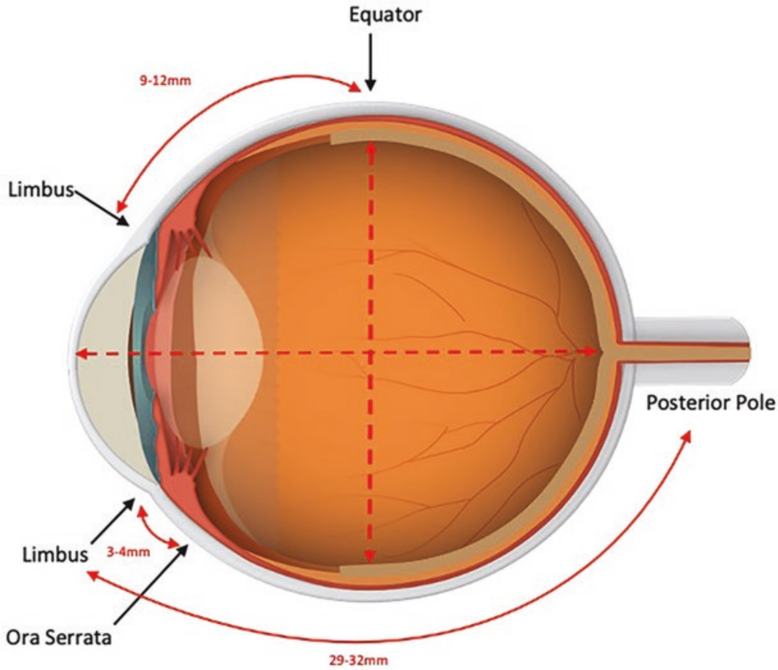

Fig. 1 Schematic representation of the distance from the corneal limbus to important surgical landmarks

- Surgical equator:
  - It is an important surgical landmark, particularly for scleral buckle surgery.
  - From outside, it is the part where the globe has the greatest circumference, located about 9–12 mm from the limbus (Fig. 1) and 2–4 mm anterior to the exit of the vortex veins.
  - From inside, it corresponds to the ampulla of the vortex veins and just anterior to the second bifurcation of the retinal blood vessels.

2 Vitreous

2.1 Biochemistry

- Water constitutes 98% of the vitreous, while proteins, extracellular matrix, and other substances represent the remaining 2%.
- The main collagen in the vitreous is collagen type II, which constitutes 75% of the total collagen in the vitreous. Collagen type II fibers are linked together by

collagen type IX. Staining patterns of other collagen fibers, including types I, III, IV, and XVIII, were previously confirmed in human retinas [1, 2].

- Hyaluronan is a polyanion that is entangled within the collagen fibers and is mainly responsible for maintaining vitreous transparency. It affects the diffusion of intravitreal drugs and plays a role in regulating the phagocytic activity of hyalocytes.
- Fibrillin is a non-collagenous structural protein, the mutation of which leads to vitreous liquefaction and subsequent higher incidence of retinal detachment (RD) in patients with Marfan syndrome.
- High concentrations of ascorbic acid in the vitreous are responsible for its antioxidant reducing the exposure of the crystalline lens to reactive oxygen species and maintaining the lens transparency.
- Significance
  - Removal of the vitreous in pars plana vitrectomy increases the risk of cataract formation.
  - This may also explain why diabetic retinopathy may exert a protective effect against the development of post-vitrectomy cataract formation; there is substantially lower oxygen tension in the vitreous cavity of diabetic eyes compared to non-diabetics.
- The vitreous holds on to chemicals such as vascular endothelial growth factor (VEGF) and transmits oxygen less readily than the aqueous.
- Significance:
  - Vitrectomy helps with improved oxygenation of the retina.
  - However, it facilitates the transport of VEGF down to its concentration gradient from the posterior segment to the anterior segment reducing the risk of retinal neovascularization but increasing the risk of rubeosis and neovascular glaucoma.
  - Silicone oil and the presence of the crystalline lens may act as a barrier to VEGF transport to the anterior segment, reducing the risk of neovascularization.

2.2 Gross Anatomy

- The vitreous volume is about 5 mL in normal eyes and up to 10 mL in high myopic eyes [1].

  Significance

  - Knowing the normal volume of the vitreous cavity, any discrepancies in the volume of tamponade injected or removed from the eye should raise suspicion during surgery. For example, removing a small volume of silicone in a recurrent case of retinal detachment should alert the surgeon that there could be some silicone under the retina not yet extracted. In another case, too little silicone injected in a retinal detachment repair with choroidal detachment could give the surgeon an idea of the magnitude of silicone underfill after the choroidal detachment is resolved.

- The vitreous can be divided anatomically into the vitreous body, vitreous base, and vitreous cortex (hyaloid surface).
- Anteriorly, it is bound by the posterior surface of the crystalline lens and the zonules. The lens is a biconvex structure that is more curved posteriorly, leading to the indention of the anterior vitreous called the patellar fossa.
- The radius of the anterior lens surface ranges from 10 to 14 mm compared to the radius of the posterior lens surface, which ranges from 6 to 7.5 mm. The retrolental space separating the lens from the anterior vitreous is called Berger's space. Significance
  - During pars plana vitrectomy, surgeons need to be cautious not to injure the posterior lens surface, which is more curved, while crossing the midline to the opposite quadrants.
- The anterior vitreous face is attached to the posterior part of the lens in an annular fashion called the hyaloideocapsular ligament of Weiger, which is about 1–2 mm wide and 8 mm in diameter.
- It is of note that the ciliary body, lens, and retina continue to develop in the first 6 years of life.

  Significance

  - When planning pars plana surgery in newborns, the small size and anterior position of the ciliary body and the relatively large size of the crystalline lens necessitate anterior placement of sclerotomies. Chap. 29 "Vitreoretinal Surgery in Pediatrics."

2.3 *Vitreous Body (Core)*

- Forming the main bulk, fibers are more densely packed in infants than adults.

  During eye movements, forces are transmitted from the eye wall to the vitreous body. Being highly viscoelastic, the vitreous movement lags behind the rotational forces of the eye wall "slack and lag," which markedly reduces the forces transmitted to vitreous attachments. Disruption of the hyaloid membrane results in an altered shape of the vitreous body which in turn causes abnormal stress on the retina. The inferonasal location of the optic nerve reduces the strain on the vitreous attachments inferiorly and nasally.

Significance

– The point of maximum strain is on the superotemporal retina, which may explain why it is the most common site of retinal tears.

- With age, liquefaction and spaces form within the vitreous gel. By the age of 40 years, 20% of vitreous is liquified, while at 80 years, 50% is liquified. Vitreous liquefaction is present more in myopic eyes and after recurrent episodes of vitreous hemorrhage.

  Significance

  – Vitreous hemorrhage absorbs faster in liquified vitreous (and vitrectomized eyes).
  – During a vitrectomy, liquified vitreous may give a false impression of posterior vitreous detachment (PVD).
  – The interface between liquified and gel vitreous has been studied in multiple mechanical models and has been shown to exert the most traction on the retina, causing retinal tears.
  – A more formed vitreous with no PVD as seein in young patients favors the decision of a scleral buckle for the repair of a retinal detachment over pars plana vitrectomy (PPV). Detaching the posterior hyaloid during PPV in these cases is very challenging with risks of causing retinal tears.

2.4 *Vitreous Base*

- It straddles the ora serrata and extends 2 mm anterior and 2–3 mm posterior to the ora serrata (Fig. 2, Video 1). It also has the highest concentration of collagen and calcium among vitreous parts and contains fibroblasts. It is firmly attached to the retina, so it is anatomically impossible to induce a PVD of the vitreous base [3]. The vitreous base posterior boundary is where the vitreous gel exerts the most traction on the retina in cases with PVD [4].

  Significance

  – Since it is impossible to perform PVD of the vitreous base, shaving (trimming/cutting short the vitreous by the vitrector very close to the retina) is the only way to remove most of it.
  – The posterior boundary of the vitreous base is a frequent site for retinal tears. Traction and subsequent retinal breaks increase with an increased angle between the vitreous and retina in cases with PVD. This increases further with the irregular posterior boundary of the vitreous base.
  – Part of the vitreous base covers the pars plana, so shaving it during vitrectomy is not necessary.

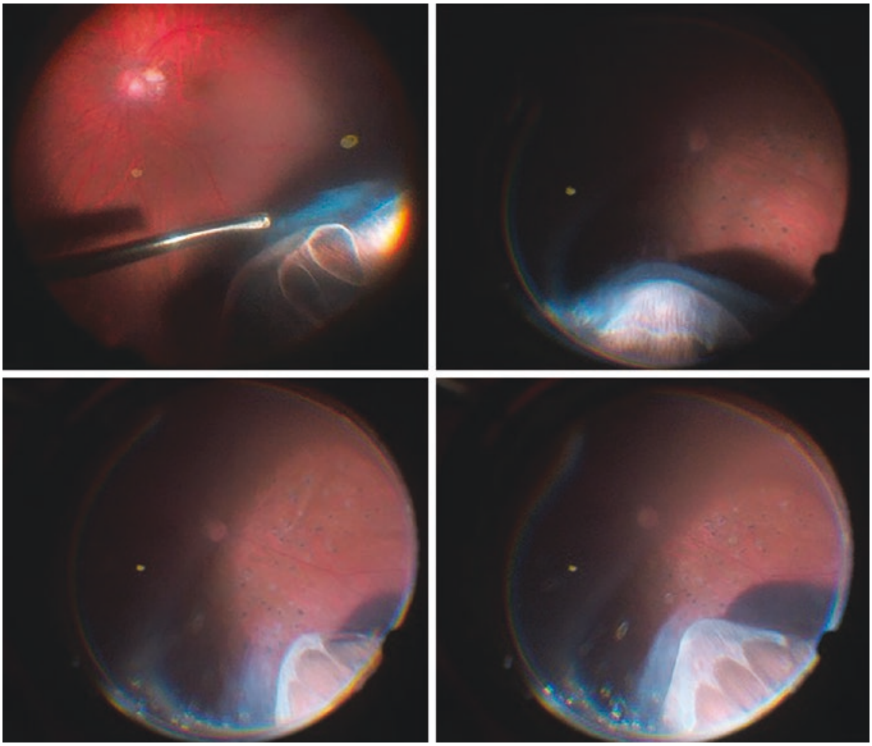

Fig. 2 Different morphological forms of the normal ora serrata. Top left, oral bays; top right, flat serrations; and bottom right and left, oral folds. Note the shaved vitreous base over the pars plicata and peripheral retina after pars plana vitrectomy with scleral indentation

– Posterior insertion of the vitreous base is an uncommon condition where the vitreous base is inserted more posteriorly down to the mid-periphery/ equator [3]. This is more common in high myopic eyes. In these cases, it will not be possible to propagate the PVD further anteriorly. It is also possible that these eyes may have an abnormal vitreoretinal interface with a high risk of iatrogenic retinal tears with PVD induction [5].

2.5 Vitreous Cortex

- It is a condensation of the vitreous and rich in hyaluronic acid for a single firm layer. Anteriorly, it separates the crystalline lens, and posteriorly, it separates the retina from the vitreous gel. Posterior vitreous detachment—a key step in vitrectomy surgery—is not done unless the posterior cortical vitreous is completely detached from the retina up to the vitreous base. Liquified vitreous does not mean that a PVD is present.

Significance

– High suspicion of still attached posterior cortical vitreous is advised, especially in myopic eyes and tractional retinal detachment.
– PVD is induced during vitrectomy by exerting sustained active suction by the vitreous cutter near the disc margin and then moving along the retina surface.
– Inducing anterior vitreous detachment is not necessary in every case but may be useful in removing hemorrhage stuck behind the lens. However, caution should be taken not to injure the posterior lens capsule.

2.6 Sites of Strong Vitreous Attachment

1. Vitreous base (most adherent).
2. Around the optic disc.
3. The fovea.
4. Along the vessels.
5. Areas of lattice degeneration.

   Significance

   - These are the areas to pull on with caution during PVD induction so as not to inflict injury or retinal tears.
   - Mid-peripheral areas of abnormally strong attachment of the vitreous could be mistaken for posterior displacement of the vitreous base, especially in myopic eyes.

2.7 Vitreous Cisterns

- Certain liquid spaces, known as vitreous cisterns, exist within the vitreous gel, including the pre-macular bursa, the space of Mertigioni over the optic nerve, and the retrolental space (Fig. 3).

  Significance

  – Vitreous hemorrhage can be trapped in the retrolental space, which can be challenging to remove in phakic patients during surgery without touching the lens. Also, vitreous hemorrhage can trap in the pre-macular bursa, causing a pre-macular hemorrhage.
  – Pre-macular bursa could be used to start the dissection in diabetic delamination using the 'in-out technique,' ensuring a clean entry between the hyaloid/membranes and the retina.
  – The 'wolf's jaw" configuration of diabetic fibrovascular proliferation along the temporal vascular arcades can be explained by neovessels' growth along the bursal wall.

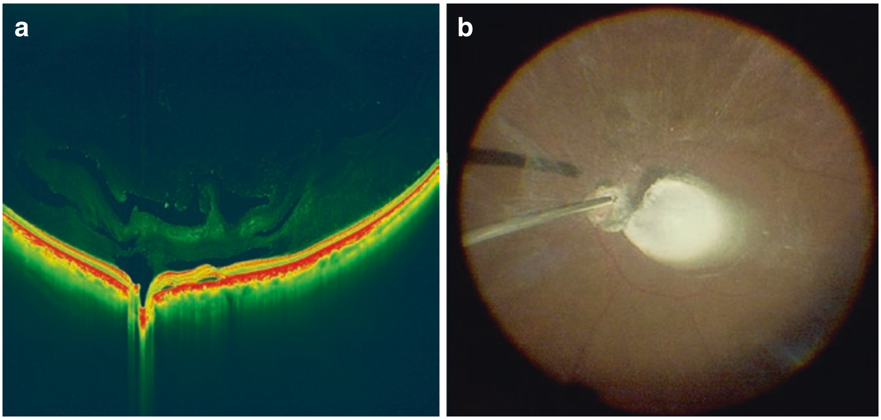

Fig. 3 A high-resolution OCT scan of the vitreous in a patient with central serous chorioretinopathy (note the 2 areas of subretinal fluid at the macula) and attached posterior hyaloid, depicting different vitreous cisterns, notably the pre-macular bursa and the adjacent space of Mertigiano over the optic nerve. (**a**). Staining of the 2 mentioned vitreous cisterns in another patient with triamcinolone acetonide during surgery for epiretinal membrane in the absence of posterior vitreous separation (**b**) (Courtesy of Adil El Maftouhi MD, Switzerland)

3 Retina and Optic Nerve

3.1 Gross Anatomy

- For description purposes, the retina extends from the optic disc to the ora serrata. The circumference from the temporal to the nasal retina is approximately 43 mm.
- The retina starts 5.5 mm (ciliary body size, 2.5 mm pars plicata and 3 mm pars plana) from the limbus nasally and 7 mm (ciliary body size, 2.5 mm pars plicata and 4.5 mm pars plana) temporally.

  Significance

  – Given that the vitreous base extends 2 mm into the pars plana, it is safest to place PPV sclerotomies at 3.5–4 mm from the limbus.

3.2 The Optic Disc

- It is a circular structure where axons of the ganglion cells converge and exit the globe into the optic nerve. Also, it is where major vessels (i.e., central retinal artery and vein) emerge.

  Significance

  – Damage to the disc results in augmented damage to the nerve fibers carrying visual impulses resulting in an augmented visual defect. Hence, cautery, laser photocoagulation, or excessive mechanical pressure on the disc should be avoided. Also, care is needed while draining fluid over the disc.

  – Damage to areas near the disc has a greater impact on vision than areas farther away.

- The optic disc is approximately 1500 μm in diameter.

  Significance

  – This can be used as a measuring unit for other areas, e.g., macular holes, submacular hemorrhage, or areas of capillary obliteration.

3.3 The Macula

- *The anatomical macula* or the area centralis is a 6 mm circle with a diameter equal to the length between the superior and inferior temporal arcades.
- *The clinical macula* is a 1.5 mm circle at the center of the area centralis.
- *The clinical fovea* or the anatomical foveola is a 350 μm circle that is 3.4 mm temporal to the disc margin and 0.8 mm inferior to the center of the disc.

  Significance

  – The position of the fovea in relation to the disc is to be considered in cases of 360° retinectomy to avoid retina rotation.

- The pressure in retinal arteries is approximately half than that of the systemic blood arteries.

  Significance

  – If the intraocular pressure is set during surgery at a higher number than half the diastolic pressure, disc pulsations will denote compromised disc perfusion. Some vitrectomy machines are equipped for measuring disc perfusion utilizing this concept.

- The thickness of the retina ranges from 2 to 4 mm in the posterior pole to 1–2 mm near the ora serrata.

  Significance

  – Breaks in the posterior pole can be left unlasered as the thickness of the retina supports it against detachment.
  – Peeling of epiretinal membranes (ERMs) is best to be done from the posterior to the anterior.

- The macula supplies a large number of ganglion cell fibers into the papillomacular bundle, and the fibers serve the temporal periphery curve around it.

  Significance

  – It is best to avoid starting/pinching the internal limiting membrane (ILM) peel nasal to the fovea.

3.4 The Ora Serrata [6]

- It is the anterior-most region of the retina, after which pars plana starts.
- It is about 2 mm wide and located 5 mm anterior to the equator and approximately 5.5 mm from the limbus.
- It represents the transition between the ciliary epithelium and the multilayered photosensitive neurosensory retina.
- At the ora serrata, variations in morphology are present. Ora bays are extensions of the pars plana into the retina. They can be enclosed by extensions of the retina to form ora islands or "enclosed ora bays." Ora folds are thickened retinal tissue extending into the pars plana. If they are not thickened, they are called "dentate processes" (Fig. 2).

  Significance

  – Vitreoretinal surgeons should be familiar with ora serrata morphology to avoid confusing the different variations with breaks or retina folds prompting surgical action.

3.5 Microscopic Anatomy

- The retina is composed of ten layers: the retinal pigment epithelium, photoreceptor layer (composed of outer and inner segments), external limiting membrane (formed by the junctions between the photoreceptors and Muller cells' stomata), outer nuclear layer (nuclei of photoreceptors), outer plexiform layer (synapses between photoreceptors and bipolar cells), inner nuclear layer (nuclei of bipolar cells), inner plexiform layer (synapses between bipolar cells and ganglion cells), ganglion cell layer, nerve fiber layer, and ILM (Fig. 4).

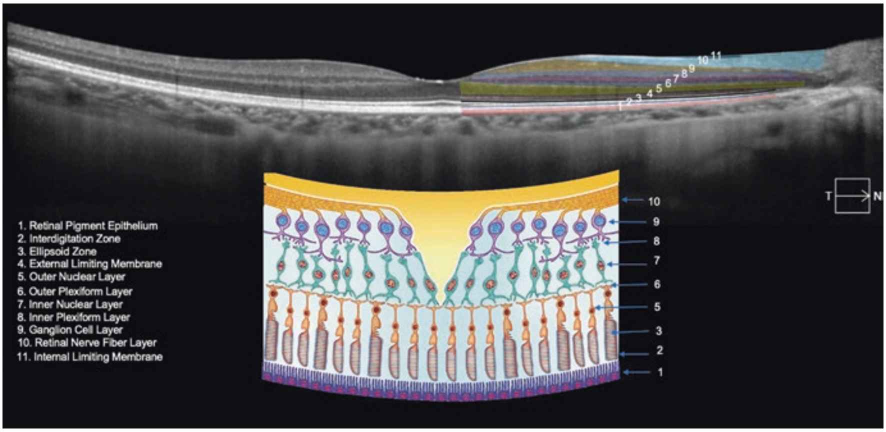

Fig. 4 Retinal microstructure as seen on optical coherence tomography (top) and corresponding diagram of the different retinal layers (bottom, photo by Ilusmedical, Shutterstock.com)

- Muller cells are an important glial cell type. They span nearly the whole retinal thickness. Their stomata form the external limiting membrane (ELM) with those of the photoreceptors. They send processes among photoreceptor discs and others up to the retinal surface, where they form footplates that coalesce together to form the ILM.
- Muller cells provide mechanical support for retinal layers acting. They also provide biochemical support aiding in transporting nutrients and washing out waste products. They form a sheath around the superficial vascular plexus.
- They are entangled with retinal cells forming the core of the so-called functional retinal columns, the smallest unit of "forward information processing." Each column contains a cone, several rods, inner nuclear layer neurons, and ganglion cells. Columns have more neurons in the fovea than the periphery.
- Two types of Muller cells exist. The first type is the foveal cone Muller cells which are present at the foveal center. They extend from the ELM to ILM, where their processes form an inverted cone at the foveal center, which forms the naval appearance of the fovea and is continuous with the rest of the ILM. The second type is the parafoveal Muller cells which assume a Z-shaped configuration. They are present in the parafoveal region and form the Henle layer and cone axons [7].

  Significance

  – One of the theories of epiretinal membrane formation is that incomplete PVD induces increased traction on Muller cells at the remaining points of attachment. This causes a fibrosis reaction along Muller cells leading to ERM and microscopic intraretinal fibrosis formation.
  – Foveal cone Muller cells are vertically arranged in the central 100μm region of the fovea (central bouquet) as they connect with the cone photoreceptors. This makes this area most susceptible to traction from ERM leading to outer retinal changes such as upward displacement of cone receptors, foveal detachment, and subretinal pigment epithelium deposits [8].

- The ILM is a rigid membrane providing nearly half the retinal mechanical strength. It can pull on the retina and cause distortion and even schisis (as in myopic foveoschisis). Hence, the rationale for ILM removal in cases of macular distortion where removal of the ILM decreases the retinal strength and increases its elasticity, thus relieving traction and aiding in retinal relaxation.
- On the other hand, removal of the ILM can cause damage, hypertrophy, and even glial apoptosis of the Muller cells. This can cause macular holes (due to loss of focal cone Muller cells), loss of foveal contour (due to damage or hypertrophy/fibrosis of the parafoveal Muller cells), and macular cystic spaces or edema due to damage of the blood-retinal barrier [9].
- However, if the parafoveal Muller cells are not damaged, they contribute significantly to the centripetal force exerted by the circle of cells around macular holes with formation of temporary glial tissue, leading to their closure [9].
- Lastly, the fact that the cone Muller cells form the central foveal depression and, at the same time, are connected to the ILM led to the recommendation of leaving the ILM just above the fovea (fovea-sparing ILM removal) by some authors.

- The ILM thickness ranges from 1.4 μm at the macular center down to 0.4 μm at the macular periphery.
  Significance
  - ILM removal near the macular center is easier than the macular periphery.
- The macular area has multiple layers of ganglion cells (three to four layers) and has the highest concentration of cones responsible for color vision and high-definition vision. The convergence ratio of cones to bipolar cells is 1:1 (that means that for every cone, there is a bipolar cell synapsing with it).
- As we go toward the periphery, the concentration of cones decreases, while the concentration of rods increases (highest concentration in the mid-periphery and nasal retina). The convergence ratio increases up to 1:20 (20 rods converge to synapse with 1 bipolar cell), aiding the retinal periphery's function to detect motion rather than detailed vision.

  Significance
  - Breaks in the posterior pole translate into bigger, more noticeable field defects than those in the peripheral retina.

4 Extraocular Muscles

- All four recti muscles originate from the annulus of Zinn at the orbital apex and insert into the sclera at variable distances from the limbus. The medial, inferior, lateral, and superior recti muscles are inserted 5.5, 6.5, 6.9, and 7.7 mm from the nasal limbus, respectively.
- The spiral of Tillaux is an imaginary line connecting the insertions of the recti muscle (Fig. 5). It is an important anatomical landmark, especially during scleral

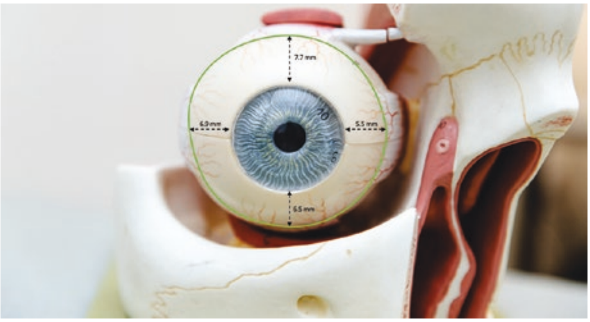

Fig. 5 All four recti muscles originate from the annulus of Zinn at the orbital apex and insert into the sclera at variable distances from the limbus. The medial rectus muscle is inserted 5.5 mm from the nasal limbus, the lateral rectus muscle is inserted 6.9 mm from the limbus, and the superior rectus muscle is inserted 7.7 mm from the limbus, while the inferior rectus muscle is inserted 6.5 mm from the limbus. The spiral of Tillaux (green circle) is an imaginary line connecting the insertions of the recti muscle

buckle surgery for retinal dialysis, as it roughly corresponds to the ora serrata location from the outside.

- The superior oblique muscle originates superomedial to the optic foramen. The muscle then runs forward and passes through the trochlea before changing its direction to be inserted in the supertemporal aspect of the globe.

  Significance

  – On hooking the superior rectus muscle, avoid sweeping the hook posteriorly to prevent inadvertent hooking or disinsertion of the superior oblique muscle. It is best to hook the superior rectus muscle from the temporal side. Hooking the rectus muscle from the nasal side may injure the trochlea.

5 Sclera

– The scleral thickness differs at different locations: at the limbus (0.8 mm), rectus muscle insertion (0.3 mm), equator (0.6 mm), and peripapillary (1 mm). This explains why scleral rupture tends to happen more commonly around the recti muscle insertion with blunt trauma. Also, this is important to note during scleral incisions for subretinal fluid drainage and when placing scleral sutures. Figure 6 shows the important structure at the posterior aspect of the sclera.

Fig. 6 The anatomy of the posterior aspect of the globe and the related important structures. IO, inferior oblique; SO, superior oblique; a, optic nerve; b, superior vortex veins; c, inferior vortex veins; d, short posterior ciliary vessels and nerves; e, long posterior ciliary vessels and nerves; x, fovea

6 Blood and Nerve Supply of the Globe [10]

- The globe is supplied by the ophthalmic artery through its branches. These include the central retinal artery and short posterior ciliary arteries supplying the retina and the short ciliary arteries supplying the anterior part of the eye, including the anterior ciliary arteries and the long posterior ciliary arteries. The anterior ciliary arteries travel along the recti muscle (one along each muscle border of the superior, medial, and inferior recti and one only along the lateral rectus).

  Significance

  – These arteries can serve as a good anatomical landmark to the recti muscles and explain why a tight encirclement buckle can lead to anterior segment ischemia.

- The long posterior ciliary arteries (usually 2) pierce the sclera near the posterior pole (approximately 4 mm around the optic nerve on each side) and then travel anteriorly between the sclera and choroid at the 3 and 9 o'clock positions (Fig. 7) to join the anterior ciliary arteries in forming the major arterial circle of the iris. The major arterial circle of the iris gives off branches to the iris and ciliary body.
- Venous drainage of the eye is mainly through the central retinal vein and the vortex veins (Fig. 8). Most of the venous drainage from the anterior segment is directed posteriorly into the choroid and then into the vortex veins. There are four to eight veins that represent the venous drainage system for the ocular choroid. Most people have at least one vortex vein for each retinal quadrant. Some vortex veins drain into the superior ophthalmic vein, while others drain into the inferior ophthalmic veins. Vortex veins can be identified during fundus examination and represent an important landmark for the retinal equator. Though their location can vary from one person to another, the vortex veins tend to be present

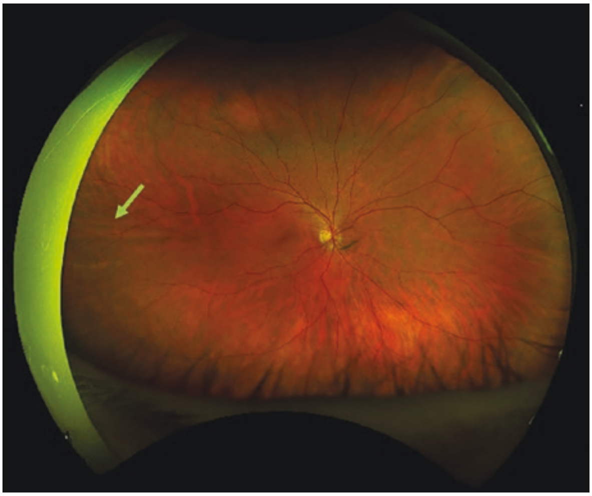

Fig. 7 Long posterior ciliary nerve and artery (green arrow) is usually located at the horizontal meridian outside the posterior pole. Also, note the presence of Weiss ring due to posterior vitreous detachment

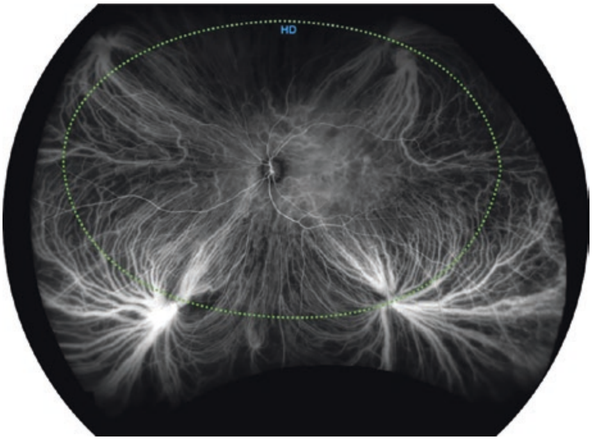

Fig. 8 Location and structure of the vortex veins highlighted by indocyanine green angiography. The ampulla of the vortex veins is an important landmark of the equator of the eye (green dotted line)

more toward the vertical meridian at the 1, 5, 7, and 11 o'clock positions. Drainage of subretinal fluid during scleral buckle surgery is therefore ideally performed above or below the horizontal muscles to avoid injury of the choroidal vasculature.

- The long posterior ciliary nerve arises from the nasociliary branch of the ophthalmic nerve. It passes along the horizontal meridian of the eye between the sclera and choroid together with the artery.
- The short ciliary nerves are branches of the ciliary ganglion located in the orbit and carry parasympathetic fibers. They penetrate the sclera around the optic nerve and continue their course in the suprachoroidal space to innervate the iris sphincter and the ciliary muscle. Their location is variable.

  Significance

  – Heavy retinal laser during surgery can cause neurotrophic keratopathy, cycloplegia, or paralysis of the iris sphincter. One needs to be cautious not to place heavy laser spots at the horizontal meridian.

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Preoperative Evaluation of Vitreoretinal Surgery Patients

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1 Introduction

- Becoming a proficient vitreoretinal surgeon begins with the ability to accurately evaluate and identify many subtle factors in the preoperative clinic that will enable a successful surgical outcome. This examination will guide your choice of anesthesia, surgical technique, tamponade, and expectations to discuss with the patient.
- The preoperative clinical examination can greatly impact the success or failure of vitreoretinal surgery. It is also the opportunity for the surgeon to discuss outcomes with the patient to mitigate any postoperative surprises. Patients should be given realistic expectations for anatomic success and vision improvement. Recovery and rehabilitation time may differ significantly depending on the surgical technique and tamponade required. Planning for this and discussing it before surgery enhance the patient's trust and confidence in the surgeon throughout the perioperative period.

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