LASER TREATMENT OF EYE FLOATERS

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This book is dedicated to the doctors who made removal of eye floaters possible:

Franz Fankhauser, M.D. for his work with the Q-switched nanosecond YAG laser,

Daniele Aron-Rosa, M.D. for her work with the mode-locked picosecond YAG laser, and

Robert Machemer, M.D. for his work in developing pars plana vitrectomy.

TABLE OF CONTENTS

INTRODUCTION…13

FLOATERS AND PRESENT TREATMENT OPTIONS

CHAPTER 1: THE VITREOUS, FLOATER FORMATION, FLOATER TYPES, AND CLINICAL COURSE
The vitreous…18, Floater formation…18, Floater types...20, Course of Floaters...22

CHAPTER 2: PROPOSED FLOATER TREATMENTS
Do nothing ("Learn to live with it.")...23, "Sunglasses"...23, Herbal medicines…24, Vitrectomy…25, Laser treatment…28, Why laser treatment is unknown...28

CLINICAL HISTORY AND EXAMINATION FOR LASER TREATMENT

CHAPTER 3: SYMPTOMS, FLOATER HISTORY, JUSTIFICATION FOR TREATMENT
Symptoms…31, Four factors in symptoms…31, Karickhoff symptom severity formula…32, Incorrect assumptions…33, Patients see what doctors can not…33, Floaters affect visual acuity…34, History…34, Justification for treatment...34

CHAPTER 4: THE FLOATER EXAMINATION
Pertinent data…36, Order of exam…36, Karickhoff "Floater Finder"…37, Direct ophthalmoscope…37, Indirect ophthalmoscope…38, Contact lens…39, Hruby lens…39, +90 diopter hand held lens…39, Locating a floater with the Karickhoff Patient Assisted method…40, Macular test…41, Demonstrating the floater to the patient (Karickhoff method, commercial method)…42, Scanning Laser Ophthalmoscope…43

OPHTHALMIC YAG LASERS: HISTORY, PHYSICS, AND OPTICS OF FLOATER VAPORIZATION

CHAPTER 5: HISTORY OF OCULAR YAG LASERS
Early history…44, Development of mode-locked (picosecond) YAG lasers…45, Development of Q-switched (nanosecond) YAG lasers…45

CHAPTER 6: SIMPLIFIED EXPLANATION OF FLOATER VAPORIZATION
Using vaporization and obliteration…48, Optical breakdown and plasma formation…48, Similarity to a lightning strike…48, Conversion to a gas…49

CHAPTER 7: LASER PHYSICS OF FLOATER OBLITERATION
How a laser works…50, Optical break-down in eye surgery…51, Plasma shields…52, Fundamental vs. the multimode operation…53, Continuous vs. pulsed emission…53, Nanosecond vs. picosecond lasers…54, Q-switching vs. mode-locking…54, Vaporization without burning…57

CHAPTER 8: LASER OPTICS FOR FLOATER TREATMENT
Proper illumination…60, Aiming beams…61, Converging treatment beam…61, Testing your laser for floater treatment…61

CLINICAL STUDIES OF FLOATER LASER TREATMENT

CHAPTER 9: INFORMAL STUDIES
Tsai…62, Geller…62, Delaney…62, Karickhoff…62

CHAPTER 10: KARICKHOFF FORMAL STUDY OF 200 CONSECUTIVE, ELIGIBLE FLOATER CASES
Conducted under the guidelines of the U.S. Food and Drug Administration and supervised by our hospital Institutional Review Board…64, Inclusion and exclusion criteria…65, The procedure…66, Monitoring procedures and statistical methods…66, Conclusions…68, Deficiencies of the Study…70

BENEFITS, RISKS, CRITERIA OF SUCCESS

CHAPTER 11: BENEFITS, SUCCESS, AND RISKS OF THE PROCEDURE

92 per cent overall…71, Case selection…71, Two basic approaches to achieve success…71, Vision frequently improved one to three lines…71, Low risk procedure…71

SELECTING PATIENTS

CHAPTER 12: SURGICAL INDICATIONS AND CONTRAINDICATIONS

Indications…73, Contraindications…74, Relative contraindications (only good eye)…76

CHAPTER 13: YOUNG PATIENTS WITH FLOATERS

Transparent threads…77, Syneresis clouds…77, Fibrin strands…77, Finding the floater…78, Karickhoff Patient Assisted Method…79

THE PROCEDURE

CHAPTER 14: THE PROCEDURE, AND DISCUSSION OF IT BEFORE, DURING AND AFTER

Discussing the vitreous face…80, Discussing multiple floaters…80, Discussing gas bubbles…81, Evaluation and procedure plan…81, Which eye first…81, The procedure…82, Post-operative instructions…83

CHAPTER 15: HOW OTHER EYE STRUCTURES AFFECT THE PROCEDURE

Cornea (RK and LASIK)…84, The lens…85, Small posterior capsulotomy…85, Contracted anterior capsule…86, Cataract…86, Intraocular lens…87, Multifocal intraocular lens…87, Intraocular contact lens…88, Floaters near the lens…88, Iris…88, Floaters near the retina…89, Vitreous…89

CHAPTER 16: TREATMENT: GENERAL CONCEPTS,
20 FLOATER TYPES AND TECHNIQUES
General concepts…91, Obtaining optical breakdown…94, Non-fibrous floaters…95, Fibrous floaters…96, Weiss rings…97, 16 techniques for Weiss rings…104, Very small floaters…108, Fan-shaped floaters…108, Peripheral floaters…109, Syneresis floaters…110, Non-suspended syneresis floaters…110, Suspended syneresis floaters…111, Syneresis cloud hidden below…112, Weiss ring/"snow globe" floater duet…113, Bean-shaped floater 114, Floaters from retinal cryopexy and the argon laser…114, Floaters in high myopia…115, Laser floater treatment following vitrectomy…115, Asteroid hyalosis non-treatment…115

CHAPTER 17: TECHNICAL DIFFICULTIES
Aiming difficulties…116, Difficulty seeing the floater…116, Losing the floater…116, Low brow…117

SAFETY AND AVOIDING COMPLICATIONS

CHAPTER 18: THE U.S. FOOD AND DRUG ADMINISTRATION
AND FLOATERS
Dr. Karickhoff's application and approval…118, FDA policy…119

CHAPTER 19: RETINAL PROTECTION
Historical lack of retinal detachments…120, Eight ways the retina is protected…120

CHAPTER 20: AVOIDING COMPLICATIONS
General lack of complications…122, General rules…122, Preventing pain…123, Preventing corneal complications…123, Preventing contact lens problems…124, Preventing gonio fluid complications…125, Preventing elevated pressure…125, Preventing retinal damage…129, Preventing retinal hemorrhage…131, Preventing macular damage…134, Absence of retinal detachments…134, Preventing cataract formation…135, No accelerated vitreous degeneration…136

CHAPTER 21: FOLLOW UP, RETREATMENT
Examination immediately after treatment…137, Examination the day after treatment…137, Re-treatments…138, Follow up examinations…138

EQUIPMENT

CHAPTER 22: SELECTION OF A LASER
Testing your YAG laser…139, Other YAG lasers…139

CHAPTER 23: SELECTION OF DIAGNOSTIC AND SURGICAL CONTACT LENSES, DESIGNING A SURGICAL CONTACT LENS
Diagnostic contact lenses…149, Karickhoff Laser Lens…149, Fundus Laser Lens…149, General concepts of treatment lenses…150, Seven treatment lenses…151, Karickhoff 21 mm lens…151, Karickhoff Off-Axis lens…152, Peyman 12, 18, and 25 mm lenses…153, Lasag CGV lens…154, Abraham posterior capsulotomy lens…155, Abraham iridotomy lens…156, Designing a surgical contact lens…157

CHAPTER 24: SELECTING, MAKING, DILUTING GONIOSCOPIC FLUID
Diluting methylcellulose…159, Methylcellulose vs. Ethylcellulose…159, Gonioscopic fluid substitutes…162, Making a superior gonioscopic fluid…162, Air bubbles in the gonioscopic fluid…163

CHAPTER 25: OTHER EQUIPMENT
Cameras and photographing floaters…164, Elbow support…166, Room light…167, Foot rest…167

LOOKING BACK—LOOKING FORWARD

CHAPTER 26: PATIENT SATISFACTION AND 15 MEMORABLE CASES…168

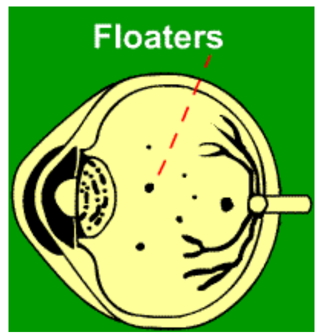
CHAPTER 27: FUTURE USE OF THE YAG LASER
IN THE VITREOUS
Treatment of persistent vitreous hemorrhage…172, Treating macular holes and membranes…172, Treating subhyloid hemorrhage…172

APPENDIX:

A) Office work-up form…174
B) Operative permit…175
C) Pre-operative instructions…176
D) Post-operative instructions…177
E) Explanation of multiple floaters…178
F) Summary of the world literature…179
G) Insurance codes…183
H) Karickhoff Floater Finder…184
I) One year follow up form…186
J) Karickhoff Mosaic Matcher ©, (Corneal Endothelial Cell Estimates at the Slit Lamp in 15 Seconds)…188
K) Karickhoff Flying Corpuscle Viewer™ (Macular function test when the macula can not be seen)…190
L) Karickhoff Simplified Outflow Facility Testing…194
M) Karickhoff Vitreous Treatment Lenses… 200
N) Designing the ideal laser for floater treatment…201
O) Dr. Karickhoff's contributions to laser treatment of floaters…205
P) Dr. Karickhoff's contributions to ophthalmology…207
Q) Curriculum Vitae…210-226

R) About the Author…227

INTRODUCTION



Vitreous opacities (eye floaters) are tiny or large, cloudy clumps of gel or cells that appear in the otherwise clear vitreous which occupies the back three-fourths of the eye. People see floaters as small specks, cobwebs, lines or clouds moving in their field of vision. The specks appear to be in the air out in front of the eye because they cast a shadow on the retina. They are seen by nearly everyone and range from being a nuisance that can be ignored, to floaters interfering with essential daily activities such as reading, driving, and using a computer. This book is concerned with the latter group where the floater can not be ignored.

Laser treatment for eye floaters has these advantages:

- is a painless, non-invasive (no intraocular infections), 20 minute office procedure;
- recovery within 24 hours and no restrictions on activities:
- is a precise obliteration of the floaters without removal of vitreous;
- is effective in approximately 92% of cases done;
- its low complication rate (0.10 %) justifies treatment of visually significant floaters;
- no bleeding since floaters have no blood supply;
- is much safer and less expensive than vitrectomy (Chapter 2);
- is equally appropriate for general ophthalmologists and retinal specialists; and
- uses equipment with which all eye surgeons are familiar (a YAG laser and a surgical contact lenses).

There are four major misconceptions about laser treatment of vitreous opacities:

(1) Many mistakenly believe that vitreous opacities are not visually significant. Every doctor knows that even a large floater in the anterior vitreous can be ignored by some patients. But floaters in the mid and posterior vitreous cast a distinct shadow on the retina and rarely can be ignored. These moving objects can bother patients greatly and ruin the quality of life.

(2) Most believe that the mechanism for laser treatment is breaking big floaters into many smaller floaters. If this were true, no

patient would be made better. Fortunately there is more than enough power generated through the phenomenon of optical breakdown and plasma formation (see Chapter 6) to transform floaters into a gas and obliterate them, not just break them into smaller pieces. The proof of this is the surgeon can easily see a bit of the floater being vaporized and disappearing on each laser shot.

(3) Most believe incorrectly that laser treatment for floaters produces retinal detachments. However, the world experience with the procedure shows it is safe for the retina (see Chapter 19).

(4) They mistakenly believe that all floaters improve with time. Some floaters do improve by partial absorption or by moving more anterior or out of the optical axis. But other floaters do not improve with time and remain symptomatic.

This procedure is virtually unknown to ophthalmologists. The procedure will fail if insufficient laser power is used. But with the power, techniques, and equipment described here, success was attained in 92 per cent of our patients (using our five criteria of success on page 67).

The purpose of this book is to present:

- the background information of this procedure including laser physics,
- what was learned from the author's performing the operation (hundreds of original observations and techniques),
- what was learned from the author's research projects, and
- the author's 14 original contributions to laser floater treatment (see Appendix O).

Sources for the book: The literature is extremely limited on laser treatment of floaters. No book has previously been written. The information on floater formation in Chapter 1 is generally known by ophthalmologists. The sources for Chapters 5, 6, and 7 are footnoted. Chapter 5 on the Laser Physics of Floater Obliteration was by far the most difficult and time consuming to research, simplify, and write. It is not necessary for a clinician to understand these principles, but they are fundamental and necessary for those who plan to do research or attempt to innovate in this field. The source for the remaining 24 chapters and the Appendix is almost exclusively from the author's performing the procedure, experimenting, trial and error, designing new devices, modifying devices, and many research projects marked in the book as

(Research project:…). A listing of a "Research project" in the text is to inform the reader that I have already done this project and my results.

This book was based clinically on my experience with over 2,000 laser floater operations. This number includes the 200 consecutive, eligible cases of my Formal Floater Study that was submitted to the U.S. Food and Drug Administration and done under the supervision of the INOVA Fairfax Hospital Institutional Review Board (Chapter 10). My 2,000 operations had a significant complication rate of 0.16 %, compared to a much higher significant complication rate for vitrectomy (see Chapter 2). Vitrectomy is the only other proven therapy. This difference in the complication rate is a compelling argument for laser treatment being the procedure of choice for most vitreous opacities.

The only effect of firing a YAG laser into the vitreous that we explore in this book is the disintegration and vaporization of the floaters. But the laser also permanently severs vitreous strands and architecture and thereby reduces vitreous traction with each shot. This reduction in vitreous traction is perhaps the reason that this procedure does not produce retinal detachments and may indeed act to prevent retinal holes and detachments.

My study of laser treatment of eye floaters has been the most rewarding pursuit of my career. But there were roadblocks.

The first problem was that our original YAG laser could not perform the procedure very well. Almost any ophthalmic YAG laser can perform this procedure in the anterior vitreous. But to perform the procedure in the mid and posterior vitreous, the laser must have the slit lamp illumination almost coaxial with the treatment beam (Chapter 22). To find a better laser, I contacted most manufacturers, had some lasers sent to me on a trial basis, and eventually purchased a currently manufactured laser that could do the procedure better.

The next problem was there were not enough patients in our practice with highly symptomatic floaters for a large study suitable for publication in a peer reviewed journal. Also, referrals from doctors for an unknown procedure were not realistic. The solution was to develop an educational website so patients suffering from floaters could refer themselves. This meant learning something about domain names, web site construction, web site housing, how to write a web site and how to supply the graphics. Fortunately the best domain name, "eyefloaters.com," was still available. Within a few months our web site, www.eyefloaters.com, was on line. To help gain the patient's confidence, an unusual amount of information was placed on our web site. There was an immediate response to our web site. Because of the web site patients from 49 states and 23 foreign countries were eventually recruited for our study.

After performing the procedure on several patients, I submitted a lengthy protocol to our hospital Institutional Review Board to perform a formal study on “Laser Treatment of Vitreous Opacities.” My plan for an IRB floater study was suddenly exponentially complicated when the hospital consulted with the FDA which then ruled that YAG lasers were not approved for this procedure, and I would need an Investigational Device Exemption for the study. This process required that I spend over two months producing reams of documents for the Investigational Device Exemption application to the FDA. However, my application did result in the FDA ruling (paraphrased) that my study of laser treatment of vitreous opacities was a non-significant risk device study. Their ruling further stated that an Investigational Device Exemption for the laser is not required in non-significant risk device studies (see Chapter 18). With this favorable ruling, my Formal Floater Study was begun. At present, laser treatment of floaters is considered an off-label use of the laser.

During this time I feared that someone would perform this procedure without proper study or equipment, would publish their poor results, and give the procedure a bad name before I could submit a large, proper IRB study to a peer reviewed journal. Therefore, I rejected all offers from newspapers and non-peer journals for interviews and articles, and asked the many patients who wanted to write a newspaper article about their good result, not to do so. For this same reason I did not submit any grant applications and bore all the costs of the study myself. It was and is my intention to present this procedure only in this book and medical journals, and not in the lay press.

For the patients in my Formal Study, it took an enormous leap of faith to board an airplane or drive for hours to obtain a virtually unknown operation that they had in most cases been warned against, that was to be performed by a surgeon unknown to them.

For me, it took an enormous faith in the efficacy and safety of this new procedure to proceed. But in spite of some mental travail, we continued the Formal Floater Study because the patient satisfaction was very high and there were no significant complications.

The final hurdle for this book was its rejection by a major book publisher because their medical advisor said “…at present there is no interest in this subject.” By definition, that would be true of any unheard of procedure. This rejection was actually a bit of good luck because it stimulated me to take the legal and business steps to found a publishing company that performs traditional as well as internet commerce.

It has taken 10 years to perform the 2,000 operations, develop my techniques and devices, complete the 15 research projects and studies reported here, and to write this book. It is hoped that this book (the only source of detailed information on this subject) will eventually lead to this procedure being widely offered to patients with visually significant floaters.

DISCLAIMER AND WARNING

Every attempt has been made to present this information in a comprehensive and accurate way. The literature searches were made by the author and by the library research staff of INOVA Fairfax Hospital of Falls Church, Virginia in conjunction with the National Library of Medicine. The sources were scant. Each clinical statement here was based on the author's understanding of the mechanisms and his clinical observations. The reader should assume that some of the concepts and techniques will be improved upon as other surgeons begin to perform the operation, and one should assume that some information may be incomplete.

The reader should proceed cautiously with this procedure, remembering that ocular YAG lasers were designed to disrupt and destroy ocular tissue, and the surgeon is in sole control of what is destroyed. The procedure requires case selection, caution and concentration. As with any operation, there may be complications. Chapter 20 on Avoiding Complications should be read carefully before performing the procedure.

The author will be pleased to correct any errors or omissions in additional printings and welcomes hearing of new techniques that other doctors may develop.

John R. Karickhoff, M.D.
2005

There have been several printings of this book since 2005. For each printing the book has been updated to new literature and development of new techniques. The most significant of these is my development of the Moses Maneuver (pages 105 and 171) which often makes possible vaporizing floaters in the more posterior vitreous. I have now performed the procedure on over 6,000 eyes.

John R. Karickhoff, M.D.
2019

CHAPTER 1. THE VITREOUS, FLOATER FORMATION, FLOATER TYPES, AND CLINICAL COURSE

THE VITREOUS

Normal vitreous appears clear. It is 99 percent water but does have a slight collagen network of fibrils that can degenerate causing floaters. The other main constituents of the vitreous are soluble proteins (mainly acid lipoproteins and serum proteins) and hyaluronic acid. These probably play a lesser role in forming floaters. The hyaluronic acid molecules can retain water and that gives the vitreous its gel consistency. At the border of the vitreous the collagen fibrils condense to produce the hyaloid "membrane." In the normal eye this structure is lying against the internal limiting membrane of the retina, but with disease and aging it often separates and moves centrally. With the slit lamp some structure such as fine membranes without definite borders are usually seen in the vitreous.

When vitreous is lost from the eye during trauma or surgery, no new vitreous forms. The space is refilled naturally with aqueous fluid or temporarily by the surgeon with fluid, gas, or silicone oil.

FLOATER FORMATION

The most common degenerations of the vitreous are liquefaction (syneresis), shrinkage, and opacification.

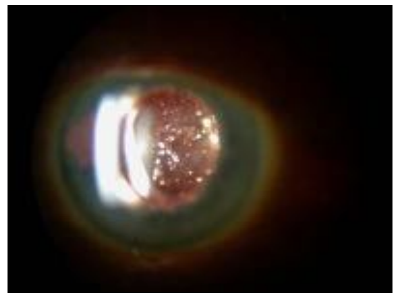
Liquefaction occurs with aging, myopia, trauma, intraocular iron and copper, inflammation, and other rarer causes. In the aging process the hyaluronic acid molecules release their water molecules and form pockets of liquefied vitreous. When this happens, the collagen framework collapses and coalesces into fibrils. Once this happens, it is permanent. Frequently this change goes unnoticed by the patient, or they note some floaters and perhaps more movement of the floaters than before. But with a slit lamp the results of liquefaction can be seen.

Liquefaction usually results in mild vitreous opacities, but in some individuals, the opacities are severe, interfering with driving, reading, computer usage, and tasks on the job. They are doubly troubling if they are bilateral or the patient has use of only one eye. These are best seen with the direct ophthalmoscope using the +10 lens held about four inches from the patient's eye while looking toward the optic nerve. Both the patients and the eye doctor can see large floaters. But only the patient can see the tiny, thread-like transparent floaters that patients describe. These are very common. Patients see floaters as small particles moving in their vision. Attempts to move the eye and get the floaters into the center of the vision for close inspection are usually unsuccessful. They are most easily seen by the patient when the pupil is smallest and when looking at a homogeneous bright background. Examples are looking out an airplane window at the clouds or at a white ceiling. With floaters there is a fast component of about a second and then a slow component of about 5 seconds as they return to their original position. Opacities from the colloid of the gel can be extremely small or can be clumps, or fiber-like strands and membranes. Traditional thinking is that these opacities are of little importance, but actually, they are quite disturbing if they are large and posterior in the eye where they cast a distinct shadow on the retina. This shadow can affect functional vision, employment, and lives. A significant new opacity generally in the periphery can indicate hemorrhage from a retinal tear. Floaters consisting of blood frequently absorb without treatment, but the floaters made up of collagen or fibrin absorb very little. When a floater is formed by the glial condensation separating from the optic nerve head leaving a Weiss ring in the mid vitreous, there is little absorption.

Other causes of floaters besides degeneration are hemorrhage from adjacent tissue and trauma. Trauma can be as coarse as a blunt blow to the head causing a vitreous detachment, or may be as discrete as a surgical procedure including LASIK. I have had at least three dozen patients that stated to me that their floaters became noticeable a week or two after LASIK surgery. Retinal detachment has also been reported after LASIK. It is thought that the mechanism of floater and retinal tear production is the axial length increase with anterior displacement of the vitreous base during the suction ring placement.[1] An alternate mechanism would be the release of the suction ring causing a sudden change in the shape of the eye.

FLOATER TYPES

Asteroid hyalosis is a vitreous degeneration visible with the slit lamp or direct ophthalmoscope that appears as hundreds of tiny floating spherical particles suspended in the vitreous. These particles, which are calcium soaps, have a golden hue. They are mobile when the eye moves but stay suspended in the vitreous. The condition is rare and usually unilateral. As an experiment, I have tried a few times to obliterate one of these opacities with the laser. They must be very hard because they seem to be totally unaffected by direct hit laser shots of 10 millijoules power. Rarely a hyaline floater conglomeration will be mixed in with the asteroid hyalosis floaters. The hyaline floaters can be treated effectively, but care must be taken not to hit the retina which is seen poorly because of the asteroids.



Asteroid hyalosis.

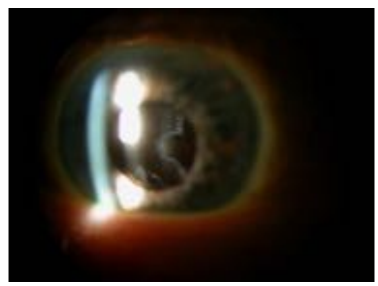
A vitreous detachment from the inner wall of the eye is common. The percent incidence of this is about equal to the patient's age. This can be a small cul-de-sac detachment, an infundibular detachment (where the vitreous has a tent shape with the apex being at the disc and the base at the ora), the rare anterior detachment, or the common posterior vitreous detachment (PVD) where the vitreous comes forward. A posterior vitreous detachment is more common in patients who are nearsighted, have undergone eye surgery, or had inflammation in the eye. When the vitreous separates from the retina, it can cause hemorrhage of the retina, a retinal tear, or a Weiss ring which is a circle of peripapillary glial tissue attached to the detached vitreous face (Color page 100, Figure 11).

The vitreous can also become organized into membranes as found in diabetes. The YAG laser can be used to attempt to cut such membranes. But the risk in this is much higher than in floater disruption.

Hemorrhage from adjacent tissue is a major cause of floaters. Usually this absorbs without complication, but two undesirable processes can occur. First, hemorrhage can lead to fibroblastic proliferation and membrane formation. And, second, these conditions can lead to retinal detachment. Hemorrhage can also lead to hemosiderosis, some blockage of the trabeculum and hemorrhagic glaucoma.

Most **treatable floaters** are one of seven types:

1) In the young and especially those with higher amounts of myopia, the gel liquefies, leaving clear spaces interspersed with string-like protein strands.



Posterior vitreous detachment.

2) In young, middle-aged, or older patients, the protein fibers of the gel can coagulate to form cotton ball like clumps or clouds. These syneresis (liquefaction) clouds are a type of fibrillar degeneration.

3) At the border of the vitreous, especially at the optic nerve where the collagen fibrils are dense, a posterior vitreous detachment (P. V. D.) can occur which moves the dense fibrils toward the center of the eye. Frequently this results in a Weiss ring type of floater. There may be an associated retinal hemorrhage (color page 99, Figure 5).

4) When only part of the peripapillary collagen fibrils are torn off during the vitreous detachment, the floater seen will be peripapillary glial tissue without the ring shape attached to the posterior vitreous face. These "incomplete Weiss rings" are very common. Such floaters, (3) and (4), pulled off the optic nerve are soft and easily vaporized with a YAG laser.

5) There is also a "floater duet." This consists of a Weiss ring ordinarily located centrally and syneresis clouds ("snow globe" floaters) located far inferior and anterior in the vitreous. The Weiss ring is seen most of the time by the patient. But the inferior cloud is not seen when the eyes are not moving, such as while watching television. But when the eyes are moved, it swings up into the vision and then quickly falls back below the line of sight. The importance of the "floater duet" is the tendency for the doctor to find only the Weiss ring and miss the inferior syneresis cloud. If that happens and only the Weiss ring is treated, the symptoms will remain and the patient will know that they have undergone an unsuccessful operation. It is very difficult to treat the inferior floater (see details in Chapter 16 of "floater duet" pg. 113).

6) Scarred tissue from cryo and laser treatment of retinal detachment and holes sometimes separates from the retina producing

floaters. These floaters are denser and less responsive to the laser than floaters that arise from vitreous degeneration, but they can normally be treated with the YAG laser.

7) We usually don't treat floaters caused by ocular inflammation because the inflammation and floaters may return after treatment. However, floaters that came from toxoplasmosis that is now quiescent is an exception. These floaters are responsive to the laser, but are generally in the deep vitreous, and, thus, should be treated only by experienced surgeons.

We do not attempt to treat tiny cellular elements or pigment granules with the laser.

COURSE OF FLOATERS

The course of floaters varies greatly according to their type. There is rarely any improvement with time in those floaters that develop slowly through vitreous degeneration. However, there is frequent improvement with those floaters that come on suddenly due to posterior vitreous detachment. These floaters improve by three means. (1) They can improve by absorption. If the floater is made up of blood, usually this will absorb in a few weeks. But if the floater is made up of fibrin or collagen, there will be little absorption. (2) The symptoms can improve if the floater moves forward in the eye. The further a floater is from the retina, the less distinct and troublesome is its shadow. Forward movement which relieves symptoms is often seen with Weiss rings. (3) Symptoms are improved when floaters move out of the central optical axis. Off-axis floaters do not cast a moving shadow across the macula.

Because some floaters improve with time as described above, laser treatment should not be offered until there has been two months without improvement since the onset.

[1] Flaxel et al: Proposed mechanism for retinal tears after LASIK, Ophthalmology, 111: 24-27, 2004

CHAPTER 2. FLOATER TREATMENT OPTIONS

DO NOTHING ("LEARN TO LIVE WITH IT.")

At the present time, if a patient presents with a visually significant floater, and the patient's retina is found to be normal, the chances are very high that they will be advised to "learn to live with it." Patients are told this because (a) the rate of significant complication from vitrectomy is high (see Vitrectomy below), and (b) because laser treatment of floaters is essentially unknown.

It is true that many patients can disregard their floaters if the floaters are small, and the patient has been advised that the floaters do not indicate any serious trouble. However, if the floaters are large and interfere with their daily function, such as reading, driving, or use of a computer, they may not be able to disregard it (see symptoms, Chapter 3).

SUNGLASSES

Two patients who came for laser treatment claimed that yellow sunglasses were some help in relieving their floater symptoms. One, a pilot, thought sunglasses reduced seeing the floaters against the bright sky. The other patient liked them for ice fishing and said many ice fishermen used them. Sunglasses would reduce the amount of light going into the eye and would possibly enlarge the pupil slightly. Any enlargement of the pupil makes floaters less obvious whereas any constriction of the pupil creates a more distinct shadow of the floater on the retina.

(Research project: The project was to attempt to see if any particular color of sunglasses was more helpful than other colors in the reduction of seeing floaters. I purchased from Edmonds Scientific 100 Roscolux different colored filters similar to that used in sunglasses (color page 99, Figure 6). Patients with floaters were given these filters in the waiting room to see if any particular color was helpful in decreasing seeing their floaters. The result was that no color, including yellow, was particularly helpful in reducing their seeing the floaters.)

HERBAL MEDICINES

Herbal medicines and nutritional supplements have been touted as a treatment for floaters, but their effect on floaters is unknown. Some evidence given below suggests that some of these products are actually more likely to cause floaters than to cure them.

To my knowledge, the efficacy and safety of any of these herbal medicines has not been scrutinized with a double blind study on floaters. The likelihood of meaningful research in this area in the future is low due to the problems cited below.

The use of herbal medicines and nutritional supplements has increased in recent years. A survey of 1,539 adults revealed that in 1997 42.1% were using these products.[1] These products are not governed by the U.S. Food and Drug Administration. Because they are not sold to treat specific diseases, they fall under the Dietary Supplement and Health Education Act of 1994. To sell these supplements, no efficacy or safety has to be proven. There is no official standard for these products.[2,3] Consequently, the purity and potency is suspect. For example, The American Botanical Council in 2001evaluated ginseng products and found that 52% of them contained no ginseng at all.[4] Research tends to be meaningless if potency is unknown.

For herbal medicines to be effective on floaters, theoretically, they would have to selectively absorb the fibrin and collagen of the floaters without absorbing the fibrin and collagen of vital structures of the eye. This absorbing of vitreous floaters is especially unlikely because it would have to occur in an avascular environment where there would be little phagocytosis. Further, it is difficult to envision floaters absorbing due to small amounts of chemicals taken by mouth when a direct hit by the laser with a 20,000 degree centigrade vaporizing temperature has little effect on some of them.

If not helpful, are herbal medicines and dietary supplements harmful? A recent study of these products (taken from spontaneous complaints to the World Health Organization, the FDA, and the National Registry of Drug–Induced Ocular Side Effects) lists approximately 40 such products that caused ocular side effects.[5] For example, there were 27 complaints to the National Registry on ginkgo biloba, one of the most popular and best selling herbal medicines. These complaints contained 2 cases of spontaneous hyphema and 7 cases of retinal hemorrhage in people taking this agent.[6,7]

VITRECTOMY

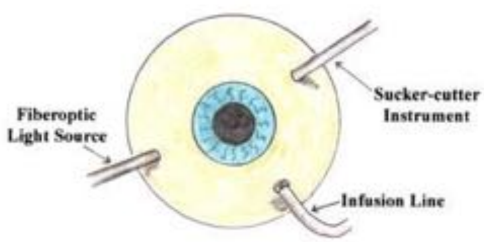
Vitrectomy can remove the vitreous fluid and anything that is in the vitreous, such as floaters, membranes, hemorrhage, debris, or small foreign bodies. This operation can also be used in retinal detachment surgery to cut vitreous strands that are pulling on the retina. Vitrectomy is a major advance and an invaluable procedure in eye surgery because it makes treatment possible for certain eye diseases where formerly the situation was hopeless. Pars plana vitrectomy and its sophisticated instrumentation was developed largely by Doctor Robert Machemer.[8] Doctor Machemer is Chairman Emeritus of the Department of Ophthalmology of Duke University. I received my post graduate training in ophthalmology at Duke and for years have served on their Advisory Board. I discussed my research study on laser treatment of vitreous opacities with Doctor Machemer. After learning some of the details, he encouraged me to proceed with my investigations on laser treatment of floaters, and gave me helpful suggestions and some safeguards for my study. After ridicule elsewhere for studying this subject, I appreciated this encouragement, coming from the "father of vitreous surgery."

Doctor Robert Machemer

Closed eye vitrectomy is the only established alternative to laser treatment of floaters. However, vitrectomy is typically used to treat only the most severe floaters that are obscuring vision because vitrectomy carries a high rate of significant complication. A partial list of complications from vitrectomy would include: cataract formation,[9] corneal complications,[10] retinal breaks, retinal detachment and endophthalmitis,[11] and recurrent vitreous bleeding.[12] For example, a series of 21 patients treated with vitrectomy for floaters resulting from other diseases had complications of retinal tears, retinal detachment, vitreous hemorrhage, hemolytic glaucoma, and corneal blood staining.[13] But these vitrectomy operations were performed for diseases far more serious and prone to complications than floaters resulting from only vitreous degeneration.

For a comparison of the safety of laser vs. vitrectomy treatment for floaters, a large series of vitrectomies done for floaters that developed from vitreous degeneration only is needed. Unfortunately, there is no such large study. However, a series of 6 vitrectomies done for only degenerative floaters had no complications (8-44 month follow up).[14] Another series of 15 eyes that underwent vitrectomy for a floater contained one patient (6 per cent) who developed a cataract one year after the vitrectomy and one patient (6 per cent) who developed a retinal detachment at 7 weeks after surgery. In this same study, 39 eyes had laser treatment of their floater and the complication rate for laser treatment was zero.[15]

In the simplest vitrectomy case, the surgical maneuver of running fluid through the eye is necessary and this contributes to the most frequent complication of vitrectomy, that is, cataract formation. With vitrectomy, cataract formation occurs within two years in nearly all patients over age 50.[9] Younger patients are less likely to develop a cataract. The average age of the 200 patients in our Formal Study of laser treatment of vitreous floaters was 56 years. So the patients in our laser treatment series were in the age group where the complication of cataract alone is very likely.



Vitrectomy.

Vitrectomy is seldom needed for floater treatment, but there are some indications for treating floaters with vitrectomy.

In spite of the high rate of complication, vitrectomy should be considered if the laser will not be effective or it can not be used, and the floaters are quite symptomatic.

Examples of floater types that should be referred for vitrectomy as the initial treatment are:

(a) a very large floater such as a thick Weiss ring that is too close to the retina for the laser treatment;
(b) extensive floaters that swing up into the visual axis on eye movement but rest too far inferior to the visual axis to be treated by the laser;
(c) an extremely thick "corn flake" type floater located anywhere in the vitreous;
(d) a Weiss ring remnant with a fan shaped opacification of the adjacent vitreous face (I believe the fan indicates a high fibrin content of the floater and a poor response to the laser);

(e) widespread, dense syneresis floaters; and
(f) patients with an especially large number of dense floaters and a cloudy vitreous who have had retinal detachment and repair with an encircling band. (A pars plana vitrectomy can be done in these patients who have an encircling band because the incisions for the vitrectomy are made 3-4 mm posterior to the limbus and their band is usually situated further back, posterior to the muscle attachments).

Vitrectomy is more likely to be recommended if the patient has already had cataract extraction because now there is no chance they could develop a cataract, and in patients who already have a vitreous detachment because retinal tears and retinal detachment are less likely.

The vitrectomy procedure normally consists of opening the conjunctiva and then making three incisions through the sclera into the eye. A tube is inserted through one incision to supply saline into the eye during the procedure and sewed in place. A fiber optic light pipe is inserted through another incision, and a sucker-cutter instrument is inserted through the third incision. The fluid inflow is started and the light is turned on, and the suction and cutting is started. As the vitreous is cut and sucked up, it is replaced with saline. Then the instruments are removed and the three incisions and the conjunctiva are typically closed with sutures. The patient requires careful monitoring, and eye drops are used in the early postoperative period.

Vitrectomy can remove any floater, but much of the vitreous must be removed in hopes of also removing the floater. Unlike the highly directed laser treatment, vitrectomy is not a precise procedure dealing with solely the floater. And due to the fluid flowing through the eye, there is much movement of the vitreous and the floaters.

If the patient has a cataract and floaters in the same eye, vitrectomy and cataract extraction with intraocular lens implant can be done in the same operation. A continuous curvilinear anterior capsulotomy is performed, and then the cataract is removed with phacoemulsification. Then a continuous curvilinear posterior capsulotomy is done and the vitrectomy instrument is inserted into the posterior chamber through the posterior capsulotomy. Important details of this operation are described by Mossa.[16]

Recently the vitrectomy instruments that go into the eye have been reduced in some cases to 25 gauge making it possible to do the vitrectomy without sewing the tubes onto the eye. This speeds the operation and may reduce slightly the rate of cataract formation because less fluid may be passed through the eye. The follow-up of their study was too short to learn the rate of cataract formation. In this first report of use of these smaller instruments, one of the 35 eyes in the study developed a retinal detachment one month post-operative.[17] Another group reported using the 25 gauge instrument on 45 patients. For their mean follow-up of 13 months, they reported a 2.2% incidence of retinal detachment and 79.3% incidence of worsening cataracts.[18]

LASER TREATMENT

This book presents the details of laser treatment of vitreous opacities. A few of the advantages of the laser treatment when compared to vitrectomy are:

- the rate of significant complication with the laser procedure was 0.10 percent in our 2,000 operations, compared to a much higher rate from vitrectomy,
- with the laser there are no restrictions on activities,
- it is a precise obliteration of the floaters without removal of vitreous,
- it is less expensive,
- there is no blood supply to the opacities, therefore, they can not bleed,
- this is a non-invasive procedure (no intraocular infections), and
- the procedure is suitable for both the general ophthalmologists and retinal specialists.

Success from laser treatment is found in Chapters 9 and 10.

WHY LASER TREATMENT IS UNKNOWN

There are several reasons why this procedure with the positive attributes mentioned above remains unknown.

(1) The procedure was conceived and performed originally by Doctors Daniele Aron-Rosa and Franz Fankhauser, probably ophthalmology’s two most respected laser pioneers. Although both of them successfully treated floaters without complications using the laser, they mentioned treating floaters only in passing or not at all in some of their writings. Also much of their writing was in the European medical literature. There has been no book written on laser treatment of eye floaters until now. Therefore, most eye surgeons have had little chance to learn about the procedure.

(2) A proper laser for the procedure was not readily available in the United States. A large, YAG laser (the Lasag Microruptor II) was designed for laser vitreous surgery by Doctor Fankhauser. It was excellent for treating floaters, but it was made in Switzerland and was not widely sold in the United States. Its production was discontinued in 1993. Thereafter, the market became dominated by small YAG lasers. Unfortunately, these smaller lasers were designed for performing posterior capsulotomies and some can not disrupt floaters in the mid or deep vitreous. In year 2000 a new, small laser (Laserex LQP 4106) came on the market that could perform the laser procedure for floaters.

(3) Many doctors believe that vitreous floaters are not visually significant. Knowing that this opinion is widespread, many photographs of visually significant floaters were placed in this book. Some floaters we have seen are so dense that when seen with the slit lamp using a contact lens, they cast a shadow so dark on the retina that it looks like a dark hemorrhage. Such a shadow can not be disregarded. It ruins a patient's quality of life.

(4) Many times patients are not examined carefully for floaters (using the +10 lens of the direct ophthalmoscope) because if one were found, vitrectomy, the well-known treatment, would not be justified.

(5) Many doctors used to believe that any manipulation of the vitreous was harmful. But in the 1970's it was shown by Doctor Machemer[8] that even complete removal of the vitreous with proper instruments can be helpful.

(6) And finally, there has been little attempt to popularize this procedure by those familiar with it.

Although the laser procedure is virtually unknown, as of this writing, about 3,500 laser procedures for eye floaters have been performed in the United States.

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CHAPTER 3. SYMPTOMS, FLOATER HISTORY, AND JUSTIFICATION FOR TREATMENT

SYMPTOMS

Simulated floater.

Floater symptoms vary greatly. They range from being annoying to being visually debilitating. The most common complaint is that patients see specks in their vision all the time. Frequently they complain of difficulty driving, using a computer, or reading. Complaints can be specific for work related tasks. I recall a policeman who retired because a thick Weiss ring prevented him from aiming with his shooting eye at critical times. I recall a college teacher of hand-ball who was severely handicapped by a floater. Another unhappy patient was an author of 40 books. She recently developed a Weiss ring in each eye that gave her daily migraine headaches and took all joy from her writing. Another patient, a church organist, said: "I can't see the notes when the floaters get into my direct line of vision. They don't pay me to play the bad notes." I recall a lawyer who had two round floaters, one much larger than the other. He called them his "moon and earth floaters." The day after treatment the floaters were gone, and he could read without effort and distraction for the first time in 20 years. In my own case I had trouble using the direct ophthalmoscope with my right eye because of a large floater. When I saw a floater, I could not tell whether it was mine or the patient's. These patients, including myself, and hundreds more have been safely and successfully treated with the laser.

Try to differentiate symptoms coming from floaters which are discrete dark masses (treatable) from symptoms coming from the vitreous face which is a vague, slightly hazy, moving glob (usually not treatable).

Four things determine the severity of symptoms of a floater. They are: (1) the size, (2) the anterior -posterior location, (3) the central-peripheral location, and (4) the personality (anxiety level) of the patient. I believe that these four factors can be related, at least theoretically, in a mathematical formula that I derived. This formula lets one predict not only the amount of symptoms this floater should produce, but also how dramatic will be the improvement if the laser eliminates the floater.

The size (mass) of the floater is a direct mathematical relationship, i.e., the bigger the floater, the more severe the symptoms.

The more posterior the floater is (the nearer to the retina), the worse the symptoms. These posterior floaters cast a very distinct shadow on the retina and that is what causes the symptoms. Young patients who have small floaters near the retina and no posterior vitreous detachment to pull them forward, usually have many symptoms, sometimes including depression and suicidal tendencies. Older patients with large anterior floaters frequently have no symptoms at all. This could possibly be because of a willingness to tolerate more visual problems, but I think it is mainly due to opacity position. It seems that the further from the retina, the less the symptoms. But it is not a direct relationship. I think the symptoms reduce by about the square of the distance from the retina.

Central floaters cause more symptoms than peripheral floaters. This seems like a direct relationship.

Finally, the more nervous and anxious the patient is, the more symptoms they mention (a direct relationship).

$$\text{Severity of Sympt.} = \text{Mass of floater} \times \frac{1}{\text{distance squared from retina}} \times \frac{1}{\text{distance from optical axis}} \times \text{Anxiety}$$

Karickhoff Severity of Floater Symptoms Formula

Floaters are best seen by patients in situations where there is bright illumination, such as looking at white paper, a computer screen, or a large fluorescent light. They are especially visible when looking at bright clouds out of an airplane window. These situations make the pupil small which forms the light into a column. This causes a distinct shadow of the floater on the retina.

Patients with floaters often see flashes of light in their eye, especially at the onset of the problem. As might be expected, patients with both floaters and flashes have a higher incidence of posterior vitreous detachment and retinal breaks than those with floaters or flashes alone.[1]

The following symptoms have the highest association with retinal tears: visual symptoms of diffuse dots, many vitreous cells, and grossly visible vitreous and preretinal blood.[2] A study of 148 eyes with sudden onset of floaters found a posterior vitreous detachment with prepapillary glial tissue on the posterior hyaloid membrane in 83%.[3]

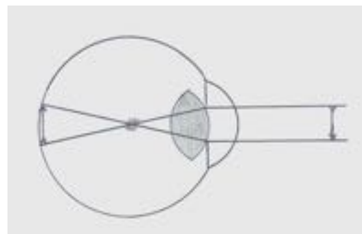
In the great majority of people with floaters, they are mild and can be ignored. But in other patients, floater symptoms can be severe and often can not be ignored. They can greatly affect concentration and the quality of life.

Doctors regularly make two incorrect assumptions about floater patients and their symptoms. (1) The doctor sees several patients with large floaters that do not bother the patients. Then when they see a patient with a small floater or one the doctor can not see, and it bothers the patient, the doctor concludes that that patient is exaggerating their symptoms. (2) They assume that all floater patients can learn to disregard their floaters because the doctor has seen many older patients with a large floater that was not bothering the patient. These two incorrect assumptions are explained once floater symptomatology is explored.

Patients can see many floaters that the doctor can not see. Keep in mind that a patient with 20/20 vision can see an object at the retinal level the size of a white blood cell. This is the basis of the blue field entoptic test that allows patients to view their own white blood cells moving in the perimacular vessels. If they can see their own white blood cells, this means their visual potential is 20/40 or better. I adapted this test so that the slit lamp is used as the light source.[4] If the patient can see something this small, then they can also see their tiny, segmented, transparent, thread-like floaters that the doctor can not see. Fortunately this kind of floater does not block vision and does not require treatment. But the point is, when the doctor can't see the floaters, this does not mean that the floaters are not there or the patient is exaggerating their symptom.

The patient sees the floater by blockage or distortion of incoming light, meaning, the patient can even see a transparent floater. However, the doctor sees a floater only by reflected light, meaning the doctor can not see a transparent floater. For the doctor to see the floater, it must be opaque and light must reflect off of it, pass out through the patient's eye, through air, through the ophthalmoscope, through air again, through the doctor's eye, and register on the doctor's retina. So, just because the doctor can not see the floater does not mean there is not a significant floater present, or the patient is falsely complaining about it.

Floaters, if situated in the optical axis, can affect the visual acuity. Most treated patients get a small improvement in visual acuity. The largest improvement I've seen has been five lines on the Snellen chart. I do not mention possible improvement in visual acuity to patients before the treatment because it is variable depending on the location of the floater.



Treating this central floater will improve visual acuity.

FLOATER HISTORY

The most important questions in the patient's history are: when was the onset; the severity of symptoms; in what activities does the floater bother the patient; presence of diabetes; past or present eye problems or surgery; any history of elevated eye pressure, glaucoma, taken or taking glaucoma drops; history of psychiatric problems; or eye diseases in the family? My floater evaluation work up form contains these questions and is reproduced in Appendix A.

The most important item to discuss with the patient is your assessment of possible improvement from the procedure. With most Weiss rings my statement is that our Formal Study showed that about 95 per cent of patients have a major improvement. If the patient has numerous floaters, my statement is that our Formal Study showed that about 75 percent had an improvement. The number varies somewhat according to the case, but I write my prediction of the percentage of improvement on their chart and show it to them. The important blank for writing this assessment is at the bottom of the work-up sheet (Appendix A).

JUSTIFICATION FOR TREATMENT

We do ask all patients to wait two months after onset before having laser treatment. If the floater is made of blood, it will usually get better in that time. If it is made of collagen or fibrin, there will be little improvement.

Visually insignificant floaters do not warrant treatment. If vitrectomy (with its high complication rate) were the only treatment available, there would rarely be justification for floater treatment. However, when symptoms are significant, the justification for treatment with the laser is (1) the very high success rate with reduction of symptoms and (2) the very low complication rate.

Keep in mind that in one study, patients were willing to trade an average of 1.1 years out of every 10 years of remaining life to eliminate their symptomatic floaters.[5]

[1] Hikichi T, Trempe C: Relationship between floaters, light flashes, or both, and complications of posterior vitreous detachment. Amer J Ophthal 117: 593-598, 1994

[2] Boldrey E: Risk of retinal tears in patients with vitreous floaters. Amer J Ophthal 96: 783-787, 1983

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CHAPTER 4. THE FLOATER EXAMINATION

A complete eye examination is done on each floater patient. Items especially pertinent to laser treatment of floaters are: the approximate refraction (helpful because it gives a general idea of the axial length of the eye which may affect which surgical contact lens you choose); corrected visual acuity; intraocular pressure; presence of corneal scaring; presence of geographic corneal dystrophy (this condition may be irritated by the surgical contact lens during the procedure); presence of a cataract, posterior vitreous detachment, and peripheral retinal pathology.

A contact lens examination is done only if the patient is bothered by their floaters and may be a surgical candidate. We use Bausch and Lomb Liquid Gel for the solution under the examining contact lens.

The order of my specific examination for floaters is: (a) look at the vitreous of the dilated eye with the slit lamp to see if there is a posterior vitreous detachment (PVD), and to see if anything is floating by when the patient looks around, (b) look at the peripheral retina with the indirect ophthalmoscope, (c) look for floaters with the +10 lens of the direct ophthalmoscope focused in the vitreous, and (d) look with a diagnostic contact lens with a flat front face. If you see significant vitreous floaters, make a location drawing from the anterior and side view. If there is more than one floater or any question of which floater you are going to treat, draw the location exactly. During surgery it is easy to go to the wrong floater.

An incomplete PVD can be missed using only the slit lamp. It is best seen with a diagnostic contact lens. A PVD means the floater has been pulled forward into the center of the vitreous cavity where the surgery is easier and more successful. A PVD is rare in patients under 30 years of age. They are found in about 10% of patients between 30 and 59, 27% between 60 and 69, and about 63% in patients 70 and older.[1] Of course you will find a full PVD associated with each Weiss ring.

What type of floaters should you expect to find? A study of 148 eyes with sudden onset of floaters found that 83% had a posterior vitreous detachment. In those eyes the primary form of the floaters was prepapillary glial tissue on the detached posterior hyaloid membrane. In the eyes with no PVD, intravitreous fiber-like opacities were present in the plicated membranes of Cloquet's canal or were associated with liquefaction of the gel.[2]

THE FLOATER FINDER

In most patients the floater is large and easily found. However, with smaller floaters that are difficult to locate (usually in younger patients) I have designed a simple, low technology device that tells the direction the floater is located from the macula and how far it is from the retina. The device is simply a white sheet of paper with some marks on it. A copy of my Floater Finder is in Appendix H. This test must be done before dilation.

In one corner of the Finder are drawn two opacities. One is branching, very distinct, appearing like a few strands of fungus under a microscope. The other opacity drawn there is a vague glob. I ask the patient which drawing most resembles their opacity. If they choose the distinct one, that means their opacity is very near the retina, casting a distinct shadow on it. If they choose the vague glob, their opacity is not close to the retina. There is also a black dot for fixation in the center of the page.

To find the direction and distance the floater is from the optic nerve, cover the patient's eye without the opacity and then hold the Floater Finder paper four inches from the eye with the opacity. Use a strong light shining from above (I use the light on top of the phoropter stand) between the paper and the eye. Ask the patient to look around to move their floater so they see it, then have them look at the black dot at the center of the paper and point on the paper with their finger to where they see the opacity. Put your finger where they pointed to and turn the page upside down. In your mind consider the central dot as their macula and then look in their eye for the floater in the location your finger is from the macula. This exercise need only be used in young patients with tiny opacities.

The best screening examination for floaters is made with the direct ophthalmoscope using usually the +10 diopter lens with the patient's iris in near perfect focus. Use the broadest beam of the direct scope. The best view comes when there is retro-illumination from the optic nerve. Ask the patient to look at the vision chart, and then as you use the scope, have them look to the right and then back to the vision chart, then left and back to the vision chart, then up and back to the vision chart, and down and back to the vision chart. The purpose of this is to try to swing the floater centrally and to discover any hidden floaters. Then do the same maneuvers while decreasing the power of the lens in the scope to take you more posterior in the vitreous.

The direct scope is excellent for learning the presence and direction of floaters, but it can also predict their depth fairly well. Use the +10 lens and adjust your head distance so the iris is in perfect focus. Locate the floater and without moving your head, put the floater in best focus and note that scope power. Then focus on the retina and note that power. An anterior floater might be recorded as 10/7/0 (indicating the iris power, the floater power, and the retinal power). A posterior floater might be 10/3/-1. With an anterior floater, I tell the patient it is treatable. If it is a posterior floater, you need to look at it with a flat faced contact lens to be sure it is not too close to the retina for treatment. This avoids the embarrassment of recommending surgery, having them sign the permit, taking them to the laser, putting on the contact and then realizing the floater is too near the retina for treatment.

You will not be able to see clear, stringy floaters near the retina with an ophthalmoscope. Of course you can't treat them either. So if you don't readily see any floaters, ask the patient if their floaters are thin, thread like, segmented, and could they draw them exactly. If they say "Yes", you will probably never see their floaters.

Occasionally it is difficult to know if the floater seen with the direct ophthalmoscope is the same one being seen with the contact lens at the laser. So, in addition to the usual drawing of the floater location, occasionally I'll draw the shape of an individual floater.

(Research project: Welch Allyn is now making a wide angle direct ophthalmoscope that has a five times larger viewing field than the standard direct ophthalmoscope. I evaluated this new ophthalmoscope for viewing floaters. Large floaters are found a little quicker with it because of the wider field and its rolling, continuous focus. But the illumination is a bit weak, and this scope does not have as much definition as the standard direct scope. It is not useful for small floaters. I do not find it useful for floater examinations.)

If opacities are seen with the direct scope, and the patient is interested in treatment, I look with the indirect ophthalmoscope. I usually see the patient two months or more after the onset, after they have been seen by their eye doctor, and after light flashing has gone away. So I seldom use scleral depression or a mirror contact lens on these patients. However, if you see them soon after onset of the floater, scleral depression should be used. Large vitreous opacities can best be seen with the indirect scope by bringing the +20 diopter lens back toward the examiner. However, the direct scope allows you to see the floaters much clearer.

(Research project: The most difficult floaters to see are those near the retina. I wondered if modifying the indirect scope would be helpful in seeing them. I tried taping a +1.25 diopter lens on the eyepieces of the indirect scope, but this was not helpful. Using a +90, +20, or a +10 lens as the objective hand held lens also did not help. So, I don't recommend this scope for seeing small floaters.)

Fundus Laser Lens.

If the floater is not found with the direct ophthalmoscope, the next step is to use a contact lens which may help you to find the floater, and it will show the floater's relationship to other structures of the eye. My favorite is the flat faced Fundus Laser Lens (Ocular Instruments Inc. order OGFA) (see Chapter 23). We use Bausch and Lomb Liquid Gel (found in drug stores) as the gonioscopic fluid for most examinations. You can get a more magnified view of floaters using the Karickhoff 21mm Vitreous Lens, but the relationship of the floater to other structures is not as true as with a flat faced lens. I advise against buying the NMR (No Methylcellulose Required) model. The optics are not as good as the OGFA model. During the contact lens examination occasionally you may see what appears to be a large, gradually curving vitreous membrane in the inferior vitreous. This is a reflection of your thumb that is holding the bottom of the contact lens. When looking for something as thin as some vitreous opacities, this reflected image can be a problem. The problem is corrected by reducing the vertical height of the slit lamp beam so it no longer strikes your thumb.

The Hruby lens with the illumination slightly to the side can be substituted for the contact lens examination above if you need only to see the relationship of the floater to other structures and don't need to see the details of a floater. The Hruby lens is not helpful for checking for a PVD because the field is too small.

The +90 diopter hand held lens with the illumination to the side can show the depth of a Weiss ring without putting on a contact lens. However, it is a bit confusing since the retinal image is upside down. For this particular examination, the Hruby lens is preferable. The +90 lens is also not helpful in checking for a PVD because the patient's upper lid blocks the view in down gaze.

Draw hyaline (soft) floaters in green and syneresis floaters in red. This is especially useful in drawing floater duets (page 113). When you show the patient the drawing, you can say you can vaporize the green one but not the red syneresis floater.

Structures dense enough to be seen with retroillumination, such as opacities, are best seen with the illumination of the slit lamp in the central position and with a thin beam about 1 mm wide. Look just outside the beam for floaters seen with the retroillumination effect.

Structures too thin to be seen with retroillumination, such as vitreous waves, tiny strands, and the vitreous face can best be seen with the illumination slightly to the side. Of course, the closer the illumination is to the center position (between the oculars) the more contact lens reflexes are seen.

LOCATING AN ELUSIVE FLOATER WITH THE PATIENT ASSISTED METHOD

In patients with a posterior vitreous detachment, the floaters are usually in the anterior half of the vitreous and are very easy to find, photograph, and treat. However, in younger patients without a posterior vitreous detachment, there often are two special challenges. The first is finding the floater. The second problem is learning whether the floater you found is the one that is bothering the patient. After wrestling with these two problems for three years, I have developed a unique two step method that frequently solves both problems. It employs the patient as your assistant in finding the elusive floater.

This Patient Assisted Method is most useful when the patient says they have one discrete floater bothering them. First use my Floater Finder (see above) to learn the general location of the floater and approximately how far it is from the retina. Then using the slit lamp and an examining contact lens, put the illumination midway between the oculars and reduce the height of the light to two notches larger than the smallest round spot of light. Then adjust the width of the light so it is about the same size as the height. Have the patient move their eye somewhat while you are looking in the general location of the floater as learned by the Floater Finder. Then ask the patient to make random movements of the eye and tell you when their floater comes into the beam of light from the slit lamp and casts its shadow on their retina. Eventually they usually say the floater is in or near the light. Then have them move their eye a little or you move the light so the floater is in the light, and suddenly the elusive floater is seen. Not only is it seen, but you know instantly that the floater you are viewing is the one bothering the patient because the patient chose the floater, not the doctor. Then you note the pattern of the blood vessels behind the floater so you can easily find the floater again when you go to the laser. It will be found that a fair portion of the floaters that have to be located in this way are too close to the retina to be treated with the laser.

Occasionally a dense floater cloud will be suspended in the optical axis, decreasing vision significantly. The question then arises as to whether the macula is normal and whether good vision would be restored if the floater were removed. The only way to learn the answer is to use the only vision test where the testing object to be viewed is behind the floater and located within their retina. That is the blue field entoptic test. In this test the patient simply looks at the blue light. If they see their own perimacular white blood cells, their macular function is 20/40 or better. I designed a device, the Karickhoff Flying Corpuscle Viewer, that lets the doctor use the slit lamp as the light source for the blue field entoptic test.[3] This test works perfectly even if a floater cloud is blocking your view of the macula. The manufacturer is no longer in business, but as can be seen, the device consists only of a round filter and an occluder for the other eye. The filter is a 430 nm. narrow bandpass interference filter that can be obtained from Edmund Industrial Optics, order G43-108, for $83.50, phone 1(800) 363-1992. This test is by far the best test for evaluating macular function any time the macula can not be seen, such as in cataract and corneal transplant candidates. (See full details in Appendix K)

Flying Corpuscle Viewer.

DEMONSTRATING THE FLOATER TO THE PATIENT

There are several ways to allow the patient to see their floaters quite clearly.

The cheapest and handiest method is the Karickhoff +20 Diopter

Lens Method.[4] To use this method, ask the patient to cover their other eye, and the doctor holds the + 20 diopter lens used for indirect ophthalmoscopy as close as possible to their eye that has the floater. Then shine the direct ophthalmoscope into that eye from about three feet away using the smaller beam of the scope and the green filter to decrease the intensity. With this arrangement the patient can see their own lashes, see micro air bubbles in their tear film, can see and draw perfectly any cataract they may have, and can see the vitreous opacity. I designed this method to let patients see their own cataract, but it works nicely for vitreous opacities.

Demonstrating the floater using the Karickhoff method.

A second way to demonstrate the floater is using a commercial device called the Eye Scope obtained from Eye Scope, P. O. Box 2, Park Ridge, NJ 07656. The Eye Scope looks like a miniature flashlight. I took it apart, and it has a tiny fiber optic pipe that brings light to the front surface. There is no lens. When the patient looks into it, they can see the same eye structures as seen with my method described above.

A third method is using the oil immersion of a microscope. This shows the opacities almost as well as the commercial device above, but the field is slightly smaller.

All three methods show only opacities that are quite central. To see a wide field the patient must look at a large white area as in using my Floater Finder. But with this method the floaters are seen less distinctly.

Rarely are patients shown their floater with any of these devices. We usually just photograph the floater using Polaroid film and show them the photograph.

SCANNING LASER OPHTHALMOSCOPE

The scanning laser ophthalmoscope can visualize only large floaters. When the output of this laser ophthalmoscope is viewed on a video screen, the movement of the floaters and their obvious degrading effect on vision is dramatic.

[1] Foos, R Y: Posterior vitreous detachment. Trans Am Acad Ophth Otolar 76:480-497, 1972
[2] Murakami, Vitreous floaters. Ophthalmolgy 90:1271-1276, November 1993

[3] Karickhoff, J.R.: Flying corpuscle macular test performed with the slit lamp. Ophthalmology. Vol. 88, Num.#9F, pg. 91, 1981

[4] Karickhoff, J R: Demonstrating the cataract to the patient. Intraocular Implant Society Journal. Winter issue, p. 51-52, 1983

CHAPTER 5. HISTORY OF OCULAR YAG LASERS

The first laser was developed in 1960 by the U.S. physicist Theodore H. Maiman.[1]

The first use of a laser for eye surgery was by Beckman and Sugar[2]. They used the laser in the free running mode for *thermal* cyclodestruction. Then Krasnov reported using a high powered pulsed ruby laser to *mechanically* disrupt ocular tissue.[3] At that time, prior to the development of lasers that could attain optical breakdown, there were some horrific stories of pulsed lasers resulting in intraocular explosions and ruptured globes. This untenable situation led to the breakthrough development of the neodymium YAG (yttrium-aluminum-garnet) laser that could safely disrupt tissue that had no pigment such as a posterior capsule or a floater. The story of this important breakthrough is told below.

The first rumor I heard that it might be possible to safely obliterate non-pigmented ocular tissue with a laser was at a meeting of the American Academy of Ophthalmology in 1982. We had just heard papers on surgical posterior capsulotomies. The discussion centered on whether it was better to perform a posterior capsulotomy with a needle at the end of cataract surgery on all patients and risk getting vitreous in the incision, or wait and do a separate needle operation after the opacification developed. Neither alternative was attractive. After we had talked ourselves out on the subject, a colleague in a rather condescending voice stood up and said: "I understand the problem has been solved by a French lady." The room was silenced, then some skeptical, irreverent chuckles were heard. But, the colleague was correct. A few months later in August of 1983 I found myself attending one of the first courses in the country on the use of a high powered laser to create posterior capsulotomies. It was led by Doctor Leeds Katzen of Baltimore. That evening there was a dance and concert by one of Leeds' patients, Lionel Hampton, and his orchestra.

Dr. Daniele Aron-Rosa

The guest of honor, an attractive lady wearing a beautiful purple dress came into the room. Later I asked her to dance. While dancing I had the honor of introducing myself. The French lady who "solved the problem" introduced herself as Doctor Daniele Aron-Rosa.

Doctor Aron-Rosa of Paris, France is mainly responsible for the development of the mode-locked picosecond YAG laser.

She had been working with a Q-switched ruby laser in the early 1970's. The laser worked in the millisecond range and enormous power was produced. She exploded some rabbit eyes with it but was unable to control the destruction.

I have read several books on inventions and the inventive process. Very often the inventive process is that the inventor has read and experimented on a problem and has conceived what they want to accomplish. Then through some chance encounter they receive information that only they are prepared to use to make the breakthrough.

Dr. Aron-Rosa reports in her book[3] that she had two such chance encounters that led to the breakthrough. Her first encounter was at a dinner party in 1973 where she met Pierre Auger, one of the leaders of nuclear physics. While chatting with him, the breakthrough concept came that allowed her to control the laser destruction. She suddenly realized what she needed was a low energy laser working at high power density that could attain *optical breakdown*. She immediately gave up ruby lasers and sought a pulsed YAG laser like those used by the military as range finders for tank cannons. Soon she found that the pulsed YAG laser worked much better than the ruby lasers.

Her second fruitful chance encounter was when she saw a television program in 1975 which featured two scientists who were able to destroy using an ultra rapid, pulsed YAG laser only one mitochondrial body inside a blood cell, without exploding the cell. They said that the more rapid the train of pulses were sent, the quicker and the more protective the plasma shield would be, and the quicker the pulse, the smaller the amount of output energy required to reach optical breakdown. These ideas were a description of the future *mode locked picosecond YAG laser*. In 1976 she started working with Jean-Claude Griesemann, a specialist in pulsed lasers. Their collaboration led to the development of clinical mode-locked picosecond lasers and her successful treatment of more than 7,000 patients.

Doctor Franz Fankhauser at the University of Bern Eye Clinic in Switzerland is largely responsible for the use of the Q-switched YAG laser as a instrument in treating vitreous pathology.[5] In my correspondence with Doctor Fankhauser (2004) he noted also the contributions of the French physicists, namely, Philippe Roussel, Didier Riquin and Pascol Rol. He stated that Doctor Roussel designed the first Q-switched laser (Microruptor I). He places the date of the birth of that Microruptor laser as May 1, 1975. That is when he and Van der Zypen, an electron microscopist, started a study of laser energy on ocular tissue. They had difficulty finding proper lasers for their experiments. Early on they found a powerful Q-switched ruby laser being used at an electronics firm for holography experiments. Later Lasag Corporation put at their disposal a neodymium YAG laser the emission pattern of which could be varied and modulated widely. They collaborated also with Dr. Hans Bebie, a nuclear physics professor, who provided physical and mathematical analysis. They worked on many clinical applications especially vitreous membranes and bands. His Microruptor I laser was refined into the Microruptor II which would operate in the fundamental mode (narrow, central beam). This allowed his laser to achieve the all important optical breakdown at much lower power than with the multimode (broad beam). Doctor Fankhauser with his associate Rol was also responsible for developing the unique aiming system that uses two continually rotating converging beams.[6] This is probably the safest and best aiming system for vitreous laser surgery. In addition Rol and Fankhauser developed the Lasag CGV surgical contact lens for the vitreous which has excellent optics and light gathering characteristics.[7]

Dr. Franz Fankhauser

Doctor Aron-Rosa's early publication on use of the YAG laser included seven floater patients, all of whom were successfully treated, but her main emphasis was on other uses of the laser.[8] Doctor Fankhauser's early series included 10 floater patients all of whom were successfully treated, but his main interest was cutting vitreous membranes.[9] The first publication involving treatment of only floater patients was by Tsai, Chen, and Su.[10] They treated 15 patients with symptomatic floaters, were successful in all cases, and had no complications. Their conclusion was the procedure was simple, safe, and effective.

European manufactures, namely the Essilor company in France and the Meditec company in Germany, developed mode-locked lasers, and Lasag of Switzerland developed Doctor Fankhauser's Q-switched laser.

American companies felt pressure to enter the market and did so mainly with Q-switched lasers.

I first used a YAG laser in 1983. It was a Meditec, picosecond, mode locked laser. However, this and similar lasers were difficult to maintain because of the necessity to buy the switching dye and to change the dye in the laser regularly. Gradually the mode locked lasers were removed from the market in favor of the more simply maintained Q-switched lasers.

[1] Oxford Family Encyclopedia, New York, Oxford University Press, p. 386, 1997

[2] Beckman and Sugar: Neodymium laser cyclophotocoagulation. Arch Ophthalmol 90:27, 1973

[3] Krasnov MM: Laser puncture of anterior chamber angle in glaucoma. Am J Ophthalmol 75: 674, 1973

[4] Aron-Rose, Daniele: Pulsed YAG Laser Surgery, Thorofare, New Jersey, Slack Incorporated, p.xiii, 1983

[5] Fankhauser, F: Clinical studies of the efficiency of high power laser radiation upon some structures of the anterior segment of the eye. Int Ophthalmol 3: 129, 1981

[6] Rol P, Fankhauser F: Aiming accuracy in ophthalmic laser microsurgery. Ophthalmic Surgery Vol.17, no.5: 278-282, 1986

[7] Rol P, Fankhauser F: A new contact lens for posterior vitreous photodisruption, Invest Oph & Visual Science Vol. 27, p. 946-950, June 1986

[8] Aron-Rosa, Daniele: Neodymium YAG laser vitreolysis. Int Ophthal Clin 25: 125-134, 1985

[9] Fankhauser Franz: Vitreolysis with Q-switched laser. Arch Ophthal 103: 1166-1171, 1983

[10] Tsai, W F: Treatment of vitreous floaters with neodymium YAG laser. British J Ophthal, 77: 485-488, 1993

CHAPTER 6. SIMPLIFIED EXPLANATION OF FLOATER VAPORIZATION

Those unfamiliar with this procedure assume that the laser beam is breaking a big floater into many small floaters. This is not the case. The laser is in large part actually obliterating the floaters. The great majority of the floater is no longer present after the laser treatment. If the floater has fairly low fibrin content (hyaline floater), the floater is gone or nearly gone the day after treatment. For example, if you treat a Weiss ring, the next morning after treatment it would be typical to see clear vitreous except for maybe a tiny piece of the ring that you missed. And if you add a few shots, that tiny piece will be removed also. The fact that Weiss rings are obliterated (not fractured into many smaller floaters) is seen on color page 101, Figure 15. The left picture is pre-operative, the middle picture is after 28 shots, and the right picture is post-operative.

If, however, you are treating a syneresis cloud with hundreds of small floaters, typically there would be a significant improvement, but it is impossible to get rid of all the floaters with a reasonable number of shots.

What happens to the floater is similar to a lightning strike in nature. A lightening strike is an example of obliteration of matter under the influence of an intense electrical (optical spectrum) field. The mechanism for this obliteration is called "plasma formation" and "optical breakdown" which are terms used in describing laser physics. Optical breakdown requires (1) a very high frequency (changing from plus to minus) electrical field in the optical region of the electromagnetic spectrum that (2) is confined to a very small area. Upon firing a laser that can produce these conditions, the clear vitreous and floater become opaque (plasma formation) at a microscopic point, and they absorb the laser energy producing a micro lightening flash (optical breakdown). The laser performs this photoconversion of the solid floater into a gas with a combination of photochemical, thermal, thermoacoustical and electromagnetic optical field effects. Each time optical breakdown occurs, the surgeon sees the micro lightening flash on the

Lightning strike.

surface of the floater and both the surgeon and the patient hear the acoustic component (a micro thunder snap). With most shots both the surgeon and the patient see the formation of a gas bubble.

It is important that the laser is firing in the range that obtains optical breakdown so that the floater will be converted to gas bubbles that are gone the next morning. If the laser is fired into the vitreous below the optical breakdown level (normally about 2.2 mJ) the floaters will only be fragmented and the success rate will be quite low.

The temperature at the center of the area of optical breakdown has been calculated to be several thousand degrees.[1] At approximately 4000 degrees centigrade all solids are converted to gas.[2] So there are more than adequate forces to change the form of matter from a solid to a liquid and to some extent to a gas. This change is evidenced on many laser shots by the formation of a gas bubble (color page 100, Figure 10).

[1] Trokel, S L: YAG Laser Ophthalmic Microsurgery, Norwalk, Connecticut, Appleton-Century-Crofts, p. 22, 1983

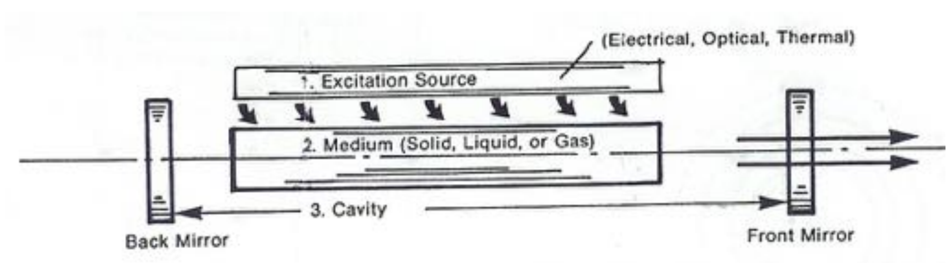
[2] L'Esperance, F A Jr: Ophthalmic Lasers, St. Louis, C V Mosby, p. 786, 1989

CHAPTER 7. LASER PHYSICS OF FLOATER OBLITERATION

This discussion could be virtually endless because it should cover all levels from laser fundamentals to plasma physics. A brief explanation is essential to understand some of the laser concepts and mechanisms and to appreciate what is possible with this treatment and how to do it safely.

WHAT IS A LASER AND HOW DOES IT WORK?

L.A.S.E.R. is an acronym that stands for Light Amplification by Stimulated Emission of Radiation. A laser consists basically of three parts (see diagram below). (1) The source of excitation can be electrical, thermal, or, as in the case of YAG lasers, it is optical (a light from a gas-filled arc lamp). (2) The laser medium can be a *gas* such as argon, krypton, a mixture of helium and neon, etc., a *liquid*, or a solid such as ruby, or yttrium-aluminum-garnet (YAG) rod. In ophthalmic lasers the YAG crystal is "doped" with neodymium making the crystal laser-active since the electron clouds surrounding the neodymium act as emitting centers.[1] (3) The cavity which houses the medium has a mirror on each end. The mirror in the rear is totally reflective, but the mirror in the front is semi-reflective allowing some of the light to escape in a controlled fashion.

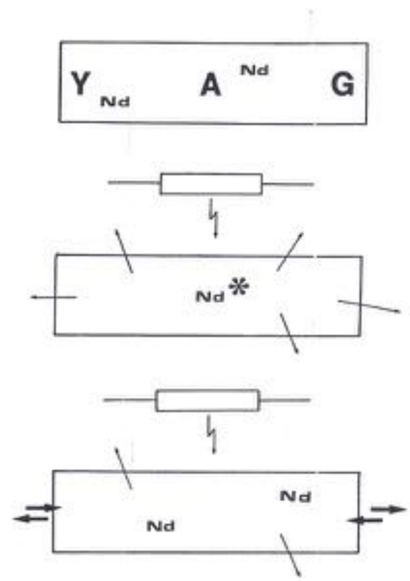


Essential components of a laser.

The laser beam is produced as follows: The excitation causes atoms in the medium to be excited into a higher energy state, called a meta-stable energy level. Interplay of two levels of excited atoms determines the characteristic wavelength of the beam, in this case, 1064 nanometers. When some of the electrons spontaneously fall back to the base state, there is a release of photons that stimulates a chain reaction. The mirrors of the cavity aid the chain reaction by propagating the photons back and forth between them. Some of the photons of this back and forth resonation escape the cavity through the front semi-reflective, partially transmitting mirror. The escaping photons are the laser beam.[2]

(See diagram to right).

YAG is the Yytrium-Aluminum Garnet crystalline support for Neodymium, the active atom. Since it is not possible to pass an electrical current through a crystal (as is done for gas lasers), strobe flash excitation is employed. Electrons are stripped off the Neodymium atoms and Nd^{+3} is produced. These ions, in turn, drop back to their unexcited state by emitting photons of light over a 10 millisecond period (longer than the time of excitation).



Neodymium doping of YAG.

When the laser beam exits the cavity it is different from ordinary "incoherent" light. The laser light is (a) exceedingly bright, (b) is nearly parallel, (c) is coherent (all rays in phase), and (d) is monochromatic (meaning no chromatic aberration when focused). These features make it possible to focus the laser light into the smallest spot. Laser light also has a characteristic laser speckle. This striking granular appearance is due to interference and reinforcement when the coherent light of the laser is reflected from an optically imperfect surface.[3]

WHY IS "OPTICAL BREAKDOWN" ALL IMPORTANT IN EYE SURGERY?

Optical breakdown is the mechanism by which the dream of having a non-thermal, highly precise method of cutting and obliterating non-pigmented tissue without opening the eye was achieved. The phenomenon of optic breakdown is usually understood only by laser physicists. Its tissue effects are totally unexpected.

In optical breakdown the power density of the laser beam at its point of focus becomes high enough so that electrons are ripped off atoms, causing ionization of the medium, and very high temperatures that are extremely localized.[4] This is quite similar to a miniature lightening strike. When the laser is fired, there is a tiny flash of light and an audible snap, and frequently a gas bubble is produced. Here, temperatures far exceed the roughly 4000 degrees Centigrade necessary to convert any matter (a floater) into a gaseous state.[5]

To achieve optical breakdown in water the power density (or field strength) must be raised to approximately 3 x 10^{12} watts/cm^2.[6] One can attain this desired power density by (1) increasing the power, (2) by releasing all the power available in a shorter time (pulsing the laser), or (3) focusing the available power into a smaller spot by using the laser in the fundamental mode, having a converging beam as it approaches the eye, and converging it further with a contact lens. On my Laserex LQP4106 laser the power needs to be about 2.2 mJ or higher to achieve optical breakdown in vitreous.

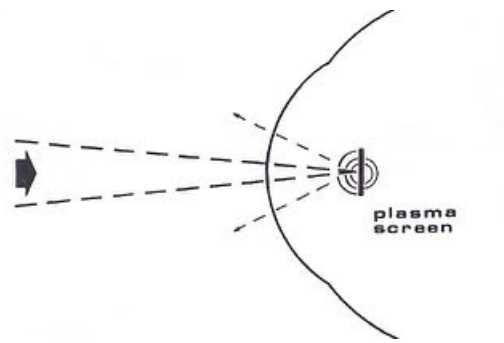
If optical breakdown is achieved, much of the floater is converted to a gas and is obliterated. If the laser does not achieve optical breakdown, only fragmentation of the floater occurs.

There is essentially no action of the laser beam except at the point of focus where optical breakdown occurs. This gives excellent protection for other structures of the eye. For example, the laser passes through the cornea and lens, but no action takes place in the cornea and lens.

WHAT IS A "PLASMA SHIELD"?

Optical breakdown occurs when the medium at the focal point becomes ionized and there is formation of a plasma and a shock wave. The heat from the colliding electrons of the ionization leads to absorption of the laser beam by transparent or nearly transparent tissue (posterior capsules and floaters) leading to their vaporization. A tiny gas bubble is also created, which at 1064 nanometers wavelength, is highly reflective and shields most of the light and shock wave from traveling toward the retina. It should be remembered that the plasma shield is only relative and does not work well at power levels higher than needed to attain optical breakdown. At these higher levels the shield tends to reflect back along the laser beam toward the laser.[7] The clinical importance of the plasma shield is that the surgeon should attempt to attain optical breakdown with each laser firing and keep the power low in the optical breakdown range. This is of greater importance as one fires the laser closer to the retina.

(See diagram to right).
The plasma screen concept: As optical breakdown develops, atoms at the area of the laser's focus are dissociated into ions and electrons forming a "gas" called plasma. Its high electron density (10^{21} e/cm^3) reflects back the 1064 nm wavelength of the YAG energy, affording relative protection of the retina.



Plasma screen (shield) concept.

WHY IS IT IMPORTANT IN EYE SURGERY TO RUN THE LASER IN THE FUNDAMENTAL MODE (MONOMODE)?

Only the central rays from the laser cavity will be allowed to escape if a shield with a proper sized hole in the middle of it is placed near the semi-reflective exit mirror of the laser. These central rays are more perfectly parallel and in phase than are the peripheral rays. If only the central rays escape, the laser is running in the fundamental (mono) mode. If the central as well as the peripheral rays escape, the laser is running in the multimode. The multimode is useful for some broad vitreous band cutting, but that mode is capable of giving a focus diameter of no smaller that 200 microns. The advantage of the fundamental mode is that of using less power and having the smallest point of focus (about 8 microns) that is physically possible (and the highest power density). This discrete focus makes achieving optical breakdown relatively easy and that limits the disruption to the focal point only. All modern YAG lasers used for capsulotomies and floater obliteration run only in the fundamental mode.

WHAT IS THE DIFFERENCE BETWEEN CONTINUOUS OR PULSED LIGHT EMISSION?

Continuous-wave lasers are low powered lasers and have a constant output of light. They are inefficient and are typically used in ophthalmology to burn tissue. The argon and krypton lasers are examples.

The typical output duration would be 0.1 to 0.5 seconds. These lasers require pigmented tissue to have a destructive effect. This concept is illustrated by a magnifying glass that can use the sun's ray to burn a hole through a leaf but will have no effect if focused on clear glass.

Pulsed lasers are very high powered (produce the energy rapidly). The pulsing is done with a shutter device in the laser cavity between the mirrors. The medium is excited with the shutter closed. When the shutter is opened, the energy is released in a few nanoseconds or picoseconds. This high power is necessary to attain optical breakdown. With optical breakdown no pigment is required to have a destructive effect. The effect will occur in clear glass, transparent tissue, water, and even in air.

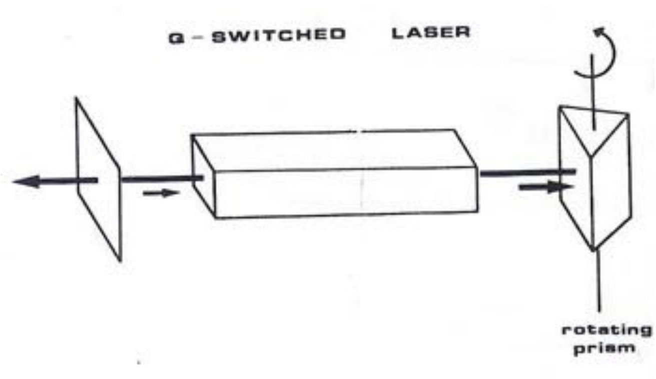
WHAT IS THE TIME DIFFERENCE BETWEEN A NANOSECOND AND A PICOSECOND LASER?

There are 1,000 picoseconds in a nanosecond. A nanosecond is 0.000000001 second. Q-switched lasers have an output of a few nanoseconds. Mode-locked lasers have an output in the picosecond range. This difference in output time gives each type of laser their clinical characteristics described later.

WHAT IS THE DIFFERENCE IN PULSING A LASER BY Q-SWITCHING (NANOSECOND OUTPUT) OR MODE-LOCKING (PICOSECOND OUTPUT)?

Both the Q-switched and mode-locked YAG lasers operate at the 1060 nanometer wavelength that is in the near infrared spectrum. But the duration of the pulse is 1,000 times longer in the Q-switched nanosecond laser. Both types are effective in disintegrating floaters.

In Q-switching there is an electro-optic polarizing shutter in the laser cavity. A short duration voltage causes the polarity to rotate 90 degrees so that the polarized laser light can now oscillate in the cavity. The origin of the term Q-switching comes



from changing the Quality of the beam. This type of switching requires very little maintenance.

The cavity of a Q-switch laser can be as short as 8 centimeters. The pulse from this type of laser is usually 10 to 30 nanoseconds duration. With this laser the area of disruption is about 1 mm. When the energy is reduced below about 3 millijoules in the mid vitreous, there will be no optical breakdown. When both mode locked and Q-switched lasers have been available in the past, most surgeons chose to use the Q-switched laser for floater work. With the Q-switched laser the indications are wider, and the sessions are shorter and fewer in number.[8]

In mode-locking, the switching device is a passive device, usually a cell that contains a photosensitive dye. This cell is placed in the laser cavity. When the excited photons bleach the dye, the pathway is free for the light amplification process to occur and there is a momentary pulse output of laser light. After this bleaching, the dye becomes opaque again typically in four or five picoseconds. But some of the remaining photons make the round trip in the cavity and encounter the dye again. Bleaching occurs again and there is another pulse output of laser light. This then reoccurs. In this way a chain (or train) of pulses (usually 7 to 20) are emitted. Typically an individual spike is about 25 picoseconds long and the interspike space is about 7 nanoseconds. This makes the whole duration of the train of spikes typically a little less than 50 nanoseconds.[9] So the total time to deliver all the energy from a shot of a picosecond laser is actually longer than that of a shot from a nanosecond laser. Usually the cavity of a mode-locked laser is longer than one meter. Since the dye cell is located near the rear mirror, the length of the cavity becomes important in reinforcing or canceling various harmonics of the photon oscillations. This intrinsic control of the harmonics of the oscillations is the origin of the term “mode-locking.”

The main advantage of the picosecond YAG laser is that the typical pulse energy for disruption is significantly less than the typical energy used with a Q-switched nanosecond YAG laser. This can be accomplished because optical breakdown can be achieved at a much lower power when the duration of the pulse is shorter. With a picosecond laser, optical breakdown can be achieved with microjoule pulse energy and the area of disruption is confined to about 100-200 microns. Because the area of disruption is so small, multiple pulses are necessary to achieve clinically significant tissue disruption.[10] This tiny area of disruption allows for working closer to the retina than with a nanosecond laser and the picosecond laser creates less of a shock wave. This is helpful in cutting traction bands that are connected to the retina as in diabetes. The area of disruption is so small that this laser has been termed a "laser scalpel." Working with it is slower than with the nanosecond laser. With a picosecond laser one can also achieve optical breakdown reliably without a contact lens. Also there seems to be less backscatter from this laser.[11] In spite of these theoretical advantages, a study in rabbits showed for pulse energies of 3 mJ or less, there was more intended retinal damage from the picosecond laser than an equivalent pulse from a Q-switch laser.[12] It is of interest that all these retinal lesions from both types of lasers healed nicely with a minimal scar, unlike retinal lesions from an argon laser.[13]

One of the most widely used picosecond lasers was the ISL (Intelligent Surgical Laser). It used Neodymium Yttrium Fluoride (Nd:YFL) which emits in the picosecond range (less than 60 pico seconds). Its characteristic feature was lack of adjacent tissue damage. This characteristic allowed it to be tried for intrastromal photorefractive keratectomy. Its best use is for cutting, not obliteration. But for floater vaporization the shock wave of the YAG laser is more helpful.

Some have proposed that the picosecond lasers might be safer for floater disruption because there is not as much shock wave to the retina from them. But, to my knowledge, there has never been a shock wave injury to the retina during floater disruption using a nanosecond laser. However, there have been spot retinal hemorrhages from direct hits or from backscatter from a shot just anterior to the retina.

Which type of laser is better for floater obliteration? They are both high-powered pulsed lasers and both work well. For working very near the retina the mode-lock (picosecond) laser is theoretically better, but seldom is one working very near the retina. If the goal were to carve a pattern in a floater, this could be done only with a picosecond laser, which to an extent, is a laser scalpel. However, the goal is disappearance of the floater. The Q-switched laser with its larger shock wave, larger area of destruction, fewer treatment sessions, and ease of maintenance is preferred. In summary, the pico-second laser is a better cutting tool, but the nano-second laser is a better disruptive-vaporizing tool. What we desire in floater work is disruption-vaporization of the floater.

In recent years the argument between Q-switched and mode-locked lasers has been settled in the market place. The problem is that mode locked lasers are pulsed by a very rapid change of transparency of a fluid dye. The dye must be obtained from the supplier (Eastman Kodak) and then be changed regularly by pouring it into the back of the laser. Because of these maintenance problems, mode locking laser pulsing has been largely abandoned and the very reliable Q-switched lasers now dominate the market.

The femtosecond laser (one thousandths of a picosecond) has been mentioned for vitreous work. I have not had access to this laser. The duration of the shot is so short that no effect is transferred to adjacent tissue. This is the unique advantage for it in dissecting a corneal flap.[14] This is also its unique disadvantage for obliterating floaters. Because it has essentially no shock wave effect, I would predict that floater obliteration would either be impossible or would require long and frequent sessions. Although these lasers do have a pulse in the 10^{-15} (femtosecond) range, they still produce cavitation gas bubbles that are made up mainly of carbon dioxide, nitrogen, and water.[15]

HOW CAN A LASER VAPORIZE FLOATERS WITHOUT BURNING TISSUE?

A continuous wave (argon, krypton, low powered) laser is similar in its tissue effects to cooking on the kitchen stove. That is, the higher you turn the power and the longer you cook, the more thermal effect you get. These causal factors and the effects have a linear relationship. At 70 degrees C. you may get denaturing and coagulation of protein, and at several hundred degrees C. you get carbonization, evaporation, and burning.

To achieve higher, very localized temperatures, a pulsed YAG laser is used. At these higher temperatures, roughly above 4000 degree C., all matter is converted to a gas. But at even higher temperatures of say 15,000 degree C. which are characteristic in the center of the focal point at optical breakdown, some of the atoms of the gas become ionized, releasing free electrons causing it to reach a plasma or fourth aggregation phase which differs from a normal gas. Here atoms, electrons, and ions are moving rapidly and colliding with one another. These collisions produce electromagnetic radiation (visible light, photons), a highly localized shock wave, and often a gas bubble. These changes occur in a few nanoseconds and are non-linear. The effects on tissue from these changes are entirely unlike those found from the kitchen stove. The high power delivered in a very short time is the factor that brings about the different effects. These effects are thermal, mechanical, and from the electromagnetic field.[16] These effects plus cavitation bubbles produce the disruptive effect on the floaters.[17]

In addition to vaporization, the shock wave is also important in tissue destruction. At the level of optical breakdown the tissue effects are ionization, mechanical effects, disruption, and disintegration. Astonishingly, there are no heat effects such as collagen shrinkage or burning surrounding the center of the explosion. At this level there is disruption, but floaters are primarily vaporized and disappear.

(Diagrams in this chapter are used with permission of Daniele Aron-Rosa, M.D.)

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CHAPTER 8. LASER OPTICS NEEDED FOR FLOATER TREATMENT

The optics best suited for floater treatment with a YAG laser is: all six beams of the laser and the slit lamp must be made nearly coaxial. The six beams consist of the two aiming beams, the treatment beam, the illuminating beam from the slit lamp, and the two viewing beams. With all beams nearly coaxial the floater can be seen, aimed upon, and treated regardless of how deep the floater is located in the vitreous. If the laser does not have this optical set up, one can treat floaters in the anterior vitreous, but visualization will not be adequate in the mid and posterior vitreous. In other words, your YAG laser needs ideally about the same beam arrangement as the typical argon laser with which you can see burns you make on the retina. Unfortunately, several YAG lasers do not have the optical set up needed. Their usual deficiency is the illuminating beam originates from an angle far below the treatment beam to reduce reflexes during posterior capsulotomies. With such an arrangement the illumination may be blocked by the iris when working in the mid and posterior vitreous. The ideal placement of the illumination beam is just inferior to the bottom of the treatment beam. Also, if the illumination beam of the laser can be placed just lateral to one of the oculars, usually this will work for treating posterior floaters (for details see Chapter 22, Selection of a Laser, and Appendix N, Designing the Ideal Laser for Floater Treatment.

Wanting to treat floaters throughout the vitreous, in September 1999 all of the manufacturers of ophthalmic YAG lasers known to me were contacted. The purpose was to find those lasers that had the needed optical setup for floater disruption. I talked with their technical design experts. Vantage, Humphrey, and HGM make ophthalmic YAG lasers but it seemed then that they did not make any that had the illumination and treatment beams nearly coaxial. Later I contacted the technical staff of A.R.C., Coherent, Laserex, and Zeiss-Humphrey concerning their lasers more recently brought onto the market. There I found some candidates.

At that time I found only three lasers that could easily perform this operation throughout the vitreous. The Coherent Epic laser attains this needed optical arrangement by using a beam splitter that reflects the illuminating beam into the eye and allows the other five beams to pass through the beam splitter. With this arrangement the beams are almost perfectly coaxial. However, the working distance was too short in this laser for holding contact lenses on the eye. The Laserex LQP 4106 laser can also perform the operation by using a special short mirror supplied by the manufacturer that reflects the illuminating beam into the eye and allows the other five beams to pass in air just over the top edge of the mirror. I have done hundreds of floater operations with this laser. I calculated that the treatment and illuminating beam have a 6.5 degree separation (almost coaxial) in this laser. Lasag's Microruptor II has been used to treat thousands of floaters. It places the illumination mirror on the same horizontal plane as the oculars but just lateral to them. I have examined the Meridian Microruptor V but not actually used it for floater treatment. It may need modification to easily perform the floater procedure. The floater operation has been performed with the Nidek YC 1300 and 1400 lasers. Probably the Alcon Nanolas 15S and other lasers can perform the operation. All of the above lasers will be discussed in detail in Chapter 22. I can verify that the Lasag Microruptor II and the Laserex LQP4106 laser can perform the operation. At this point if other lasers are purchased for use in floater treatment, they should be purchased with an agreement that they can be returned if the buyer is not satisfied.

The treatment beam is in the near infrared spectrum and is invisible. Therefore, another needed feature is a low powered visible aiming beam so the surgeon will know the location of the treatment beam. In ophthalmic YAG lasers a helium-neon beam (632.8nm) is used and is coupled in a parfocal fashion to the treatment beam. Due to chromatic aberration the treatment beam and the aiming beam may not be perfectly coincident. The treatment beam comes to a focus slightly more posterior than the aiming beam and this difference increases somewhat in the posterior vitreous.

Another needed parameter is for the laser beam to be a converging beam so it can be brought to a discrete focus on the floater. Theoretically, the more the beam converges the better, but due to aberrations and the limits of pupil dilation, a compromise of 16 degrees convergence is used in most YAG lasers.

Here is how to test your laser to see if it can treat floaters in the posterior vitreous. With a dilated pupil and using a flat faced contact lens, see if you can simultaneously shine the two red aiming beams of the laser and a small white illumination beam of the slit lamp onto the optic nerve head. If the aiming beams are within the illumination beam on the optic nerve head, your laser is suitable for floater work. However, if the iris blocks the illumination beam so it can not illuminate the optic nerve head, your laser will not be able to treat floaters in the posterior vitreous.

CHAPTER 9. INFORMAL STUDIES

Tsai reported 15 cases of obliteration of vitreous floaters using the Nd:YAG laser. This was the first laser treatment series that contained only cases of vitreous floaters. He used shot powers of 5 to 7.1 mJ. All cases were successfully treated and there were no complications.[1]

Dr. Tsai of Taiwan is the most experienced doctor in the world in laser treatment of vitreous opacities (6,000 cases). In 2007 we corresponded so some of his invaluable experience could be published here. He performed cases prior to 1995 with the Lasag Microrupter II and after that with the Nidek YC-1300. He preferred the Peyman 18 mm surgical contact lens. Although quite familiar with the indirect ophthalmoscope, he preferred the convenience of the direct scope for evaluation since it could readily reveal the x, y, and z axis of the floater and its relation to the optic nerve.

He classified most floater patients as follows: a) Those complaining of a clump of black ink. Upon examination most of these had retinal tears or detachment and were referred to a retinal specialist. b) Those complaining of a big, black spot. Most of these had a Weiss ring related to a PVD. These were treated with high satisfaction. c) Those whose floaters appeared as filaments, a web or bubbles floating. Most had myopia greater than 3 diopters and had myopic degeneration. d) Those who complained of small black particles, yet no definite floaters were seen on examination. Most of these had greater than 3 diopters of myopia and were around 20 years of age. These were difficult to treat, but placing random laser shots greater than 5 mm anterior to the retina around the visual axis seemed to have good results. These floaters probably were close to the retina making them quite visible to the patient but not to the doctor. This author has not treated any of these cases.

He warned against treating too close to the lens of the patient because the plasma shield can reflect the laser beam toward the lens. He did not see any case where the YAG laser caused a complication.

Geller's report also contained only cases of laser treatment of vitreous floaters. 112 eyes were treated. The success rate was 85 per cent. 5 cases had transient high intraocular pressure that was controlled with medication and returned to normal.[2]

Delaney's report contained 39 eyes with floaters that received laser treatment. 38% of these had moderate improvement, 61.5% had no improvement, and 7.7% were subjectively worse.[3] (However, the maximum shot power used in this study was 1.2 mJ. This low level of power probably did not achieve optical breakdown which is usually about 2.2 mJ in vitreous. Therefore, the mechanism for treatment in this study as suggested by the authors was probably fragmentation only. The average shot power in other studies was 4 to 6 times the power used in the Delaney study. At these higher powers, optical breakdown is achieved and the floaters are primarily converted to a gas rather than being fragmented only. This difference in mechanism most likely explains the difference in success rates.)

My informal study of 61 cases was unpublished, but was included in (a) our application to the U. S. Food and Drug Administration and in (b) our application to the hospital Institutional Review Board for our Formal Study. The first patient in this informal series was operated upon June 21, 1999 and the last had surgery on August 30, 2001. The main findings of this study were:

- The procedure was successful in 92 per cent of cases.
  (The criteria of success were the same as in our Formal Floater Study (see Chapter 10).
- There were no significant complications.
- The average follow up time was 8 months.

(See Appendix F, World Literature, for some other very small series.)

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CHAPTER 10. KARICKHOFF FORMAL STUDY OF 200 CONSECUTIVE, ELGIBLE FLOATER CASES

(This is the only formal study of laser treatment of vitreous opacities set up under the guidelines of the U. S. Food and Drug Administration and supervised by a hospital Institutional Review Board. The author was the Principal Investigator.)

In September 2001we began our preparation for my formal research study to determine the effectiveness and safety of laser treatment of eye floaters. An extensive application for my study was prepared and submitted to the INOVA Fairfax Hospital Institutional Review Board of Falls Church, Virginia. The Board required clearance from the U. S. Food and Drug Administration for use of a YAG laser in the study. Therefore, an extensive document on the use of the laser and the proposed study was prepared and was submitted to the FDA. The FDA ruled (paraphrased) that my study of laser treatment of vitreous opacities was a non-significant risk device study. It further stated that an Investigational Device Exemption for the laser is not required in non-significant risk device studies (see Chapter 18). With this favorable ruling, my Formal Floater Study was begun. My study was further reviewed by the hospital Institutional Review Board to ensure that the study was well designed, all possible subject safeguards were built in, that complications would be promptly reported, and subjects were informed about all aspects of the study including the risks and benefits.

That Board voted to approve and to monitor our study. All data and progress of the study were sent to the Board and also to the U. S. Food and Drug Administration.

After approval of the study, the Principal Investigator was required to take a course from the U. S. Food and Drug Administration that concentrated on ethics and examples from history of abuse of patients in research studies. After passing the test, enrollment of patients began.

Each new floater patient was asked to become part of our formal research study, with the understanding that the procedure itself was the same as in our informal study presented in Chapter 9. In this Formal Study we used the same laser, the same laser technique, and the author again performed all the procedures. The only additional requirements of the research subjects were that they sign an extensive informed consent document before the procedure began and agree to an examination one day and one year after the procedure. Out of town subjects were given an examination sheet that was easily filled out by their local eye doctor and faxed to me one year after the procedure.

The first patient in the study was operated on August 1, 2002.

INCLUSION AND EXCLUSION CRITERIA:

Inclusion:

- Has significant symptoms from the floater such as difficulty in driving, reading, use of a computer, significant annoyance, or their concentration significantly affected
- Has had the floater longer than 3 months without significant improvement
- Is 21 years of age or older
- The floater must be at least 3 millimeters from the lens and the retina
- Follow up can be obtained
- Reasonable cooperation by the subject during surgery

Exclusion:

- Asteroid hyalosis (hundreds of tiny floaters)
- Floaters too numerous to treat
- Floaters caused by recurrent inflammation
- Floaters from vitreous or pre-retinal hemorrhage
- Patients with flashes

- Patients with unusually high anxiety or depression related to the floaters
- Floaters associated with untreated, symptomatic retinal tears or retinal detachment
- Floaters off the central visual axis to the point they are untreatable
- A floater that is so large that the surgeon believed it could not be eliminated with reasonable laser power, a reasonable number of shots, and less than 5 treatment sessions.

(Indications and contraindications are listed and explained in detail in Chapter 12.)

THE PROCEDURE

After dilating the pupil, an anesthetic drop is placed on the cornea. In every case a surgical contact lens with magnification was placed on the eye using gonioscopic fluid. Usually the Karickhoff 21 mm Vitreous Lens and/or the Karickhoff Off-axis Vitreous Lens were used. The aiming beams of the Laserex LQP 4106 YAG laser were placed on the floater and the laser was fired. This vaporized a small part of the floater and a gas bubble was frequently produced. The power settings were 5 to 10 millijoules with the larger setting used in the posterior vitreous and on the denser floaters. Most isolated floaters required less than 100 shots. If the patient had multiple floaters, a maximum of 300 shots per eye were given. Then the patient was given written instructions on what to expect (see Appendix D) and an appointment for the next day.

The patient was seen the next morning. Almost every patient reported an improvement and asked for their other eye to be done if it had floaters. Usually some additional shots were given to the first eye and then the other eye was treated. Rarely three sessions were necessary for the same eye.

The patients were instructed to contact the Principal Investigator at once if there were any problems. The Principal Investigator did a one-year follow up examination on the local patients. If the patient was from out of town (they came from 48 states and 19 foreign countries for the study), they were given a one-year follow up form (see Appendix I) that their local ophthalmologist filled out at their one year examination. The patient sent it to us as a FAX. If the FAX was not received, the patient was e-mailed or called.

Monitoring Procedures and Statistical Methods:

A sequential identification number is given to each subject as they entered the study. All the information underlined below was recorded during pre-operative examinations, at the end of the laser procedure, and during postoperative examinations on the subject's chart. No special case report forms were used. All of this data from the charts was later transferred to master sheets and analyzed to provide the following information:

Age- The average age was determined and the range of age was stated.
Sex- The percentage of male and female subjects
Floater type- The percentage of each floater type
Eye- The percentage of right and left eyes
Vision preoperative- The average preoperative vision
Vision postoperative- The average postoperative vision
(If there is significant loss of vision in any patient, that was stated in the analysis and the patient was identified by their study number)
Pressure preoperative- The average preoperative pressure
Pressure postoperative- The average postoperative pressure
If there was significant pressure elevation in any patient, that was stated in the analysis and the patient identified by number.)
Shots- The average number of laser shots and the range of shots per session
Power- The average laser power setting and the range of setting
Complication- Any complication was noted. The following complications were specifically looked for: elevated tension, lens damage, vitritis, retinal hemorrhage, retinal tears, retinal detachment. Any complication was individually analyzed and discussed.
Follow up- The average length of follow up and the range of follow up
Patient evaluation- The percentage of success and failure as judged by the patient (see Criteria for success below)
Surgeon evaluation- The percentage of success and failure as judged by the surgeon (see criteria for success below)
Complications- The type and frequency of any complications were calculated.

Criteria for success were:

1) the patient's evaluation that functional problems such as use of a computer, reading, or driving had been significantly improved,

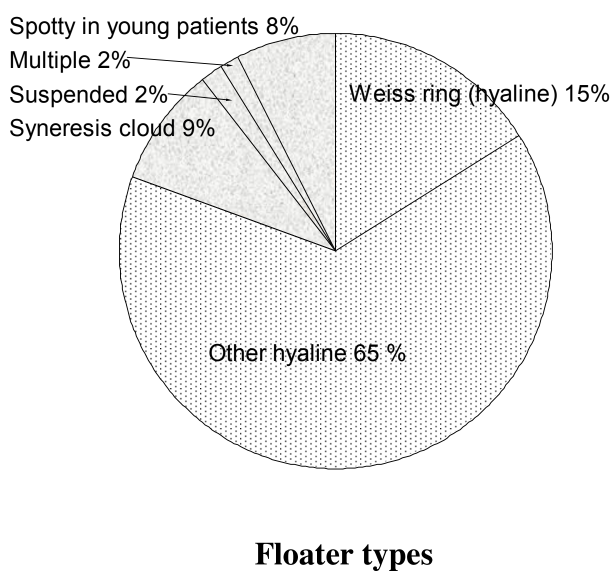
2) the patient's evaluation that their seeing the floater had been significantly reduced or eliminated,
3) the surgeon's evaluation from examination that there had been a significant reduction or elimination of the floaters,
4) pre- and post-operative photographs documented improvement, and
5) a lack of significant complications.

CONCLUSIONS

The treatment was successful in 92 percent of cases. There were 16 failures in the 200 cases. When there was failure, there was no harm done, and there was no evidence that an operation had been done.

There were no significant complications.

The 200 cases consisted of 161 hyaline floaters (condensations of the posterior layers of the vitreous that have detached from the retina). Of these, 32 were in the form of a Weiss ring. Of the non-hyaline floaters there were 3 clouds suspended in the pupillary axis, 3 multiple scattered floaters, 18 syneresis clouds, and 15 cases of spotty floaters in patients younger than 40 years old.



Floater types

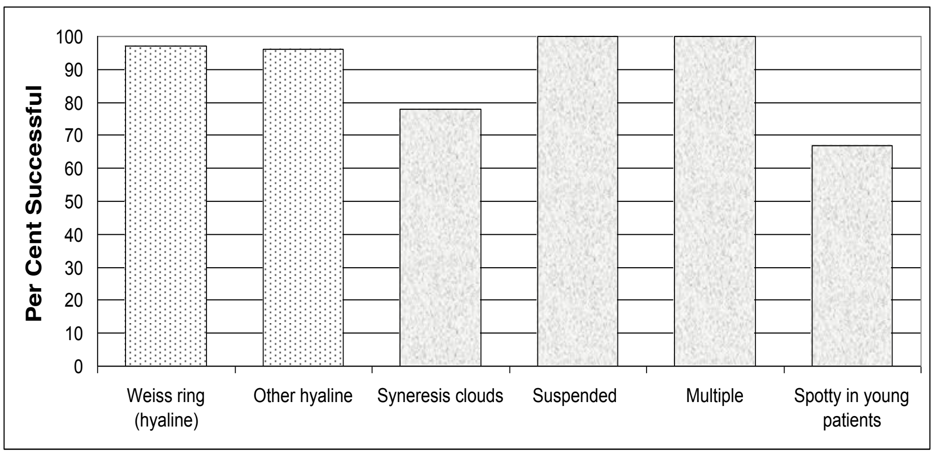
Treatment of hyaline floaters was the most successful (96 percent of cases). Treatment of syneresis clouds and treatment of young patients were the least successful (73 percent of cases).

There tended to be a slight improvement in vision acuity with the procedure (see chart below).

Sometimes patients gained significant vision. One patient gained 5 lines of vision because the floater was suspended in the pupillary axis.

No patient lost significant vision.

There tended to be a moderate reduction in intraocular pressure with the procedure (see chart below). (The post-operative pressures were taken the morning after the procedure. Probably this reduction in pressure resulted from the patients being more relaxed in the postoperative visit. Preoperatively many of the patients had traveled long distances and were anxious about having an unusual eye procedure.)



Successful treatment

There were 7 cases of insignificant complications in the series. Two of the seven cases had an insignificant complication of a harmless circular retinal hemorrhage. Both of these hemorrhages occurred in the same clinical situation and were semi-intentional. The situation was the floater was very close to the retina. The laser beam was positioned onto an avascular portion of the retina so any hemorrhage would be harmless. Using the Peyman 18mm vitreous surgical contact lens, the project was to fire the laser progressively closer to the retina to see how closely one could work to the retina without getting a hemorrhage. When a tiny retinal hemorrhage appeared, the question had been answered cases. The hemorrhage was gone the next week without a scar. Since then, there have been no further retinal hemorrhages while using that lens. In the second patient the project was the same but using the Peyman 25 mm surgical lens. The answer was learned in the same way, and there have been no further hemorrhages with that lens.

Five of the seven cases had moderate pain and tearing for about 10 hours after the surgery. (My investigation of this problem revealed punctate staining of the cornea without pressure elevation. The very thick gonio fluid (*methyl*cellulose) was suspected to be the cause of the problem because some of these cases lasted 25 minutes, depriving the corneal epithelium of its needed oxygen which is normally obtained from the oxygen absorbed in the tear film. In addition it usually took an hour for this gonio fluid to clear from the eye. A much less viscous gonio fluid (*ethyl*cellulose) was obtained from Alcon Surgical Corporation. It clears off the eye within 5 minutes after the case. Since switching to the Alcon gonio fluid, there have been no more cases of superficial punctate keratopathy.)

Average age	56 years
Sex	Males 65%, females 35%
Eye	Right 59%, left 41%
Average vision	Pre-op. 20/27, post-op. 20/24
Average tension	Pre-op. 15.6, post-op 13.6
Average number treatment sessions	1.6
Average number of shots per session	58 (Varied from 1 to 174)
Average power	7.7 mJ (Varied from 2.6 to 10 mJ)
Follow up	Average-13 mo. (Shortest-12. Longest-18.)

Table 2. Other parameters.

DEFICIENCIES OF THE STUDY

The photographs were disappointing. No camera has ever been designed to take floater photographs. The problem is compounded because the photograph is needed before the start of surgery to be sure you have a suitable image. This means using Polaroid film (with its poor resolution) or digital imaging. Thin floaters are best imaged with side illumination like the slit lamp. Other floaters, especially large solid ones, are best imaged with coaxial illumination. But no commercial camera does it both ways. A fourth camera setup is presently being evaluated. It uses a digital camera attached onto the slit lamp ocular with a homemade ring.

CHAPTER 11. BENEFITS, SUCCESS, AND RISKS OF THE PROCEDURE

Reading without troublesome floaters.

The benefit is the removal or reduction of the floater and the elimination or reduction of symptoms. Floater symptoms vary greatly, but the most common complaint is that patients see specks in their vision all the time.

When a very brief statement of surgical success is needed, the use of 92 per cent success is appropriate. That number is accurate, but it is a composite of all types of floaters. Success with opacity obliteration is like any other surgical procedure in that case selection and the surgeon's experience affect it. Success can be above 95 percent with narrow case selection. As one gains experience and tries more difficult cases, the success rate drops. Many cases are so straight forward that one can not only predict accurately the success, but one can predict fairly accurately how many shots it will take to clear the opacity. Success rates of various types of floaters and our criteria of success are given in Chapter 10.

Success can be obtained in two ways: (1) eliminating or reducing the floaters or (2) moving the floaters so they are seen less by the patient. In each case you decide which method (or rarely a combination of the two) you will use.

A benefit of success is a fairly frequent improvement in visual acuity. This improvement is not mentioned to the patients preoperatively, but it is logical that if a floater were located in the central visual axis of the eye, the acuity would improve if the floater is removed. I have seen as many as five Snellen lines of improvement from obliterating a floater.

In general, this is a low risk procedure. The U. S. Food and Drug Administration approved our application to perform a study on the Laser Treatment of Vitreous Opacities and ruled it a "non-significant risk device study." After gaining this FDA ruling, we did our 200 case Formal Study (Chapter 10). There were no significant short or long term complications in the 200 patients. The complication rate for all our 2,000 floater operations has been 0.10 %. Patients should be informed that with any surgical procedure, complications can arise. Our search of the world literature through the local hospital library, Med-Line source, and the National Library of Medicine and unpublished studies revealed a total of 208 human cases of laser treatment of vitreous opacities in which an assessment can be made of success and complications. There were no significant complications, although there were 5 cases of transient pressure elevation and one case of transient vitritis. More details on risks are given in Chapter 21 on Avoiding Complications.

In spite of this excellent record of safety, the operative permit should contain the statement that complications are quite unlikely, but can occur. Hemorrhage, retinal detachment, damage to the lens, elevation of ocular pressure, and others are possible. No listing of complications is complete.

CHAPTER 12. SURGICAL INDICATIONS AND CONTRAINDICATIONS

The brief list of Inclusion and Exclusion Criteria for our Formal Study (Chapter 10) is similar to the list below.

In general, indications for laser treatment are:

- Patient has significant symptoms from the floater such as difficulty in driving, reading, using a computer, significant annoyance, or their concentration affected.
- Patient has had the floater longer than 2 months without significant improvement. (The advantages of waiting 2 months or more is: it may allow time for a posterior vitreous detachment to become more complete which brings the floater forward for easier, safer treatment; if the patient gets a retinal tear during the waiting period, your treatment can not be blamed; and some floaters, especially if made of blood, go away in that time.)
- Patient is 21 years of age or older.
- The floater must be at least 3 millimeters from the lens and the retina.
- Follow up can be obtained.
- Reasonable cooperation by the patient during surgery.
- Patients are treated regardless of whether or not they have a posterior vitreous detachment (P.V.D.), but there are three advantages if they do have a P.V.D. (1) The P.V.D. pulls the opacities to the center of the eye away from the retina. (2) Any residue from the treated opacities disperse better if there is a P.V.D. And (3) if they already have a P.V.D., you can't create one, although creation of one is extremely rare.
- Patients with peripheral retina pathology were included. I have treated with no problem many patients with severe peripheral retinal degeneration including one with an asymptomatic hole with a round operculum and another with retinoschisis in the same quadrant as the floater. I have treated without difficulty about 30 patients who formerly had a retinal detachment treated with cryo or with an encircling band and buckle. Before treating these patients, a careful check is made to be sure the retina is flat both anterior and posterior to the band, and there are adequate treatment scars. If a patient has a symptomatic retinal tear, they should be referred for treatment prior to laser treatment of their floater. Perhaps the reason that laser treatment for floaters is not harmful in the presence of peripheral retinal

pathology is that with each shot of the laser, theoretically, vitreous traction is reduced.
- Very diffuse opacities, such as syneresis clouds, are slower to disrupt. But they are candidates if the floaters are fairly central.
- Floaters from old, inactive toxoplasmosis can be treated.
- Far off-axis floaters that move central on eye movement.
- Multiple floaters of generalized vitreous syneresis are usually treated unless an unreasonable number of laser shots would be required to obtain a significant reduction of the floaters.
- High myopia such as –10 to –20 diopters does not contraindicate surgery, but it can present a slight technical problem. When doing a posterior floater, one should be able to push the slit lamp joy stick forward and see the retina. In eyes where the high myopia is from excessive axial length, the retina can not be seen with the Karickhoff 21 mm lens. If that is the case, switch to the Peyman 25 mm lens. (see other problems in high myopia in Chapter 16).
- Success (8 of 18 eyes) has been reported in treating persistent vitreous hemorrhage in diabetic patients with a flat retina. 1 to 6 treatments were required over several weeks.[1] No such case has presented to me.
- This procedure has not reactivated optic neuritis in now quiescent multiple sclerosis patients.

In general, contraindications are:
- Asteroid hyalosis (hundreds of tiny floaters): Patients with severe asteroid hyalosis often have a drop in their vision from this disease to the 20/40 level. Laser treatment has nothing to offer to these patients. I have tried twice to obliterate a few asteroid hyalosis opacities and achieved no noticeable effect from the laser hits. (If these patients develop a cataract, the cataract and treatment of the asteroid hyalosis can be done as a combined operation. After removing the cataract with phacoemulsification, under viscoelastic an anterior capsulotomy pick is used to make a tear in the posterior capsule. Then using the capsulotomy forceps this tear is converted to a circular capsulotomy. A core vitrectomy is then done through this opening to get rid of the asteroid hyalosis. Then the lens implant is put in place. Usually the patient will report postoperatively that they see much better than before the cataract developed. Mossa has published the details of this operation.[2]
- Multiple floaters caused by acute ocular inflammation such as pars planitis or sarcoidosis.

- Floaters associated with untreated, symptomatic retinal tears or untreated retinal detachment.
- Floaters peripheral to the central visual axis to the point that they are untreatable.
- Excessive lenticular astigmatism. This can prevent a precise focus of the laser treatment beam and would thus be a contraindication. Lenticular astigmatism is recognized by the combination of excessive astigmatism in the glasses and spherical keratometer readings. On the other hand, excessive corneal astigmatism presents less of a problem because this astigmatism is largely neutralized by the surgical contact lens.
- Long, hairy, rope-like opacities associated with syneresis. These opacities look like Christmas tree trimmings. The treatment would be endless and excessive energy would be required. Attempting to move these opacities to another location in the vitreous has not been effective.
- The floater must not be so big that the surgeon believes it could not be eliminated with reasonable laser power, a reasonable number of shots, or less than 5 treatment sessions. Be suspicious that a floater with sharp ends may be very difficult to treat. Sharp ends may indicate a high fibrin content. Those opacities tend to break into smaller pieces rather than disappearing. Rounder opacities seem to disintegrate quite easily.
- Patients that think they have floaters but actually are seeing the waves or folds in clear vitreous. The laser can be tried, but does not seem to be very effective in treating the vitreous face without floaters.
- If an area in the face of a posterior vitreous detachment is heavily opacified, this area can be very difficult to disrupt. If the area is large, it is impossible.
- Flashes, unless infrequent and weak, are considered a contraindication to floater treatment. Since a percentage of these patients with flashes do develop retinal detachment, one should be cautious.
- Patients with unusually high anxiety or depression related to the floaters.
- Patients with a history of significant psychiatric problems that may recur or worsen if there is no improvement with treatment or if there were a complication. Some of these patients can be considered for treatment if their psychiatrist sends a letter clearing them for the treatment.

- Glaucoma, on glaucoma medications, a history of glaucoma, or high pressure is a contraindication; however, a few careful exceptions can be made. (see Chapter 20, Avoiding Complications, the section on preventing elevated pressure; see Appendix L, Simplified Outflow Facility Testing)
- A floater that is a piece of internal limiting membrane removed from the retina during a vitrectomy can not be effectively treated with the laser.

RELATIVE CONTRAINDICATION

Patients with poor vision in the other eye have a relative contraindication. However, after some experience, surgery can be done on the better eye if the patient is mentally well balanced, and it can be done with a fairly low number of shots and the floater is fairly central. For example, surgery would be indicated in a one-eyed patient if the floater were a thin Weiss ring or an isolated fairly small floater. Surgery is not indicated if there are multiple floaters, large floaters, or floaters close to the retina. Obviously the level of vision remaining in the worse eye is a factor to be weighed. It is only the extremely low rate of complication of laser treatment of floaters that makes operating in a one-eyed patient reasonable. I have operated on one-eyed patients about 140 times.

Presence of some multifocal intraocular lenses. (For example, the Restor lens divides the laser beam so that floater treatment is more difficult. Other multifocal implants may do the same thing.) However, laser treatment can be done through regular (monofocal) and accommodative implants (Crystalens).

The “Floater Duet” situation (having both a Weiss ring type floater and multiple syneresis floaters located in the anterior inferior vitreous in the same eye) is a relative contraindication (read carefully page 113 and 114). The laser can treat the Weiss ring but can not treat the anterior inferior floaters. Only if the Weiss ring is quite large and the anterior inferior floaters quite small should the eye be treated.

[1] Little, H. L.: Q-Switched neodymium:YAG laser surgery of the vitreous. Graefe's Arch Clin Exp Ophthalmol 224:240-246, 1986

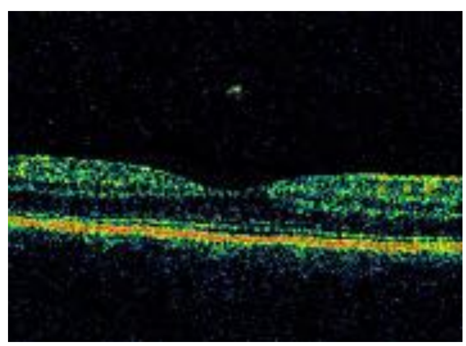
[2] Mossa et al: Floaterectomy: Combined phacoemulsification and deep anterior vitrectomy. J Cataract Refract Surg 28:589-592, April 2002

CHAPTER 13. YOUNG PATIENTS WITH FLOATERS

Floaters in patients younger than 35 years old are frequently different than those in older patients. Younger patients may require some differences in the examination and treatment.

The floaters of young people are usually one of four types:

1) The most common type is transparent threads or specks that can be see quite distinctly by the patient but not by the doctor. Up until this point these "invisible" floaters have been somewhat a mystery because they can not be seen by the doctor using the indirect or direct ophthalmoscope, using a contact lens at the slit lamp, and can not be photographed. Such usual methods don't visualize these floaters because the floaters are not opaque enough to reflect light back through the patient's eye, through air, through the ophthalmoscope, through the doctor's eye and register on his retina. However, with the advent of OCT they can finally be documented. Their location near the retina can cause severe symptoms of a moving shadow, and this location usually makes treatment unsafe. The patient can see these floaters very easily because the transparent fibrils or specks distort the light just before it strikes their retina. Young patients seem more emotionally disturbed by their opacities than older patients. For example, one young patient stated that the opacity was causing trouble in his marriage. He explained that it bothered him so much that he complained all the time and took it out on his wife (a physician). Another patient said he was very sensitive to these floaters and the dilating drops might cause him to faint. I took my chances and dilated him. He did not faint. Feeling confident, I described his floaters. At this, he fainted. Some are suicidal over their floaters. If you



OCT documents "invisible" pre-macular floater.*

*Courtesy of Valla Djafari, M.D., Vienna, VA have to tell these patients that you can not see or treat their floaters, do expect an emotional response of stunned silence, argument, hostile questions, or crying. It is reassuring to the patient to give the explanation above of why they can see their floaters and you can't.

2) The next most common type of floaters in young patients is multiple syneresis clouds. Many laser shots are required to treat these cases. The patients are improved but all the floaters can not be cleared.

3) Another type is thin fibrin, silk-like strands. The success here again is partial.

4) And finally, some of these patients have isolated solid floaters.

Typically younger patients complain much more than older patients, but their opacities are only a fraction of the size of those found in older patients. The explanation for this curiosity may be in the location of the opacities. In an older patient, the opacity, although large, is frequently more anterior due to a posterior vitreous detachment and casts little shadow on the retina. In young patients who rarely have a posterior vitreous detachment, their floaters are more posterior casting a distinct shadow on their retina.

The first step in these younger patients is to check with the slit lamp for a posterior vitreous detachment (PVD). If they don't have one (they usually don't), the chance of finding a treatable isolated floater is probably less that 50 percent. I announce then that they don't have a PVD and the chances of finding a treatable floater is not high, but I will look diligently. Here is the order of the diligent search: Look with the indirect scope to be sure the retina is normal; look with the direct scope; then look with a contact with a flat front face. If then I have to announce the floater can't be found or can't be treated, they seem at least partially satisfied. If they have one or two isolated opacities, they will usually be very near the retina and most commonly slightly above the superior temporal retinal artery about three disc diameters from the disc. The floaters found in that location were not treatable.

Deciding whether to attempt treatment is also difficult. Sometimes a few shots can get rid of the problem. If the retina is somewhat out of focus while looking at the floater, and the macula or no vessel is in the back-scatter area, treatment may be tried.

Perhaps the greatest need in laser treatment of floaters is a better way to find the offending floater in young patients.

(Research project: I wondered if the Scanning Laser Ophthalmoscope might be helpful in locating these small floaters in young patients. The instrument literature was obtained and I spoke with an expert technician of the manufacturer. A digital video produced by this instrument was studied. It showed movement of floater clouds and partial blocking of the central vision. The video did not show small floaters. This instrument was designed to examine the retina and choroid and is not helpful in locating small floaters.

I wondered if Optical Coherence Tomography might help visualize the floater. I contacted Humphrey who makes the unit and talked with their technical staff. They felt that the OCT unit would not locate floaters. They said the unit was designed for the immediate pre-retinal area, the retina, and the choroid. They felt that the great majority of floaters would be too anterior to be visualized by the unit.)

Eventually, I did develop an invaluable method for finding these small floaters that requires the purchase of no new equipment. In this Patient Assisted Method one shines a small beam of the slit lamp onto the retina using a flat-faced examining contact lens. Ask the patient to move their eye around and tell you when the troublesome floater is in or near the light. Then ask them to move their eye slightly while you search that area. You will see the floater go by. Follow the direction it went, and you will find it. Many good ideas in medicine are learned by serendipity. This valuable technique was learned while hunting for a small floater when the patient said, “The floater just passed through your light beam.”)

CHAPTER 14. THE PROCEDURE, AND THE DISCUSSION BEFORE, DURING, AND AFTER

DISCUSSING THE VITREOUS FACE

If the patient has a floater plus a prominent vitreous face, or tiny strings, or faint shadows, it is important to explain carefully that the procedure gets rid of only the globs and solid floaters, not the cloudy vitreous face. Stress that you can't do anything about a wrinkly vitreous face, and they are going to still have mild fuzziness in their vision from the vitreous face after the laser procedure. Tell them that most patients can mentally disregard the vitreous face after the formed floaters are gone. Explain that the cloudy vitreous face is like looking through wrinkled cellophane. If you don't give this explanation before starting the case, they will be surprised to be left with a faint haze. When you are concentrating on the floater, it is easy to forget to give this explanation of the vitreous face that will remain, so be mindful to always discuss this before surgery.

DISCUSSING MULTIPLE FLOATERS

When a patient has, for example 100 floaters, the procedure can not get rid of all of them with a reasonable number of shots. The patient must be told that. Better yet, tell them and also give it to them as a handout like what is in quotes below. This handout is also reproduced in Appendix E.

"When a patient has one floater, the laser treatment can usually eliminate almost all of it. These patients are relieved of their symptoms and their satisfaction with the procedure is very high.

However, when a patient has, let's say, 100 or more floaters, usually in the form of a cloud, the laser treatment can never eliminate all the floaters with a reasonable number of laser shots and their satisfaction is never complete. What we are hoping for is an improvement (not a cure) so the patient does not feel the need for vitrectomy. For these patients we can usually improve the symptoms by reducing the number of floaters and sometimes by moving the cloud away from the central visual axis. These cases usually take about three times the number of shots and three times as long as when treating one floater. About 75 per cent of these multiple floater cases do have significant improvement."

DISCUSSING GAS BUBBLES

Tell the patient that during the procedure the laser converts the floater to a gas. Therefore, they are going to see these gas bubbles produced inside their eye on many shots. Tell them these are harmless, and they will all be gone tomorrow. Explain that everything they see in their eye during the procedure is upside down. They will think they are seeing debris from the floaters breaking up and falling to the bottom of their eye. But that is not the case. What they are actually seeing is the laser shot changing the floater from a solid to a gas, and the gas bubbles are actually going up, not down.

EVALUATION AND PROCEDURE PLAN

The evaluation and procedure schedule in the office is as follows. The evaluation is most often in mid to late morning. If the patient is a candidate, the first eye is done in the afternoon. Rarely are both eyes done the same day. That would scare most patients and make the surgeon appear too aggressive. The patients feel much more confident when I say, "Let's have this be the plan. I'll do one eye today. If you tell me in the morning that you had a major improvement, we'll add a few shots to that eye, and then do the other eye. If you don't get a major improvement, we won't do your other eye." They appreciate that plan. But the next morning nearly every patient wants his or her other eye done. Both eyes can certainly be done on the same day and occasionally when snow has disrupted the schedule, this has been done. But it takes a major leap of faith for the patient to have both eyes done, by a surgeon they have known only an hour, using a procedure that their own eye doctor has told them did not exist or shouldn't be done. The third morning, additional shots are frequently done in the second eye, and then they are released.

With bilateral floaters, on which eye does one operate first? Does one operate on the (a) easier floater to do, (b) the more difficult floater to do, (c) the worse floater, or (d) the lesser floater? I choose none of the above. When dealing with a procedure with nearly a zero complication rate and where there is essentially full recovery the next morning, there is no medical imperative to weigh the choices above. The first eye done is the one that will have the more dramatic, quick improvement. With this plan the patient returns the next morning reporting a dramatic improvement, and asking to have their other eye done. If you do the less dramatic eye first, their improvement may not be enough for them to want their other eye done, and it would have been the more dramatically improved eye.

You will note that this approach is different from what we use in cataract surgery where the complication rate is a bit higher and the recovery is much longer. In cataract surgery we operate on the poorer seeing eye first, not wanting to disturb their better seeing eye until we have gained good sight in the poorer eye.

THE PROCEDURE

The procedure is as follows: After dilating the pupil, an anesthetic drop is placed on the cornea, followed by a surgical contact lens. The aiming beams of the laser are placed on the floater and the laser is fired. This vaporizes a small part of the floater frequently producing a gas bubble. The power setting is 5 to 10 millijoules with the larger setting used in the posterior vitreous and on the denser floaters. Most isolated floaters require less than 100 shots. I give a maximum of 300 shots per eye total. Almost all of the patients report an improvement the next morning and want their other eye treated. Usually some additional shots are given to the first eye and then the other eye is treated.

Performing laser procedure.

As we sit down at the laser, I say: “This procedure is very easy on the patients. You won’t fall asleep but the procedure will not bother you.” As soon as I have made good progress, I say for example: "Your floater is now 50% gone." Later I say: "It is now 95% gone."

When finished and I take the contact lens off, I tell them one of two things: (1) If they had an isolated floater like a Weiss ring, I just say, “Cover your other eye. Is the floater gone?” These patients usually know immediately that they have been cured. (2) If they had multiple floaters, they will not be able to tell immediately if they are better. So I just tell them the floaters were significantly reduced. Then I explain that they will not know how much improvement they have until the next morning when the pupil is normal size and the gas bubbles are gone.

POST-OPERATIVE INSTRUCTIONS

We then return to the examining lane, and take a very quick look at the fundus with the indirect ophthalmoscope, and I pronounce everything is "fine." The post-operative instructions below in quotes are then given as a hand-out and I go over them. They are reproduced in Appendix D.

"Your vision will be somewhat blurred for 4 to 8 hours. This is because the eye is dilated, there is still some grease on the eye from the contact lens, there may still be some dazzle from the laser, and there are now gas bubbles in your eye.

You may feel that there are more floaters now than before the operation. This is because you are seeing gas bubbles in the vitreous. These bubbles will be gone by tomorrow.

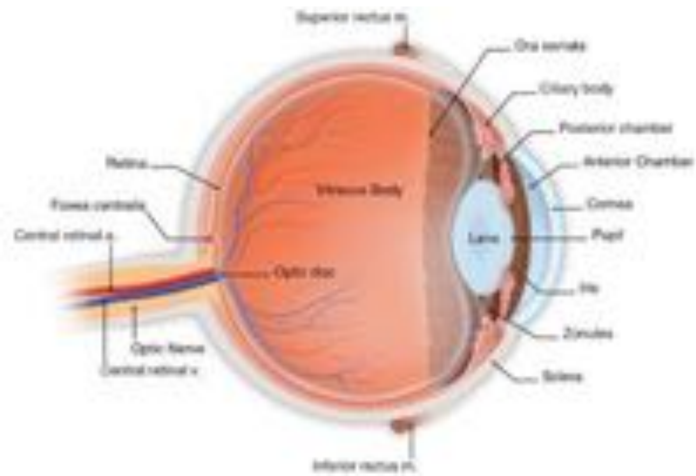
Occasionally on the day of surgery, patients will have some foreign body sensation and tearing, and a little running of the nose from the eye that had surgery. This comes from a slight abrasion of the front of the eye from the contact lens used during the surgery. Almost always this is fine the next morning.

If you have any trouble, call Dr. (name) at (phone number). What is trouble? Call me if you have a lot of pain, the vision decreases significantly, you develop lightning flashes in the eye, have loss of vision in one area, the eye turns red, or if there is anything else that worries you.

On your next visit __________, _______________,2005 at _______(a.m.) (p.m.) we will assess everything in detail."

CHAPTER 15. HOW OTHER STRUCTURES EFFECT THIS PROCEDURE

THE CORNEA



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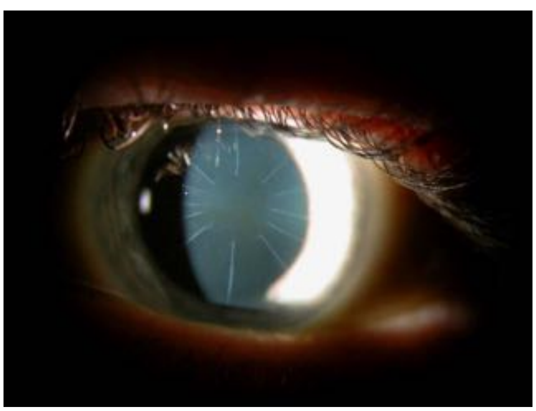
Previous radial keratotomy may affect the surgery. If the clear central optical zone from the radial keratotomy is 4 mm wide and the floater is central, there should be no problem. However, if there are greater than 8 incisions and the optical zone is as small as 3 mm, the incisions may defocus the treatment beam enough to prevent optical breakdown. The only way to know if treatment is possible is to dilate the pupil, put the treatment contact lens on the eye, and see if the aiming beams come to a fairly good focus on the floater. If they do, this indicates you can get optical breakdown. This is not an absolute indicator, however. The aiming beams are small and the treatment beam is wide. So the aiming beams can be defocused, but there is enough undistorted treatment beam to get optical breakdown. When the treatment beam is focused on a floater and passing through an RK incision, there is no damage to the radial keratotomy incision or the cornea. Tissue disruption occurs only at the focal point of the laser.



Radial keratotomy.

Treating patients who have had previous LASIK is not a problem especially if the floaters are central. However, when the floaters are somewhat peripheral requiring the eye to be turned, the laser beam can be defocused by the postoperative knee of the cornea at about 3 mm off center. This is especially seen in cases of high preoperative myopia. Wait perhaps three months for the LASIK flaps to heal before doing the floater treatment.

Performing LASIK.

Perhaps 50 patients have sent e-mails saying that their floaters appeared within a day to two months after their LASIK treatment. It has been found that LASIK can induce posterior vitreous detachment and retinal detachment. (see Chapter 1, page 19).

If a patient desires to have both LASIK and the floater treatment, they should have the floater treatment first. If the floater is done first, the patient can have the LASIK done in the next few days and both procedures will be finished in a week or two. However, if the LASIK is done first, the patient needs to wait about three months for the flaps to heal before the floater procedure can be done.

Geographic corneal dystrophy can be irritated by the surgical contact lens.

A penetrating keratoplasty seldom presents a problem because its irregular astigmatism is largely canceled by the surgical contact lens.

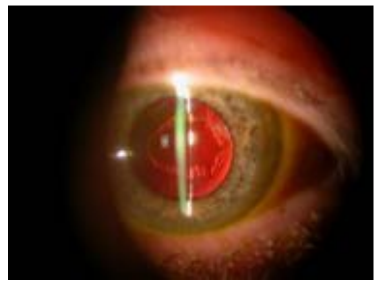
Conductive keratoplasty (CK) does not present a problem here because CK corneal irregularity is neutralized by the surgical contact lens, and CK surgical scars are peripheral to where our treatment beam passes through the cornea.

Conductive keratoplasty

THE LENS

The degenerated anterior lens capsule of a patient with pseudoexfoliation defocused the laser beam to a moderate extent.

A small posterior capsulotomy makes alignment of the aiming beam on the floater more difficult. It is also more difficult to get the whole beam through a small capsulotomy, meaning the power will be decreased and it will be more difficult to obtain optical breakdown. Here the Karickhoff 21mm lens is better than the Peyman 18 mm lens because the beam is narrower with the former lens. It is possible to obliterate a Weiss ring through a 3 mm capsulotomy. If the capsulotomy must be enlarged, this should be done as a separate procedure at least a week prior to the floater procedure to be sure there is no elevated pressure.



Adequate posterior capsulotomy

The incidence of retinal detachment following YAG laser posterior capsulotomy is 0.5% to 4.16%[1] Why is the incidence of retinal detachment after the YAG floater procedure essentially zero? One theory is that in posterior capsulotomies vitreous can come forward through the capsulotomy increasing vitreous traction on the retina. However, in the laser floater procedure, not only can vitreous not come forward, but each shot from the laser decreases vitreous traction by severing vitreous strand and thereby decreasing traction on the retina.

Rarely a patient will have a floater and contracted anterior capsule. Hopefully the floater can be lined up and enough power can get through the opening to obliterate the floater. If a laser widening of the contracture must be done, do it as a separate procedure and wait a week to be sure there is no pressure elevation. Do not do a combined procedure. Again, if there is any pressure elevation, it probably will be incorrectly blamed on the floater procedure.

Elschnig's pearls blocking laser access to a peripheral floater were removed with the YAG laser set at 4.5 mJ using the Abraham capsulotomy lens. The floater was then successfully vaporized.

Pearls removed with YAG laser

The presence of mild lens opacification does not prevent floater disruption. Since the treatment beam is wide and unfocused as it passes through these structures and there is no significant thermal component except at the exact point of focus where the optical breakdown occurs, there is no damage to the lens.

(<u>Research project</u>: In an attempt to prevent degrading the laser beam from excessive lenticular astigmatism, I taped different astigmatic lenses onto the laser where the beam exits nearest the patient. It did not work. The lenses increased the distortion of the laser beam. It might be possible to fit such a patient with an astigmatic soft contact lens that would allow treatment of the floater.)

INTRAOCULAR LENS

Treating through an intraocular lens (or lenses) is different than treating through the natural lens. There are several points to keep in mind:

(a) There is more of a troublesome reflex of the illumination mirror of the slit lamp than with the human lens due to the IOL being flatter.

(b) One needs to be sure the treatment beam is not distorted and weakened by passing through the edges of a capsulotomy if it is present. If the capsulotomy is large, let's say 4 mm, little difficulty is encountered. But the smaller the capsulotomy, the more difficult the case. And the smaller the capsulotomy, the more central the floater must be to disrupt it. Using the Karickhoff 21 mm lens helps because there is not much coning with this lens making the beam narrower as it passes through the capsulotomy.

Piggyback IOL's.

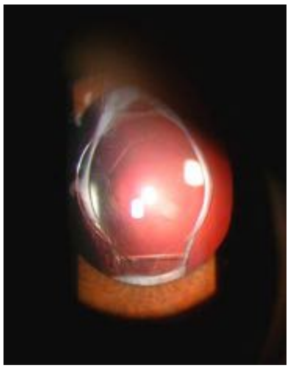
(c) Don't hit the IOL.

(d) If you need to work near an IOL, you may want to switch to the Abraham iridotomy or capsulotomy lens. Beware of hitting the IOL. Do not use these lenses if the patient has their natural lens. The optics can become confusing (see Chapter 21 on Complications).

(e) In the presence of a wide capsulotomy, don't accidentally extend the capsulotomy so that vitreous herniates into the anterior chamber.

(f) If the floaters are severe, keep in mind this patient is a better candidate for vitrectomy than any phakic patient because this patient can not develop the most frequent complication of vitrectomy, a cataract.

Multifocal intraocular lenses, especially the Restor lens, routinely present a problem in laser floater treatment. Any light, including the laser treatment beam, passing through these lenses is distorted and split into two or more beams. This reduces the effective laser power and precise



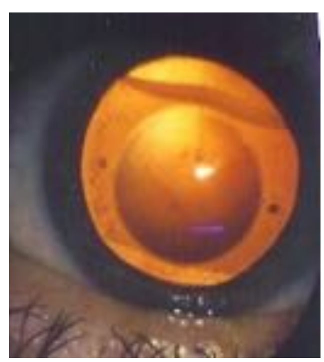
Accommodative IOL.

focusing, making it more difficult to vaporize some floaters. With multifocal intraocular lenses, it is theoretically possible for one focus of the aiming beam to be on the floater and another focus nearer the retina without the surgeon's knowledge of this. Therefore, any shot near the retina must be done carefully in the presence of a multifocal lens.

Unlike multifocal implants, accommodative intraocular lenses do not distort the laser beam. The two accommodative implants available now are the AT45 Crystalens (Eyeonics Vision, Aliso Viego, California, USA, and the 1CU (Human Optics, Erlangen, Germany).

Multifocal IOL.

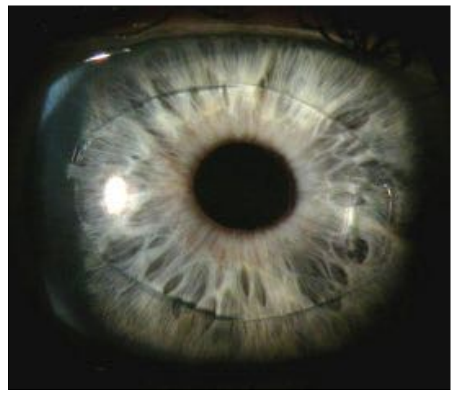
Treating a floater through an Intraocular Contact Lens (ICL) can be different. (a) The number of reflexes you see is increased slightly due to the extra lens in the eye. The reflexes are a bit worse with a posterior chamber ICL than with an anterior chamber ICL. (b) The area through which the laser beam must pass is limited by the size of the optic of the intraocular contact lens. This is not a problem for central axis floaters, but it makes treatment of off-axis floaters more difficult. (c) Intraocular contact lenses are usually placed in eyes because of high myopia. In high myopia sometimes the floaters tended to break up into smaller pieces more than being converted to a gas and thereby obliterated. Also the vitreous in high myopia may tend to become somewhat smoky where the laser is fired. This smokiness was not seen the next day. Patients with myopia greater than minus 9 before the intraocular contact lens was inserted should be informed that their floaters might tend to break into smaller pieces more than usual. (d) The anterior and posterior capsule of the patient's natural lens seems less obvious in the



Posterior chamber intraocular contact lens.

presence of an posterior chamber intraocular contact lens. This increases the danger of hitting the posterior lens capsule. It is, therefore, advisable to avoid placing shots in the anterior vitreous in this situation.

When working on a floater near the lens, put the illumination to the side so you can see the lens in profile so you will not place shots near the lens. Opacities suspended in the anterior vitreous in the central visual axis near the lens or an IOL, can sometimes be removed with as little as one shot to a suspending strand. Again, do not use the Abraham capsulotomy or iridotomy lens when working near the natural lens. With these lenses the distance from the posterior lens capsule to where you are working is too small.



Anterior chamber intraocular contact lens.

It is easy to obliterate small floaters close to the lens by reducing the power. However, floaters in this location are seldom symptomatic.

THE IRIS

A well dilated pupil is important for the procedure, especially if the floater is far posterior or off axis.

FLOATERS NEAR THE RETINA

When working near the retina, put the illumination between the oculars so the floater and the retina can be seen simultaneously. If the illumination is placed to the side, the retina is not seen well.

Macular damage from the aiming beam or the illuminating (slit lamp) beam shining on the macula supposedly never occurs, but this possibility should be kept in mind. The continual movement of the beams during searching and aiming and some movement of the eye during treatment provides some macular protection.

The HeNe aiming beam is closer to the doctor than the YAG treatment beam due to (a) an off-set in design, (b) the difference in the wave length of the two beams, and (c) chromatic aberration. This difference increases when working deeper in the vitreous. Therefore, one must aim anterior to the floater so the treatment beam will hit the floater. When working near the retina, aim significantly anterior to the floater. (See laser techniques on page 105 for floaters near the retina.)

Most floaters that are very near the retina are in young patients that do not have a posterior vitreous detachment. These floaters are long, fiber-like, segmented, and transparent with darker borders. These usually can not be seen by the doctor and, therefore, can not be treated.

There is a major reduction in coning of the laser beam when switching from the Karickhoff 21 mm Vitreous Lens to the Peyman 25 mm lens. So be cautious of retinal damage any time when using the Peyman 25 mm lens. (See the Chapter 23 on Surgical Contact Lenses for additional detail on treatment near the retina.)

I have treated about 30 patients that had previously had cryo or laser treatment for retinal tears and never had a problem. I have treated about 20 patients who previously had a retinal detachment treated with an encircling band and buckle. Most of these patients had the floater on the side of the eye near the buckle. This placed the laser shots somewhat nearer to the retina elevated on the buckle. Again, there were no problems.

THE VITREOUS

The vitreous in the presence of high myopia can be different from usual in character. In a few of these long eyes (such as minus 10 diopters) the vitreous became moderately smoky or cloudy during treatment. Check the vitreous in high myopes carefully pre-operatively to see if there is any cloudiness. The patients did not seem to notice the created haze. In high myopia sometimes the floaters tend to break into smaller pieces rather than being converted to a gas and obliterated. Patients with high myopia should be warned of this possibility. The floaters in these eyes tend to be longer than usual and tend to go posterior making full treatment impossible in some cases. On these very long eyes sometimes you must use the Peyman 25 mm vitreous lens to get a crisp focus on the posterior floaters. Beware of using this lens on a normal length eye since this lens has little coning and is more apt to cause a retinal hemorrhage.

[1] Galand et al: Posterior capsulorhexis in adult eyes with intact and clear capsules. J Cataract Refract Surg 22: 458-461, 1996

CHAPTER 16. TREATMENT: GENERAL CONCEPTS, 20 FLOATER TYPES AND TECHNIQUES

(All the techniques presented in this chapter were learned while using the Laserex LQP4106 laser. The techniques may not apply exactly to other lasers.)

GENERAL CONCEPTS FOR THE SURGEON

There are two main types of floaters we treat: (1) floaters that have been pulled off the internal limiting membrane of the retina by a posterior vitreous detachment. These are located on the posterior vitreous face, are soft and can usually be completely vaporized by the laser; (2) floaters that are located within the vitreous as a result of vitreous degeneration. These syneresis floaters are dense, fibrous, and difficult to vaporize completely. The goal is to move these out of the visual axis and to thin them. Recognizing whether it's type (1) or type (2) determines the treatment used.

First, there is no substitute for experience. With increasing experience, your skill, your confidence, and your relaxation improve. And for better or for worse, you start to attempt more difficult cases.

At surgery, neither the surgeon nor the patient should be stretching or stooping. If the patient is stretching to reach the forehead rest, his head will fall backwards during the procedure. If he suddenly realizes this and brings his head forward at the wrong time, it could cause you to hit the retina.

The surgeon's elbow should be elevated with a support pad.

The movable slit lamp fixation light is not used because one hand of the surgeon is needed to hold the contact lens and the other controls the joy stick. It is more efficient to just tell the patient where to look.

The surgeon's concentration should be perfect. Hits on a floater often move it posterior. Good concentration is required to always be aware of the distance to the retina (noted by the clarity of focus of the retinal vessels with the illumination in the central position between the oculars) and the distance to the lens (seen in profile with the illumination slightly to the side).

Good dilation and stereopsis are especially important for examination and treatment in the vitreous.

(Research project: To get a sense of the amount of dilation needed for the procedure, I placed fluorescein dye on the cornea under the contact lens so

I could see where the aiming beams hit the corneal surface. As an example, when using the Peyman 18mm lens and focusing on a floater in the mid-vitreous, the two aiming beams (which I assume represent the periphery of the treatment beam) were about 3.5 mm apart when they hit the corneal surface.)

The treatment usually takes about 15 to 25 minutes. It can be done faster using a laser with a multi-burst mode, but the last four firings of a burst of five are not as accurate as the first firing, and there is a tendency to use too many shot with the multi-burst mode. Excessive shots are, I believe, the cause of the rare pressure elevation.

Put the contact lens on very gently. The slower it is applied, the more reassuring it is but the more apt you are to get an air bubble under the contact. Patients react less to the insertion of the contact lens if the surgeon presses the tip of his ring finger on the bridge of the patient's nose during the insertion. Difficulty putting in the contact lens and frequent changes of the contact lens can rarely cause corneal swelling, and temporary myopic shift. If the superior conjunctiva slides onto the cornea and is seen under the contact lens, raise the patient's chin.

Eye surgeons see no gas bubbles (cavitation) when performing YAG posterior capsulotomies. But when one uses that same laser in the vitreous, both the surgeon and the patient will see a gas bubble produced on most shots. Unless told otherwise, the patients think the gas bubble formation is the floater coming apart and falling to the bottom of their eye. However, what they are actually seeing are gas bubbles going upward in their eye (the image is inverted to the patient). Cavitation here is desired, but in some circumstances (for example, on submarines) it can be life threatening. Because of this association of cavitation and sound production, submarines must travel slowly. If they reach the speed where propeller cavitation occurs, the cavitation noise will be heard for miles and their location revealed.

When working near the lens, place the illumination beam slightly to the side so you can see the lens in profile. This also reduces the contact lens reflexes. When working in the middle and posterior vitreous, put the illumination beam in the central position between the oculars so you can see the distance to the retina as you work. Except when working near the lens, I keep the illuminating beam in the central position (between the oculars).

The diameter (if round) or the width (if rectangular) of the illumination beam is important. On the Haag-Streit slit lamp the diameter of the smallest beam is about ¼ mm, the next larger beam is 1 mm, the next is 2 mm, and there are also larger diameters. If the illumination is too wide, you can't find the aiming beams once you have found the floater, and you don't see vitreous details. If it is too narrow, you don't have enough light to find the floater, and you don't see the retina well. So, I use only the 1 and 2 mm beams. A 2 mm diameter illuminating beam is the size usually used with the Laserex LQP4106 laser. However, if the floater is jumping away each time it is hit, switching to the 1 mm diameter beam reveals more readily its new position after the hit.

To find the floater, put the illuminating power switch of the slit lamp in the next to weakest position and use the 2 millimeter round illumination beam.

There is some movement (one or two millimeters) of most floaters when hit by the laser beam. This movement is harmless. When a patient not undergoing laser treatment looks side to side, their vitreous opacity frequently moves as much as 10 mm. And this extensive movement occurs all day, every day without harm to the eye.

Very dense, big, fibrous opacities require a lot of laser energy, and they seem to move posterior while treating them. I assume this is because to get optical breakdown, you need to aim at their anterior surface. When they move too close to the retina, you can take your fingers off the contact lens and have the patient move their eye far down and then back to the center position. This will usually bring the floater forward a bit. If that doesn't help, you can have them back the next day, and frequently you will find the opacity has moved back to the original position.

When working in the posterior vitreous especially with the Peyman 18 mm lens or the Lasag lens, the aiming beams becomes less precise and fuzzy and optical breakdown is more difficult to obtain. You can usually improve the resolution and optical breakdown by switching to a longer focal length contact lens such as the Karickhoff 21 mm Floater Lens.

In most YAG lasers the treatment beam is off-set slightly posterior to the aiming beams to protect the IOL when performing a posterior capsulotomy. This anterior-posterior off set is exaggerated when working in the posterior vitreous due to the greater focal distance and also due to chromatic aberration. So, when working near the retina, place the aiming beam significantly anterior to the floater. That way the treatment beam should be on the floater.

The main cause of failure in floater vaporization is insufficient power. To obliterate vitreous opacities, you need to run the laser above the threshold of optical breakdown in vitreous. On my laser this means setting the power above 2.2 mJ. My average power setting in the mid vitreous is 7.7 mJ. Optical breakdown is more likely to occur the higher the power and the smaller the spot size. The percentage of optical breakdown shots improves with learning to aim the shot properly.

Here are two examples:

(1) If the YAG beam (not the HeNe beam) is aimed into the middle of the opacity, the opacity will block the beam from coming to a tiny focus, and optical breakdown will not occur. (2) If the YAG beam is aimed at the front surface of the opacity, the beam comes to a tiny spot focus, optical breakdown occurs, and some opacity disintegration occurs.

In spite of your best efforts, optical breakdown will not be achieved on some shots. You will know this because you don't see the light flash and you don't hear the snap. Some sophisticated patients are also quick to learn that sometimes when you hit the foot pedal, there is no flash, no snap, and no gas bubble formation. And they may tell you. You need to stop, analyze the cause of this and correct it. The most frequent causes of loss of optical breakdown are:

(a) Part of the treatment beam is blocked by the iris. This is indicated sometimes by seeing only one aiming beam on the floater. Try raising or lowering the chin rest and usually the second aiming beam will then appear on the floater. At other times, blockage of part of the treatment beam is indicated by part of the illuminating beam hitting the iris. If this is the case, correct it by having the patient turn their eye a bit.
(b) The floater is off axis or the eye is turned off-axis so that enough corneal striae have developed to degrade the focus of the treatment beam. Correct it by using one of my off-axis contacts.
(c) The floater is more posterior than the focal distance of the contact lens you are using. The focal spot of the aiming beam will be fuzzy. You also diagnose this better with experience by learning the depth of focus of each contact you use. Go to a longer focal length contact lens.
(d) The floater has a high fibrin content,
(e) There is debris, gas bubbles, or other floaters anterior to the floater upon which you are working,
(f) The floater is in the far posterior vitreous, or
(g) You are working through a small pupil, a small capsulotomy, or an IOL with its increased reflexes.
(h) The floater is peripheral. First, turn the front of the contact lens toward the floater. This gives more discrete focus. Second, change to one of my off-axis contact lenses.

There is some spontaneous absorption of some floater fragments remaining after laser treatment. This is especially useful when the remaining fragments are from a Weiss ring that has gone too far posterior for further treatment.

The most common cause of failure is inadequate power. The ideal power setting is (a) when you are getting adequate disruption of the floater, but (b) you are not bouncing particles away so that you have to hunt for them. The more posterior you are working in the vitreous the more laser energy is absorbed by the vitreous, and a higher power is required to disrupt the opacities. For my laser, 8.5 mJ would be a typical power setting for the posterior vitreous. 5 mJ would be a typical setting for a floater 1/3 of the way back into the vitreous.

When the illuminating beam is being reflected back to the surgeon more than usual by the cornea, this probably means the treatment beam will also be reflected back more than usual when fired. This is not harmful to the surgeon. If you tilt the contact lens slightly and get rid of some of the illuminating beam reflex, you may notice a sudden increase in the treatment beam power because it is not being reflected back.

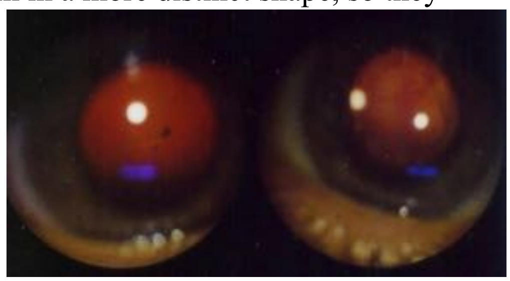
The three basis treatment techniques are vaporization, relocation, and thinning:

(1) Floaters that were pulled off the internal limiting membrane by a PVD (Weiss rings and other hyaline floaters) are hit directly with the laser beam. These soft floaters are attached to the posterior vitreous face. The goal is complete vaporization, i.e., a cure (see page 97). In our 200 patient FDA/IRB monitored study this type of floater was completely or nearly completely vaporized in 96% of cases.

(2) Floater clouds that are suspended in the visual axis are treated indirectly by cutting their thin superior vitreous strands that are holding the clouds in place (see page 111). Frequently the floater will drop to the bottom of the eye with a near miraculous improvement. If the floater does not drop, the cloud is treated directly. Success rate has been near 100%.

(3) Floaters within the vitreous that have developed from primary vitreous degeneration (syneresis) are usually multiple, often cloud-like, fibrous, and more difficult to vaporize. There may be hundreds of floaters. All can not be removed with any reasonable number of shots, so the goal is a significant thinning, not a cure. A significant improvement was achieved in about 85% of such cases in our study.

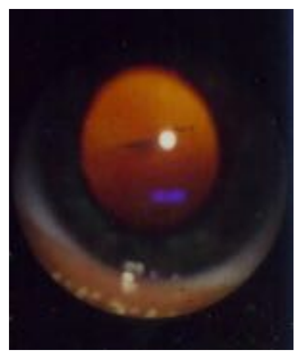
Non-fibrous floaters: These floaters are frequently round with no holes in them. My theory is that these floaters are round because of a low fibrin content that would hold them in a more distinct shape, so they assume a round shape. The success rate with these is very high. They seem to break early and more easily than other isolated floaters.



Round floater, pre & post op.

Fibrous floaters: Fibrous appearing floaters seem to be harder to obliterate. Some want to break into smaller pieces instead of being completely cleared from the vitreous. You can assume that a floater has a high fibrin content if it is (a) flat or flat with a bend in it like a corn flake, (b) it has tiny holes in it, (c) it has sharp points, or (d) it is in the form of a sheet or a fan. The fibrin is what keeps the floater in its distinctive shape. These fibrous floaters are similar in difficulty to obliterating the thicker, fibrous areas of a posterior capsule. These floaters also seem to move posterior during the procedure due to the many shots required. Be sure to treat them from their periphery inwardly so no particles are lost.

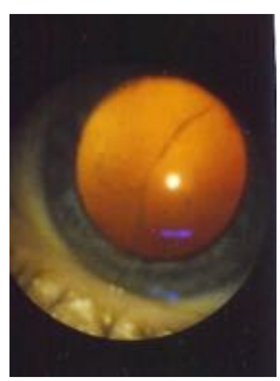
Very fibrous floater.



Fibrous floater.

Stringy, fibrous floaters with and without a PVD can be treated with good results. One such stringy floater had one end of the string very near the lens. In this case the part near the lens was untouched but the rest of the string was removed. The patient was happy. This result was some verification of the concept that the closer the floater is to the retina, the more symptomatic is the patient.

Treating **very thin cobweb** floaters gives variable success. One patient got major relief

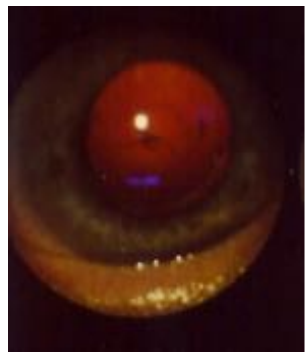


Stringy floater.

of symptoms. Another cobweb floater with a bulge on the main strand could not be affected by the laser.

Long, slightly broad, softer looking floaters respond nicely to the laser, but it requires a large number of shots to significantly reduce or eliminate them.

The results treating **long, hairy, rope-like floaters** are quite variable. Some are just so fibrous they are impossible. They usually are just too long and take too many shots. But occasionally they surprise you. One was entirely obliterated with 293 shots. Our records show a straight rope that broke up nicely. Usually these rope-like floaters take more than one session. There were two cases of hairy ropes that seemed suspended at the top with three silk-like threads of vitreous. The threads were cut and the ropes moved downward, clearing the central visual axis and pleasing the patient.



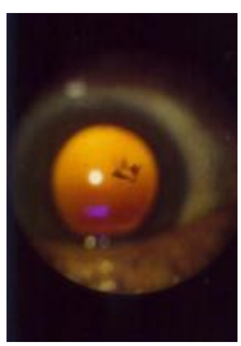
Rope-like floaters.

Long, large floaters on the detached vitreous face seem to have a higher fibrin content and don't break up or vaporize easily.

It seems better to **work from only one end** of a long central floater. On one case I worked on one end of the floater, but when I started working on the other end, the floater suddenly became very mobile and was lost. However, the next day it was found and obliterated.

Weiss rings, their remnants, and other prepapillary glial tissue on the detached posterior hyaloid membrane:

Vogt's or Vossius rings are usually called Weiss rings. However, the earliest descriptions were by Vogt[1, 2]. This type of floater develops when the vitreous detaches from the optic nerve head bringing the ring-like condensation of the vitreous fibers into the mid-vitreous. Almost all of



Pre-op.

Post-op.

Weiss ring.

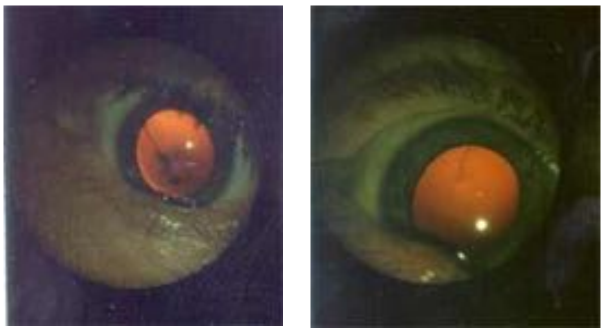


Figure 1. Suspended floater: pre & post op.
One laser shot used.

Figure 2. Patient origin.

Figure 3. String like floaters.
Pre-op. Post op.

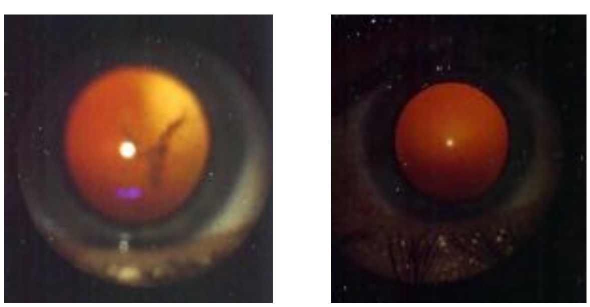


Figure 4. Linear cloud.
Pre-op. Post-op.

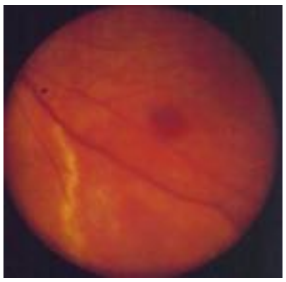


Figure 5. Retinal hemor-
rhage following P.V.D.

Figure 6. Trial colors
for sunglasses reducing floaters.

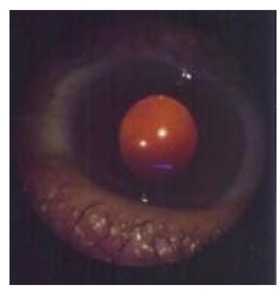
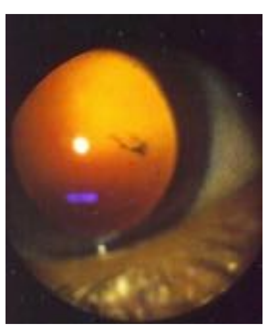


Figure 7. Rectangular floater.
Pre-op.   Post -op



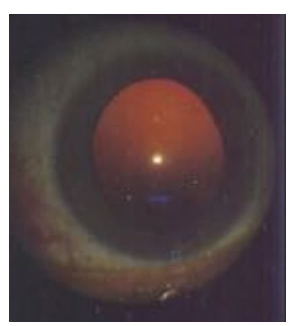


Figure 8.   Linear floater.
Pre-op.   Post-op.

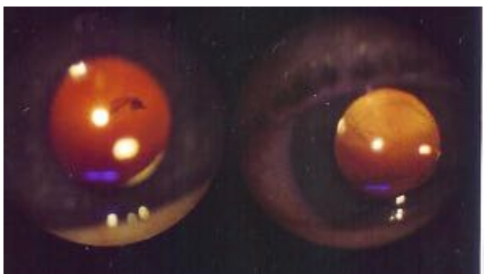


Figure 9. Pre-op floater (left), then
the 20 minute laser procedure, and
the post-op. photo (right) on same film.

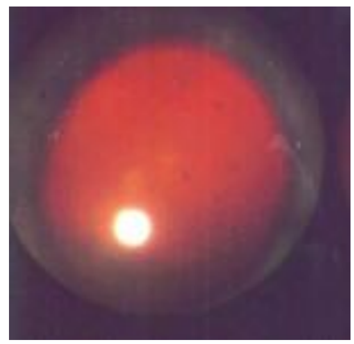
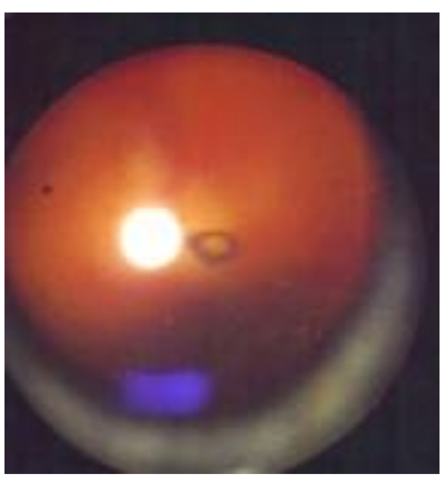


Figure 10. Gas bubbles
from laser.



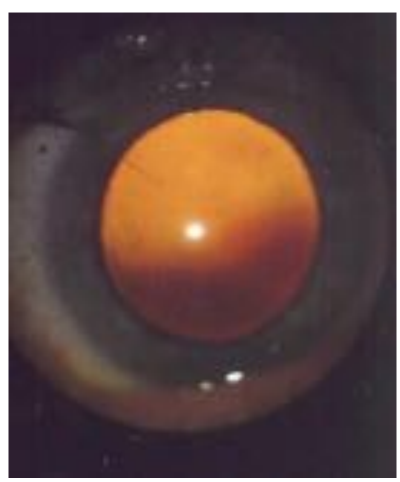
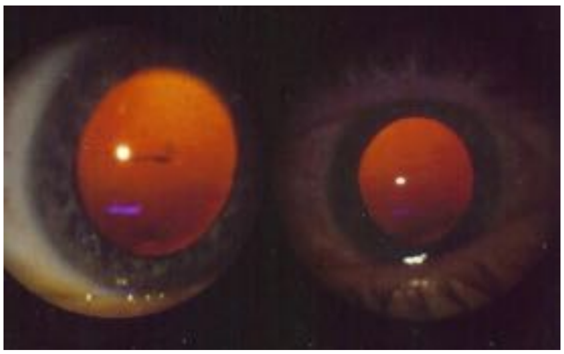


Figure 11. Weiss ring: pre-op. and post-op.



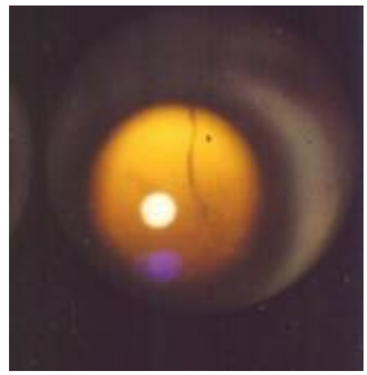


Figure 12. Linear floater, pre & post. op.

Figure 13. Linear floater.

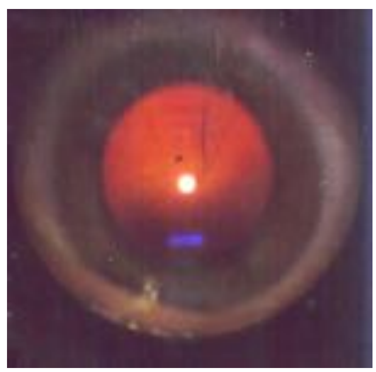
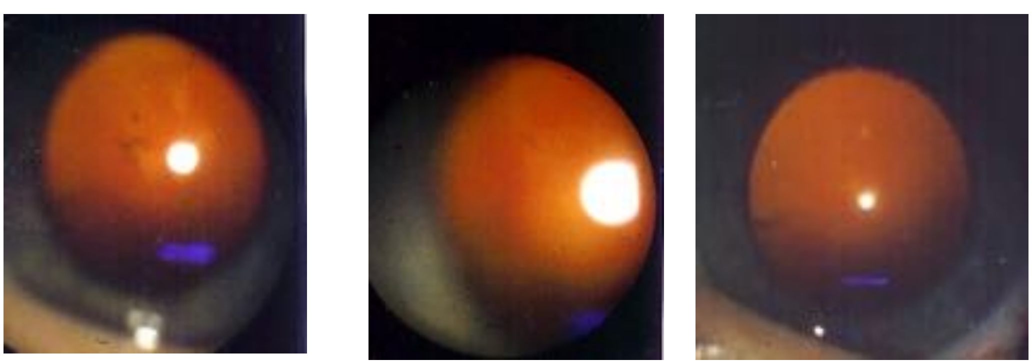


Figure 14. Fan shaped floater.



Pre-op. After 28 shots. After 67 shots.

Figure 15. Weiss ring treatment in stages.

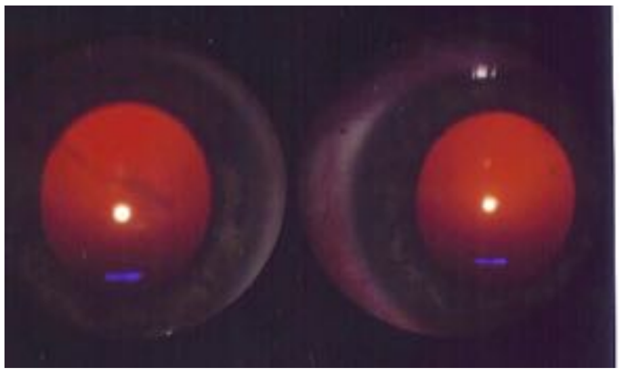


Figure 16. String-like floater: pre-op. & 20 min. later.

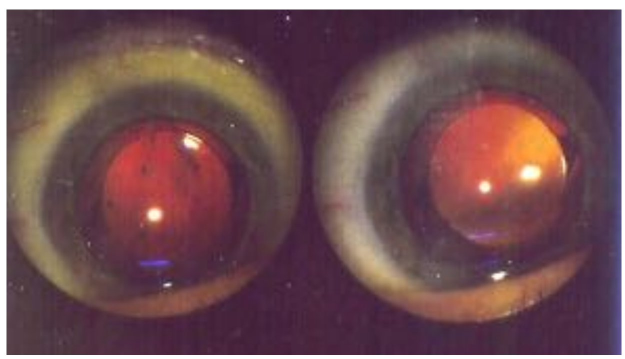


Figure 17. Suspended broad floater.
Pre op.   Post op.

Figure 18. Angle in pigment dispersion syndrome.

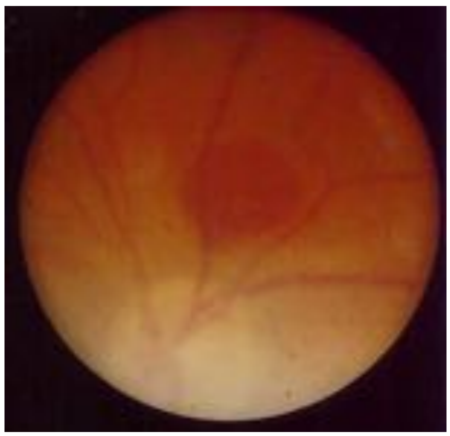


Figure 19.
Retinal hemorrhage from floater treatment at one day.

Figure 20.
Retinal hemorrhage from floater treatment at 14 days.

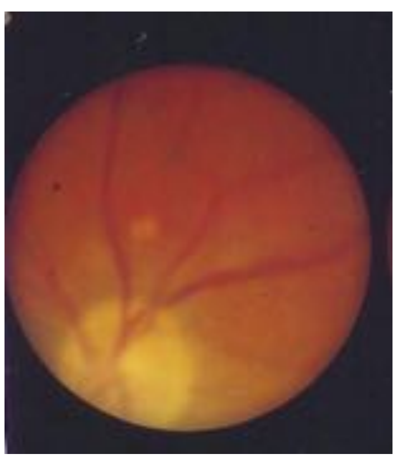


Figure 21.
Retinal scar from floater treatment at 2 years.
(All of lesion is shown.)

Figure 22.
Retinal scars of panretinal photocoagulation treatment.
(1/20 th of lesions shown).

these can be cleared with the laser (see front book cover, and see colored page 101, figure 11). These very symptomatic floaters fortunately are only seen in the presence of a full posterior vitreous detachment, so the floater is almost always found to be a safe distance from the retina for treatment. Complete removal of a Weiss ring produces a very grateful patient. Their appreciation is similar to that heard with the removal of a 20/80 cataract. Only two of the approximately 90 Weiss rings seen by me could not be offered surgery. One was rejected because the ring was too thick, and the other one was too close to the retina. The success rate with Weiss rings is above 97 percent. In spite of the high success rate, some thick Weiss rings are slow to start breaking up. Then once started, they go on to complete obliteration. Rarely, even a thin Weiss ring can be fibrous and very difficult to obliterate.

Weiss rings are the most successful floater to treat, the most interesting, the most dramatic, and our favorite.

Weiss rings are also the most difficult to treat because they are the only floaters that characteristically move posterior during treatment. Reducing the power to 6-7 mJ helps these floaters to stay attached to the vitreous face during treatment. At the point in the treatment when they become detached from the vitreous face, they always move toward the optic nerve head (their origin). Probably these floaters move posterior because there is no true vitreous posterior to the floater to slow its movement. Because the floater moves toward the retina during treatment, a Weiss ring is by far the most likely type of floater to be associated with a retinal hemorrhage produced by the laser. The more posterior the floater is preoperatively, the more likely some will remain untreated.

16 surgical techniques for Weiss rings: Because of this posterior movement during treatment, we had to develop 16 surgical techniques to vaporize as much of the floater as possible in nearly every case:

1) Always plan on having the patient back the day after treatment because it usually takes two days to treat this type of floater. Usually before the floater is completely obliterated the firing must be stopped because the floater has moved too close to the retina to complete the treatment in one session.
2) One way to delay the floater from going posterior is to work on it from one end of the floater, leaving the other end attached to the vitreous face. Look carefully for the main attachment of the floater to the vitreous face and try to avoid shots there. That attachment prevents the floater from moving posterior.

3) The most important rule is to use the lowest power possible to vaporize the floater without separating it from the posterior vitreous face. Once is has separated, turn up the power to complete the case.
4) If you want to split the floater, hit it in the center.
5) It is extremely important to hit the floater only in the center when working near the retina so the floater will block the back-scatter of the laser beam.
6) Many Weiss rings have a tail. A general rule is: on anterior rings, obliterate the floater's tail first and then work on the body; on rings near the retina, don't work on the tails, but hit only the solid part of the floater that will block the back-scatter of the shot.
7) If the patient is jumpy, don't fire the laser when close to the retina.
8) If the ring or glial tissue on the posterior vitreous face is spread out much, start the laser shots superior and work downward. Don't make the mistake of starting the laser shots inferior in the vitreous because the gas bubbles from these shots rise and can make it difficult to see to lay down the central and superior shots.
9) Small pieces of Weiss rings have a tendency to jump during treatment outside the treatment field. If this happens, have the patient move their eye a lot to try to find it. If you don't find it, put on the Karickhoff Off-Axis Lens and rotate it toward the periphery looking for the floater. When you find the piece, hit it on its edge that is most peripheral to the optical center. This usually moves the floater back toward the center so you can continue to work on it.
10) As the floater moves posterior from the laser hits, you start making a decision on every shot as to whether or not it is safe to treat. You make this judgment based on how stable the patient remains during the surgery and how much the retina is in focus when you are focused on the floater. The illumination from the slit lamp should be midway between the viewing oculars. If the illumination is to the side, one will not see the retina immediately behind the floater and can not judge how close is the retina. One nervous patient moved while I was working near the retina and a hemorrhage resulted. I recall also an alcoholic patient with a tremor. The anterior shots were done and most of the Weiss ring was eliminated, but the small particles near the retina were simply left untreated because his tremor made producing a retinal hemorrhage likely.
11) When the floater moves posterior or it is located posterior when first seen, it frequently can be made to come forward again by having the patient look downward then back to the

central position (the Moses Maneuver, which is further explained on page 170). If that doesn't help, let go of the contact lens and tell the patient to look up, down, right, left, and then back to the center and quickly grasp the contact again. Letting go is more effective than holding onto the contact as they attempt to move their eye. If this technique fails to move the floater forward, the floater usually will move forward from normal eye movement. The patient can return for more treatment in an hour or the next day. Also be very aware of the location of the macula when working far posterior on these rings.

This very posterior round floater was removed using the Moses Maneuver.

12) If the gas bubbles start to move the floater upward, hit the floater on the top and it will move down.
13) The preferred way to treat a Weiss ring is to make the first shots at the thinnest part of the ring so that you cut the ring making it into a "C." Then start at either end of the "C" completely obliterating that area before moving on. Treat the densest part last. In this way you can always find what remains of the ring because it is whole, big, and dense. If you start treatment at the densest part, you will surely lose track of several fragmented small parts of the ring as you work. Remember to work from one end only so the main floater will maintain a connection to the vitreous face. When all connection to the vitreous face is severed, the floater moves posterior with every shot.
14) If the patient has had the Weiss ring for months or years, it may have degenerated and come apart in one area. Then it will appear as a "C" with a tiny ball on each end of the "C." It may look like a arm bracelet. When the "ring " is no longer a "ring", it is best to again work from one end of the floater.
16) When working near the retina doing a Weiss ring, be sure the patient keeps their forehead against the forehead strap. If their head is away from the strap, and they move it forward as you fire the laser, you may hit the retina. Make sure that the patient's stool is high enough so that their forehead is naturally against the strap without them needing to stretch.
17) You will have such high success with these cases that you must resist the tendency to promise them a dramatic, near miracle type improvement. Making such a promise is a mistake because in a few

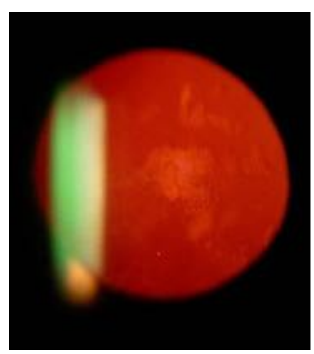
cases you have to leave small floaters near the retina untreated. It is better at the end of the procedure when you know the ring is gone to have them lean back from the laser, have them cover the other eye, have them look at the wall and ask, “Is it gone?”

One Weiss ring remnant looked liked a fried egg with a dense central yolk and a thinner egg white. After the first treatment, the egg white was gone, and the patient said the floater was then easier to see through, was thinner, and moved faster. He said: “It is now a butterfly, not a cockroach.” The second treatment eliminated the rest of the floater.

On the second day of treatment a large remnant may disintegrate easily because it absorbed some fluid from treatment the previous day. Occasionally you may decide to leave a small, thin part of the floater untreated rather than risk a retinal hemorrhage. Thin floaters may absorb in time.

One Weiss ring was associated with linear clouds. The ring was removed, but the clouds could not be removed completely.

It was initially surprising to me that treating through an obvious cataract does not prevent the removal of a Weiss ring. Nor does the procedure make the cataract worse. The reasons for this are (a) the laser beam is fairly broad where it passes through the cataract and (b) there is no action (optical breakdown) from the laser except at the point of its focus. Below is a photograph of a Weiss ring type floater that was completely removed through the cataract shown.



Floater (left) was completely removed firing through cataract (right).

Some of the PVD’s that bring about Weiss rings also cause a hemorrhage at the disc when they tear off. The question is, how long does one need to delay treatment of a floater to avoid producing further hemorrhage of the disc. Usually we wait two months to treat most floaters. But a personal friend came to town who had had the PVD five days previously that caused his disc hemorrhage. He was treated on the fifth day after the PVD occurred and had no new hemorrhage and had near total removal of the Weiss ring.

Rarely peripapillary tissue that has detached, and is on the vitreous face, can be highly mobile when hit with the laser. Upon examination this type of floater usually appears round with only a tiny strand connecting it to the vitreous face. The first laser hit may break the strand, and the floater will shoot off somewhere. Then after every hit, you have to hunt for the floater. If you lose the floater, have the patient sit in the waiting room for a while, and you will probably find it again. On one such patient, hunting and shooting the floater required three surgical operative sessions in one day.

A very small floater (the dilemma floater): The patient is typically young and complaining of a single, fairly distinct floater which indicates it is near the retina. If one looks and finds a floater in the mid vitreous, you probably missed the one bothering him. The dilemma is trying to learn whether the floater that you are thinking of treating is the floater that is bothering the patient. If unsure about this, usually choose to treat it because tiny floaters require just a few shots for obliteration, and you have a chance of getting success in three different ways. If the floater you treat is the one bothering the patient, you can (1) obliterate it or you can (2) move it. And if it is not the one bothering the patient, your shots (3) may move the one that was bothering the patient. Sometimes you can use the Karickhoff Patient Assisted method (see Chapter 5) to learn if the floater you are planning to treat is the one bothering the patient.

We have had seven patients between 25 and 35 years old that complained of only one floater bothering them. In all seven the floater was located about four disc diameters from the disc along the superior temporal artery of the retina. All were too close to the retina for treatment.

A **fan-shaped floater** (color page 101, Figure 14) usually comes from peripapillary glial tissue that is now on the detached posterior vitreous face. This thin, distinctive fan-shape probably indicates high fibrin content. These fan-shaped floaters have only moderate response to the laser. We have seen about five of these. There was some success but none were obliterated completely. The tail of one such fan presented stretched across the optical axis. We cut it completely in two, but the severed part moved only slightly out of the optical axis.

On a case of a Weiss ring with a small fan attached, the Weiss ring was obliterated and the fan was broken up. But it was very difficult to get rid of the small fibrous pieces of the fan. Some were obliterated and the remaining pieces were broken into smaller pieces.

One patient had a large, thin, lacy fan floater. Half of it was obliterated, but then the fan moved too close to the retina to continue. In spite of this being only a partial treatment, the patient experienced a major improvement.

No harm is done in trying laser treatment on fan-shaped floaters, but advise the patient before the laser procedure that vitrectomy may be needed to get rid of their fan floater.

On these cases (as on most cases) the Karickhoff 21 mm contact lens or the Karickhoff Off-Axis lens is used. These patients are very grateful for obliteration of their fan floater.

Peripheral floaters, especially those below, are more difficult to treat because the laser does not focus as well in the periphery as in the central optical axis and this poor focus makes the laser less effective. Another problem with treatment of a peripheral floater is it may move centrally, and you still may not be able to vaporize it. The patient would perceive this as being made worse. However, most floaters that move centrally can be vaporized. The procedure is not offered to many patients with peripheral floaters. Tell patients on whom you are going to treat a peripheral floater that rarely the floater will move centrally, and they would be made worse, and they may need to return for addition treatment.

In general you can not treat peripheral floaters with a mirrored contact lens. Use the Karickhoff Off-Axis Lens (shorter focus) or the Karickhoff Off-Axis 30 mm Lens (longer focus) to treat these floaters.

Peripheral floaters don't bother the patient as much as central floaters. If they have two floaters and one is peripheral, it may not be necessary to treat the peripheral one. If a peripheral floater stays peripheral on eye movement at the slit lamp, don’t treat it as you may make it more mobile and make the patient worse. If it moves centrally on eye movement, treat it.

When hit with the laser, peripheral floaters almost always swing more peripheral and go out of sight. Perhaps this is because most peripheral floaters are attached by vitreous to the ora serrata and that attachment serves as a hinge for the floater to swing on. When central floaters are hit with the laser, they don’t swing peripheral.

Generalized haze of the vitreous face usually responds little to the laser. However, scattered floaters on the vitreous face often do respond to the laser. Patient should be told that the **folded vitreous face** does not respond much to the laser, but if their floaters are obliterated, they will usually be able to ignore the folded vitreous face. In some patients a very folded and prominent vitreous face in the optical axis is their only problem. Placing about 50 shots in it may result in a large reduction of symptoms.

Syneresis floaters:

Vitreous degeneration (syneresis) can produce floaters that are scattered throughout the vitreous, or the floaters can be clumped into clouds with seeds (milk pod floaters). The latter tend to vary a lot in their response to the laser. These syneresis floaters do not obliterate as readily as floaters that have been pulled off the peripapillary area with a vitreous detachment.

Do not attempt to treat the numerous opacities from generalized vitreous syneresis because it would be an endless process. If, however, they have a massive clump among the scattered opacities, you can attempt to treat the clump.

The location of a syneresis cloud when the eye is at rest in the primary position should be documented in the preoperative drawing because that is the floater that will bother the patient when driving or watching TV. If the cloud is central, it needs to be cleared more substantially than if it is off-axis.

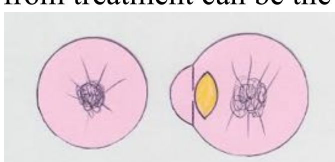
Non-suspended syneresis cloud floaters (milk-pod floaters) are seen in cases of advanced syneresis, usually in a young patient, and usually with no posterior vitreous detachment. The milk-pod is an area where the fibrils from syneresis are much closer together and there are clumps (“seeds”) on the fibrils. This milk-pod can be dense enough to be like a small cloud.

It is easy to get rid of the clumps (the “seeds”), but getting rid of the fine structure of the cloud is more difficult. It may take 100-300 shots. A laser with multiburst mode would make the case move faster, but the last 4 shots of a 5 shot burst would not be perfectly placed. If the laser is fired in a relative clear area of the cloud, there is no tissue reaction, just a little vitreous movement. When treatment is finished on the seeds, the area can appear to be milky. The milky area will be clear the next day. This is quite similar to doing posterior capsulotomies where the opening has been made but the nearby vitreous becomes cloudy in the process. That vitreous is perfectly clear the next day. Start with the Karickhoff 21mm Vitreous Lens and work on the central area. Then go to the

Karickhoff Off-Axis Lens. If you give additional shots the next day, use the same lenses in the same order.

Be hesitant to work on a thin cloud that is far posterior because of possible retinal damage from the laser beam back-scatter. One cloud was so far posterior that optical breakdown could not be attained. Its superior attachments were cut as described below and the floater slipped below the optical axis.

Suspended syneresis floaters are fairly common**.** Look carefully with a contact lens for what appears to be suspending strands. If the floater is suspended in the central visual axis, the visual acuity is decreased and the floater can be nearly incapacitating. The improvement from treatment can be the most dramatic of all floaters. Since there is usually vitreous traction on the floater in all directions toward the periphery, frequently, cutting the floater in two will allow both ends of the floater to leave the visual axis. If that does not work, just thin out the floaters as much as possible. It doesn't take much movement of a central suspended cloud to significantly improve vision and symptoms (color page 98, Figure 1, and color page 102, Figure 17). It seems that the more anterior the opacity, the more it moves out of the visual axis when the suspending strands are cut. This is especially true if the patient has an IOL and you are able to cut attachments closer to the IOL than you could with a natural lens present. If central suspended floaters are not treated, and if a PVD occurs later, the suspended floaters fall and become "snow globe" floaters (described on the next page) which can not be treated with a laser.



Central suspended cloud

We are reluctant to offer treatment if the floater clouds are at the periphery of the optical axis (rather than central) because there is some chance they could move more centrally from the treatment.

A few patients who were treated for central syneresis clouds went home greatly improved and then had to return for an additional treatment and did well. What happens in these cases is the floaters are partially disintegrated but some of them go peripherally and are hidden behind the iris making both the patient and the doctor think that they have been obliterated. Later the floaters move centrally, and then are easily treated.

One **broad, thin floater** slightly posterior to an IOL was suspended from above. Shots placed in a horizontal line across the floater near the top of the pupil cut the bottom part of the floater free. The floater immediately sank below the optical axis (color page 101, Figure 13).

I try not to have my expectations too high with syneresis cloud floaters because these floaters are rarely completely removed. These patients can be told that postoperatively the clouds are usually still there, but they will be much less dense and they will move faster. If one reduces the cloud with either method (direct hits or moving it), these patients are very grateful. To be certain that their expectations are realistic, these patients are given pre-operatively a small handout (See Appendix J). Be reluctant to operate on an anxious, jumpy 40 to 50 year old patient with syneresis clouds. In my experience it is difficult to satisfy them even with a significant floater reduction. They usually want a complete cure.

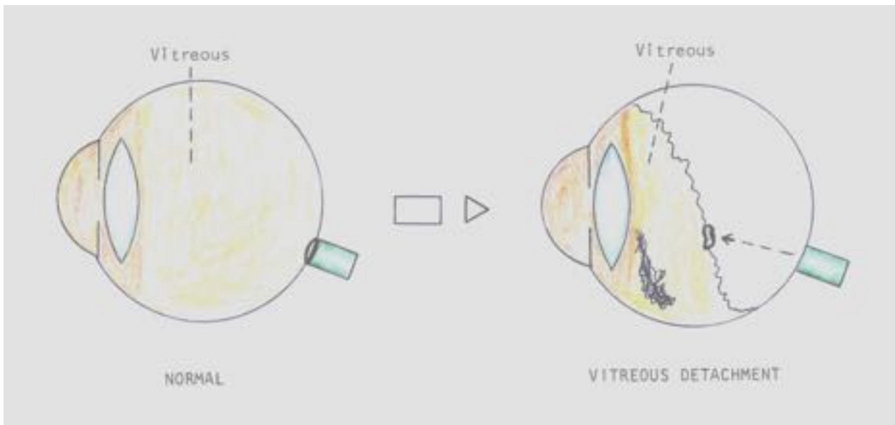
There is generally a tendency for syneresis clouds to move upward during the treatment, making them difficult to visualize. Perhaps the gas bubbles from the treatment carry the cloud upward. Using the Karickhoff Off-Axis lens is helpful here. The cloud usually comes down some the next day, but quickly goes back up with more treatment.

"Snow globe floaters" are multiple syneresis clouds that are hidden in the anterior, inferior vitreous. They are not seen by the patient or the doctor when the patient is looking straight ahead. But they swing up into the optical axis when the eyes are moved; then they fall. To avoid missing these, every floater patient should be told to look down and then straight ahead while the doctor uses the direct ophthalmoscope. It is difficult to treat these floaters because the patient has to swing them up to be seen by the surgeon, they are a moving target during treatment, and usually these floaters swing up too close to the patient's lens for safe treatment. If there are any visible attachments going down to such a hidden floater, cut those and hope to get some effect.

Many fine fibers spanning between syneresis clouds usually mean there will be a slower breakup of the floaters due to higher fibrin content.

A few patients have said that laser treatment greatly reduced their floaters, but the remaining floaters move faster than before the laser treatment. If the patient is anxious, they should be told pre-operatively that their remaining floaters may move faster after the procedure. I assume this increase in movement is because the vitreous architecture has been segmented by the treatment so the vitreous doesn't have to move as a whole.

Weiss ring / "snow globe" ("floater duet") : About one eighth of Weiss rings or some other hyaline floaters are combined with syneresis clouds that are located in the anterior inferior vitreous ("snow globe" floaters). It is possible that these “snow globe” floaters were suspended in the central vitreous prior to the PVD that created this “floater duet.”



(left) Drawing of a normal eye;
(right) a Weiss ring / snow globe combination (floater duet“)

The patient may or may not see the Weiss ring which is normally near the central visual axis. Their syneresis clouds (“snow globe” floaters) are hiding far inferior, and are seen only when the eye is moved. Then it swings up like a windshield wiper. When it swings up, it is appreciated that this floater is often much bigger than the Weiss ring, and it bothers the patient more. There are three reasons why the hidden floaters can not be treated: (1) the laser beam can not aim low enough to hit it, (2) ordinarily when it flips up, it is too close to the patient’s lens for safe treatment, and (3) it is a moving target. With this floater “duet” the question is, do you have a patient who will understand and be satisfied that you can get rid of the Weiss ring but frequently can't do very much for the hidden syneresis cloud that swings up? Only vitrectomy can get rid of the inferior floater. You need to carefully explain that the laser can provide only a “partial” improvement of their floaters. That is, you are treating one member of the combination but not the other. If the patient is anxious or exaggerates his symptoms, do not operate on these cases. In the evaluation, rate both the upper floater and the lower cloud on a 0 to +4 scale and record it like 4/2, meaning the hyaline is twice as big as the syneresis cloud. Don’t operate unless the hyaline floater is worse than the syneresis cloud. If you operate, do the Weiss ring only. Do keep in mind that if you are tempted to treat the inferior syneresis cloud, it is possible to make it seem worse by spreading it. While treating the Weiss ring, the inferior syneresis floater occasionally will come up. This could make their symptoms worse. Another problem is the inferior floater of this combination is far anterior and close to the trabecular meshwork. Avoid treating this type of floater in a patient with borderline tension (for fear of a pressure rise). One such patient had had some optic nerve damage from elevated pressure following cataract surgery. His pressure during the floater evaluation was 15 OU. After treating this type of floater, his pressure stayed at 19 in the operated eye and 15 in the un-operated eye. For these reasons, **most "floater duet" patients are best referred for vitrectomy**.

The real problem in this "floater duet" is diagnosing the Weiss ring but missing the "snow globe" floaters. In you make this mistake, you will take the patient to the laser and remove the Weiss ring. The next morning they tell you they are still severely bothered by their floaters. When you have them move their eye around, then at this late stage you find the inferior floater, the other half of the combination. The lesson is: any time you diagnose a Weiss ring, look for an associated floater far inferior and tell the patient you can't treat it. Look for it by using the +10 direct ophthalmoscope and having the patient look forward, then up, and then forward. This maneuver will swing the anterior–inferior floater upward into the central visual axis so you will not miss it.

One patient had a **bean-shaped floater**. When it was hit with the laser, the "bean" suddenly unfolded into a hairy rope. Only half of the rope could be vaporized because it was quite fibrous. Do not operate on such a floater.

One **thin wafer-like floater** that was near the retina was treated. It was gone after 7 shots of the laser. To treat such a floater you must know exactly what is a safe distance from the retina to fire using the 21 mm lens.

The rare **cigar shaped, moderately dense syneresis cloud floater** especially responds to the laser and gives the patients complete or nearly complete relief of symptoms.

Floaters from retinal cryopexy and argon laser photocoagulation are occasionally seen. Each of these patients had many scattered round floaters that responded very little to the laser. These floaters probably detached from the areas of cryo or photocoagulation retinal scarring.

Floaters in the presence of high myopia can be difficult to treat, especially if they are syneresis floaters and the patient has had LASIK. In high myopia there is a tendency for the floaters to separate from the vitreous face and go near the retina where they can no longer be treated. Reducing the laser power is helpful in preventing the floaters from going posterior. In some of these long eyes (such as minus 10 diopters) the vitreous had tiny specks in it and seemed slightly cloudy pre-operatively and became cloudier during treatment. In most, this haze was better the next day. In high myopia sometimes the floaters tend to break into smaller pieces rather than being converted to a gas and obliterated. Such patients should be warned of this possibility. Do remember that if the patient had refractive surgery (LASIK, intraocular contact lens, IOL) and now has a plano refraction, they still have the vitreous of a high myope. On these very long eyes sometimes you must use the Peyman 25 mm vitreous lens to get a crisp focus on the posterior floaters. However, beware of using this lens on a normal length eye since this lens has little coning and can make a retinal hemorrhage more likely than with stronger lens.

Rarely in high myopia, there will be a Weiss ring with a large fuzzy floater attached to the ring. Upon hitting the attached floater, you discover it is **folded anterior limiting membrane of the retina** which appears as a clear sheet similar to posterior lens capsule and is very slow to vaporize. Fortunately after easily vaporizing the ring, the attached floater usually moves temporal and the patient is improved. If anterior limiting membrane of the retina is across the visual axis, it can be frequently be split in two, and the nasal and temporal vitreous will pull the two pieces apart, providing a clear central optical pathway.

In **laser floater treatment after vitrectomy**, the floaters jump away more when hit and can be difficult or impossible to find. These patients should be told of this possibility.

With a solid hyaline floater with **no obvious connections to the vitreous face**, there is increased chance when hit with the laser, it will move excessively and may be lost and can not be relocated.

Asteroid hyalosis floaters usually do not disturb vision enough to require treatment. These floaters are not affected even from direct hits with the laser set at the maximum power of 10 millijoules. However, (1) if a hyaline floater conglomeration is mixed with the asteroid hyalosis floaters, the hyaline floaters can be treated. (2) Also, if the asteroids are clumped together, breaking up the clumps with the laser, improves the symptoms. These two treatments have not been previously reported. Care must be taken not to hit the retina which is seen poorly because of the asteroids.

[1] Vogt, Klin. Mbl. Augenheilk, 72: 212, 1924

[2] Vogt, Klin. Mbl. Augenheilk, 75: 463, 1925

CHAPTER 17. TECHNICAL PROBLEMS

Since the floaters are suspended in clear vitreous, excellent stereopsis of the surgeon is very helpful.

Sometimes you will see the floater with only the red aiming beams but there is no white slit lamp beam on it. This is due to the aiming beams and the illuminating beams not being quite coaxial in the Laserex LQP4106 laser. This becomes more of a problem the closer you are working to the retina. I calculated that there is a 6.5 degree separation of the center of the treatment beam to the top of the illuminating beam in this laser. To correct the problem, turn the eye down slightly or lower the chin rest. Another way to solve the problem is to turn up the power of the aiming beams and use them as the only illumination. However, with that setup (using red light only) you see the retina poorly. Here the only safe way to fire the laser is as follows. See the retina by focusing the bright red aiming beams on it, then pull the joy stick of the slit lamp toward you until the floater comes into focus, then fire. When you use this sequence, you will know exactly how far it is from the retinal to the floater.

Another technical problem is when the white illumination light and only one red aiming beam are on the floater. Here the eye is too low so that the upper iris is blocking the upper aiming beam. Raise the chin rest.

If the laser aiming beams keep slipping horizontally out of the center of the slit lamp illuminating beam, the screw that secures the slit lamp mirror from turning sideways needs to be tightened.

When an opacity is nearly disintegrated, you may decide to look for a larger opacity, and finding none, attempt to re-find the one that was nearly disintegrated. With much effort you may never find it again. The explanation of this is not obvious, but it does happen. Fortunately, the patient doesn't know you lost it. The Karickhoff Off-Axis Contact Lens is very helpful in this situation. With this lens, you just rotate the lens. Its prism allows you to look all around the area and come back exactly where you started. With it you don't have to ask the patient to turn their eye to look for the floater; just rotate the lens.

Sometimes a floater is seen in the lane but is not seen when at the laser using a magnifying contact lens. If this happens, take the magnifying contact off and put on the flat faced contact to search for the floater.

There are six ways that **floaters are lost** during treatment. (1) Gas bubbles can carry the floater upward out of sight. There is little one can do about this. (2) The patient can look away and shake the vitreous moving the floater out of sight. This problem is almost eliminated by using a fixation light on the other eye. (3) The floater is lost when contact lenses are changed. Solve this situation by not moving the fixation light to get more room to change the contact lenses. (4) The impact of the laser beam on the floater can knock the floater out of your viewing field. With some practice, you can use this impact to your advantage. For example, if the floater is starting to move upward, start hitting it on its top, and it should start to move downward. (5) You make the mistake of starting the treatment in the densest part of a floater or cloud, and it separates the floater into too many parts to follow. (6) You are dealing with a solid floater attached to a very thin, vitreous face. After vaporizing part of the floater, on the next shot the remaining part can disengage from its vitreous face attachment, and suddenly disappear. With searching, you may find the remaining part usually touching the retina and moving widely on eye movement. You can not treat further, and this is a disappointment for the patient. However, two positives come of this situation. One is that the patient is now disturbed much less than pre-operatively when the floater was suspended constantly in their central vision. Second, with time most such loose floaters quite suddenly disappear. I suspect they become trapped in the lens zonules.

If the patient has a low brow, it shoves the contact lens down. The only way to correct this is to bring the patient's chin forward over the top of the slit lamp chin rest so the brow is made to tilt backwards. It becomes painful for the patient to have their chin resting on the thin vertical plastic front of the chin rest. Therefore, a piece of wood of proper thickness and length was made so that it could be placed on top of the paper tissues of the chin rest. It was colored black with a marker, and a tight rubber band was put around it so it would be held tightly to the front of the chin rest and would not fall to the floor when they took their chin off it. In doing so the patient is comfortable during the procedure with their chin extended anterior over the chin rest.

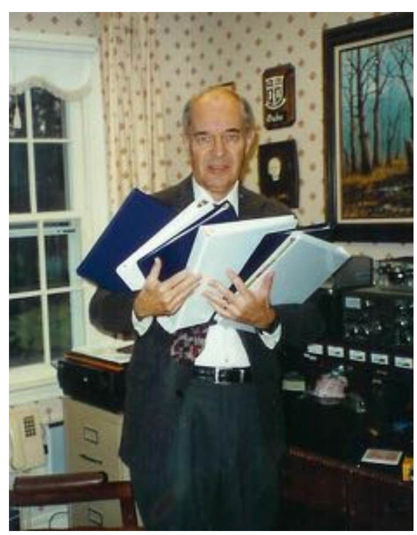
Elevated, custom chin rest.

CHAPTER 18. U. S. FOOD AND DRUG ADMINISTRATION AND FLOATERS

YAG lasers have been used to treat vitreous floaters since 1983. However, the United States Food and Drug Administration had never taken a position specifically on floater treatment, and I assume that no data on floater treatment had ever been submitted to them.

When the Institutional Review Board of INOVA Fairfax Hospital considered my application to do a Formal Study of Laser Treatment of Vitreous Opacities, they were uncertain whether the U. S. Food and Drug Administration had approved YAG lasers for this procedure. They contacted the FDA and requested a ruling. The FDA returned a ruling on January 31, 2002 stating that the procedure posed a significant risk and an Investigational Device Exemption would be required for me to proceed with my Formal Study. This ruling meant that no doctor could do laser treatment of vitreous floaters without an FDA Investigational Device Exemption. This FDA letter placed in doubt whether this procedure could ever be studied formally under IRB supervision.

After receiving that letter, I gave up on the procedure, thinking that FDA approval might take years. But I then learned that Congress had passed a law requiring the FDA to give a decision on all such applications within 90 days of the time the FDA received the application. Customarily such applications are made by the manufacturer of the laser using their staff, time, and expertise. But since this was a new procedure, there was little interest from anyone but myself. After an agonizing week I made the decision to personally apply to the FDA for an Investigational Device Exemption. After two months of research and writing, the application



Author with FDA application.

with copies was submitted on March 11, 2002 (see photo). The application reviewed: manufacturing the laser, the effect of the laser on floaters, all animal studies, all human studies, the world literature, my past cases, my research, expertise, contributions, instrument designs, etc. The main point in favor of my application was that I had already done (without knowing that YAG lasers were not FDA approved) the very same study that the application was for. In my unauthorized study of 61 patients there was a significant reduction of floaters in 92 per cent of patients and there were no significant complications.

On March 20, 2002 the FDA informed me that after considering my application, they had ruled (paraphrased) that my study of laser treatment of vitreous opacities was a non-significant risk device study. Their ruling also informed me that an Investigational Device Exemption is not required for a non-significant risk device study. This ruling, based on my application, obtained FDA approval for a YAG laser to be used for floater treatment for the first time. Even with this FDA approval, I assume that using a YAG laser to treat floaters remains an off-label usage. When they wrote their initial letter requiring an Investigational Device Exemption, they had to be cautious because it is likely no one had ever submitted any data to them on laser treatment of vitreous floaters, and at that time they did not have the benefit of my pilot study of 61 patients.

It should be remembered that the FDA does not approve or disapprove of procedures. They approve or disapprove of equipment (for example lasers) and their uses.

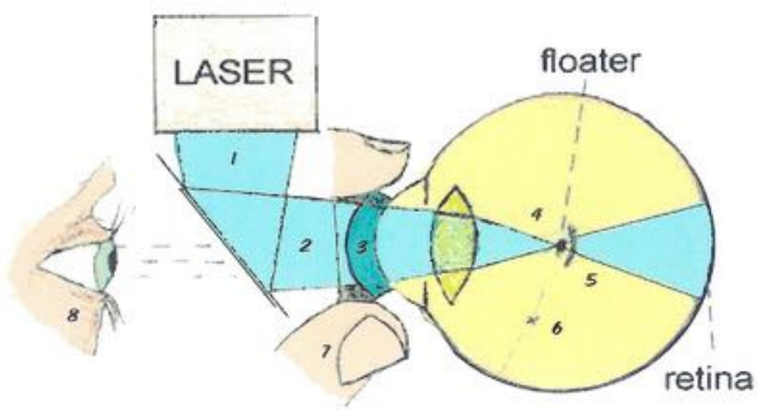
Although my FDA application was exhausting, it is important because my obtaining this positive FDA ruling did set a precedent for future studies on laser treatment of vitreous opacities using standard YAG lasers.

CHAPTER 19. RETINAL PROTECTION

Our review of the world literature and our own cases revealed that the incidence of significant damage to the retina from treatment of floaters using a pulsed, YAG laser has been zero. I have placed over 150,000 laser shots into the vitreous, have done this procedure on many patients who formerly had retinal tears, and have done this procedure on approximately 50 patients who have had retinal detachment surgery. Even in these patients with known retinal deterioration, the procedure has never caused significant retinal damage.

With the zero incidence noted above, patients should still realize that posterior vitreous detachments, retinal tears, and retinal detachments which are usually age related do occur regularly in patients who have never had eye surgery. Therefore, it is possible that these conditions could occur months or years after a patient has had laser treatment for floaters and be related or unrelated to the laser procedure.

(The numbers in the picture refer to the paragraphs below.)



In this procedure the retina is protected in eight different ways on every laser shot:

1) The laser beam in this procedure is not a parallel beam that could miss the floater and then hit the retina with full power. Instead, it is converging at a 16 degree angle as it leaves the laser. It is converged more by the surgical contact lens, and then by the patient's lens, bringing the beam to a pin point focus on the floater. Behind the

floater, the beam (if it is not totally blocked by the floater and the plasma shield)(see 5 below) immediately diverges so that its power is greatly reduced, spread out, and defocused when it reaches the retina.

2) The laser beam is invisible. Because it is invisible, there is very little reaction with tissues anywhere along the beam except where it comes to a pinpoint focus on the floater.

3) A special surgical contact lens that focuses the beam away from the retina is used in every case. This contact lens reduces back- scatter to the retina and holds the eye still.

4) The phenomenon that obliterates the floater is called "optical breakdown." In optical breakdown, electrons are stripped off their atoms, heat is produced for a few nanoseconds, and destruction and vaporization of the floater occurs. This occurs only where the laser comes to a pinpoint focus (on the floater). There is no optical breakdown in front of the floater or behind it (near the retina).

5) Any time there is optical breakdown, a plasma shield also develops. In a plasma shield, which is located immediately behind the floater, the vitreous turns black for a microsecond, blocking the laser beam from going towards the retina.

6) Each time the laser is fired, it severs vitreous strands that can pull on the retina. This can be helpful because one of the main causes of retinal tears and detachments is vitreous pulling on the retina. It has been shown in rabbits that multiple YAG laser shots such as those used in this procedure can indeed liquefy the vitreous which would greatly reduce vitreous traction.[1]

7) There is a tiny shock wave created in the vitreous each time the laser is fired. Some of this shock wave is transmitted to the retina, compressing it against the underlying layer. However, in the history of this procedure there has never been retinal damage from this shock wave when using a modern, pulsed YAG laser. The strength of the shock wave is monitored on every shot since it is transmitted through the eye to the contact lens, and then to the surgeon's fingertips holding the contact lens. If there is any significant shock wave felt, the surgeon reduces the laser power.

8) The light we use to see the floater is simultaneously illuminating the retina. Therefore, on every shot, the distance from the floater to the retina is monitored.

[1] Nasrallah et al: Can the neodymium:YAG photodisruptor liquefy the vitreous? Ophthalmic Laser Therapy 3: 63-69, 1989

CHAPTER 20. AVOIDING COMPLICATIONS

Laser photo disruption of floaters is far less risky than one would expect. The lack of complications is mainly due to (a) floaters being avascular, (b) the pinpoint accuracy of the laser, and (c) the low power required to get optical breakdown (where the reaction become non-linear) from a pulsed YAG laser.

I had two significant complications in the 1,225 times I have done the operation. In one patient there was a significant pressure rise that required medical and surgical treatment (details in this chapter under Preventing Pressure Elevation), and in another patient a micro rupture of the posterior lens capsule which may require cataract surgery (details in this chapter under Preventing Cataract Formation). Both complications are avoidable and that is described below.

I also had five small, mostly semi-intentional retinal hemorrhages. These healed with a very minimal scar and were of no consequence (details are below under Preventing Retinal Damage).

There were no new posterior vitreous detachments produced by the procedure.

One would think that the process that creates syneresis clouds would be an ongoing one. But no patient contacted a year or two after our laser treatment has ever said that floaters were continuing to form. Perhaps in each patient there is a limited amount of vitreous architecture available to develop into floaters.

GENERAL RULES

An important rule is to disrupt any floaters or strands near the lens first. The rule can also be stated: "Work from the front to the back of the eye." One reason for this rule is that clearing the anterior floaters makes it easy to see the more posterior floaters. A more important reason is that you must increase the power as you move posterior due to vitreous absorption of the energy. If you forget to turn up the power as you move posterior, the worst event is you don't get optical breakdown which will remind you to turn up the power. However, if you work from the back of the eye to the front, you must reduce power as you go. If you forget to reduce power, near the front of the eye you will get excess effect and possibly lens damage.

Second, “Work from the top of the eye to the bottom of the eye.” If you do the reverse, gas bubble that rise from working in the inferior vitreous may impede your disrupting superior floaters.

PREVENTING GONIO FLUID COMPLICATIONS

Four patients experienced moderate to severe pain for about 15 hours after the treatment. At that point I did some experiments and learned that the cause of the pain was thick gonioscopic fluid (hydroxypropl methylcellulose) causing anoxia of the corneal epithelium during long cases. By switching to a less viscous gonio fluid (hydroxyethylcellulose) no patients have had pain, but we have had a handful of cases with slightly decreased vision and a scratchy feeling for a few days (see Chapter 24 on Gonioscopic Fluid). Unfortunately, Alcon discontinued making the ethylcellulose gonio fluid in April of 2003 and they were the only manufacturer. In Chapter 24 are instructions for how to make your own ethylcellulose gonioscopic fluid. The pain can also be prevented by diluting methylcellulose (2/3rds) with Dacriose (1/3). This is discussed fully in Chapter 24.

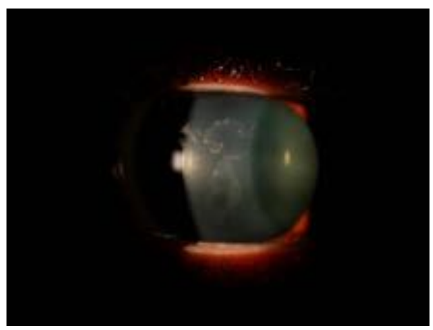
PREVENTING CORNEAL COMPLICATIONS

Few corneal complications are seen despite the treatment beam passing through the cornea. The cornea is protected from the treatment beam because the beam is broad and defocused when going through the cornea, is infrared with very little absorption, but mainly because there is no optical breakdown in the cornea. There is no tissue reaction to the laser except where there is optical breakdown and that occurs only at the point focus of the beam.

Very rarely a non-contact lens wearer will have some drying, foreign body sensation, very slight pressure rise, decreased distance vision, and improved near vision for two days postoperatively. Examination reveals superficial punctate keratopathy. What is the cause of their SPK? I think the most likely cause is lack of oxygen to the corneal epithelium while the surgical contact lens is on the eye. I do not think that the corneal endothelium plays a part in this epithelial problem because if the epithelial edema were from a damaged endothelium, the edema would be localized to the central area where the shots pass through. If you get a telephone complaint of slight pain, foreign body sensation and slightly blurred vision, do not assume, however, that it is corneal edema from the surgical contact lens. It could be elevated intraocular pressure. Check the IOP or have it checked immediately. I feel that in some cases of SPK the cause is mild, chronic staphylococcal infection. That is discussed in the next section concerning contact lenses.

When treating both eyes at the same sitting, tell the patient to blink the first treated eye when you start treating the second eye. At this point both eyes are anesthetized and the patient will get no stimulation to blink the first eye. This leads to drying of the cornea and pain for one day.

Check each patient for geographic corneal dystrophy. I have done the procedure with no problem in these patients. But in one case, the contact lens had to be reinserted about 5 times due to air bubbles. The next day his geographic dystrophy was much more obvious than preoperatively, and the eye was red. I suspected an early staph keratitis. Additional treatment as planned for the second day was cancelled and antibiotic drops were started.



Geographic dystrophy one day postoperatively.

Wait about 3 months before doing this procedure in a post-operative LASIK patient. This allows for reasonable healing of the corneal flaps. Perhaps wait longer if they have had an enhancement of their LASIK procedure.

In our one case of performing the procedure through a cornea with healed herpes simplex, there was no activation of the herpes.

PREVENTING PROBLEMS FROM THE PATIENT'S CONTACT LENSES

Patients should stop wearing contact lenses a week before laser treatment of floaters.

If the patient has been wearing contact lenses the day before or the day of the treatment, usually you will find a diffuse punctate keratitis the morning after treatment. If additional treatment is then given, the keratitis will be made worse. In one such case, before I realized this corneal problem was coming from wearing contacts, there was a temporary shift in the axis of astigmatism. The patients will describe a slight fuzziness of vision. It takes a few days for this to clear. If a patient calls from out of town with what sounds like superficial punctate keratitis (a foreign body sensation and seeing better at near than at far), the problem is they now have no way to check their best corrected distant vision because they are now more myopic than their glasses correct. But they can check their distance vision using binocular field glasses. The focus on the binoculars will correct for their unilateral myopic change and this assures them that their decreased distance vision is only a temporary refractive change.

Early on a patient from out of town arrived wearing contact lenses and she had slight redness from them. Her floaters were treated with the laser and the next day she had staphylococcal keratitis with peripheral leukomas. It cleared with antibiotics-steroid drops. Another patient had their contacts off only two days before surgery. He developed superficial punctate keratopathy and limbal leukomas of staphylococcus postoperatively.

One contact lens wearer got staphylococcal keratitis with peripheral leukomas from just the examining contact lens usage without any laser treatment. Probably this patient had a chronic low-grade staphylococcal infection pre-examination. The contacts were discontinued. She was treated with an antibiotic-steroid eye drop and the condition cleared rapidly. Three weeks later she had the laser procedure for the floater and the following day she had red, swollen conjunctiva and whitish, peripheral corneal infiltrates. This rapidly cleared again without treatment.

These problems are eliminated if they stop wearing contacts a week before surgery.

Why are contact lens wearers more susceptible to superficial punctate keratitis? Wearing regular contact lenses produces a relative lack of oxygen in the corneal epithelium. But when the surgical contact lens and its grease are placed on the eye and there is no blinking for the duration of the procedure, there is no oxygen transfer to the cornea. Probably this oxygen deprivation is the cause of the keratitis but other factors may be involved. For instance, long term contact lens wear has been shown to produce a thinning of the cornea by 30 to 50 microns compared to normal subjects. This is unrelated to their degree of myopia.[1] This thinning or compacting of the cornea may be a factor in these patients getting keratitis.

PREVENTING ELEVATED PRESSURE

When doctors first learn of this procedure, they assume that retinal damage would be the major complication, but it is not. Although the incidence is very low, the main complication to be aware of and to prevent from this procedure is elevated pressure.

The pressure is always checked the morning after treatment, and except in a few cases the pressure was the same or lower than pre-operatively.

However, I am aware of six cases among the approximately 3,500 cases done in the U.S. of elevated pressure post-operatively that required treatment for glaucoma. Glaucoma drops were somewhat helpful in these cases. An argon laser trabeculoplasty was helpful in one case. In two cases a trabeculectomy was required. This represented a 0.25 per cent incidence of pressure elevation requiring treatment. In one case a posterior capsulotomy widening was done at the same time as the procedure for the floaters. Both procedures do produce some debris that can cause some pressure elevation. These should be done as separate procedures.

In our series of 1,225 operations there was one case of pressure elevation (incidence of 0.14 per cent) that required treatment. Most likely this problem occurred in this patient because of several reasons: he was given 565 laser shots in this eye (the highest number I have ever given), he had a mild plateau iris, his floaters tended more to break into smaller ones than to disappear, the floaters were severe and were more anterior (nearer to the trabecular meshwork) than most. This patient received medical treatment for the pressure elevation and then had a trabeculectomy that controlled the pressure. Some months later he underwent cataract extraction in that eye and has been 20/20 since without treatment. In spite of the pressure complication, the patient reports so much relief from the floater procedure that he feels that the overall experience was a positive one. After this case, to prevent pressure elevations, we limit the maximum number of total shots per eye to 300 and have not had another pressure elevation.

There may be three mechanisms for the elevated pressure. (1) If the elevated pressure lasts less than 24 hours, it may be from the extra volume of the vitreous from the gas bubbles generated during treatment. (2) If the elevated pressure lasts longer, it could be from prostaglandin release. This seems very unlikely because the tissue being disrupted is avascular. Therefore, we do not prescribe postoperative NSAID drops to prevent a pressure rise. These drops are expensive, and pressure elevation is very rare. (3) The most likely mechanism for sustained pressure elevation is debris from the surgery accumulating in the trabecular meshwork. This probably comes from using an excessive number of shots. This is more apt to occur when using the multi-burst mode, since the total energy builds up much faster than when using the single burst mode. The last case of elevated pressure I heard of had received 1500 shots. Again, in an attempt to prevent a pressure rise, our maximum number of shots is 300 total per eye. The presence of a wide posterior capsulotomy would make debris reaching the trabeculum more likely.

To prevent post-operative pressure elevation:

(a) Don't operate on anyone with elevated pressure, glaucoma, someone taking glaucoma medicines, or having a history of glaucoma (see below for exceptions and experience with pigment dispersion syndrome).

(b) Don't use more that 200 shots in patients with borderline pressure.

(c) Don't use an excessive number of shots (more than 300 total per eye); this means not treating patients with several long, thick floaters because you know before starting that the case will take greater than 300 shots.

(d) Try to use less than 50 shots on any floater that is close to the trabeculum (like a veil floater just behind an intraocular lens).

(e) Beware of pseudophakic patients with vitreous in the anterior chamber or a very wide posterior capsulotomy since vitreous debris is more likely to enter the anterior chamber and deposit in the trabeculum in these patients.

(f) Never widen a posterior capsulotomy at the same sitting as the floater treatment (one known case of floater postoperative pressure elevation was for this reason).

In spite of the warnings above, I did the laser procedure on two patients who had pigment dispersion syndrome (PDS) (color page 102, Figure 18) which often leads to glaucoma. One patient had backward iris bowing and transillumination defects. She had numerous small floaters and one large cloud. There was no pressure elevation postoperatively. Another PDS patient with transillumination defects and Krukenberg spindles had the procedure with no pressure elevation.

Confluent transillumination defects in PDS.

We made an exception to the

first rule above by operating on a Weiss ring in a patient whose pigmentary glaucoma was controlled by two medicines. He had no postoperative pressure elevation. The exception was made because (a) Weiss rings are small in comparison to most floaters and usually take only 60 or 70 shots to remove them. This is far short of our arbitrary 300 shot maximum. (b) His Weiss ring was far posterior and it seemed that the chance was small of any debris from the surgery coming forward and obstructing the trabeculum. (c) Due to his vitreous detachment, all of his vitreous was now between the floater and the trabeculum preventing any debris from moving forward. And (d) I have used a way of treating pigmentary glaucoma that I have not published but is very effective and will frequently provide a permanent cure. The method is to first do an argon laser trabeculoplasty to reduce the pressure, and the next week do a laser iridotomy. Normally the effect of a laser trabeculoplasty lasts only a few months or years because the trabeculum soon fills again with pigment. To avoid this loss of effect, the week after the trabeculoplasty, a laser iridotomy is done that stops the zonular rubbing. The iridotomy thus makes the effect of the trabeculoplasty permanent. This treatment was based on our research and was the first published paper on iridotomies in pigmentary glaucoma. We now have 20 years follow-up on those patients.[2]

An exception was also made when we treated another patient with glaucoma. He came from out of town. His pressure was 30 in the eye that had the Weiss ring. He was sent home and told he could come back when his pressure was in the mid teens. He returned four months later on Xalatan and Timolol with a pressure of 14. The Weiss ring was removed with 124 shots in two sessions. There was no pressure elevation.

Perhaps it is safe to treat Weiss rings in the presence of controlled glaucoma, but not other types of floaters. More patients are needed to know that answer.

Rarely an exception is made to the rule of a maximum of 300 shots per eye. But one can be made in the following way for patients with a very large or long, but very treatable, floater. The patient is told that if in the process of treatment there is any pressure elevation, the treatment will be stopped. If they want to be completely rid of the floater, it would have to be done by vitrectomy. Then 300 shots are given in usually one or two sessions, and the pressure is followed for two months. If there is no rise, 100 more shots will be added.

Probably a post-operative pressure elevation is a combination of the pre-operative facility of outflow and the amount of debris produced by the surgery. If you suspect such a rise, learning the patient's pre-operative facility of outflow ("C" value) is probably the best test to predict how much debris from the floater procedure would be needed to compromise the trabeculum to the point that the pressure rises. Testing "facility of outflow" is preeminently revealing when looking for the mechanism of increased pressure, or when elevated pressure is temporarily masked by decreased aqueous production, or when the mechanism of drug action is sought. Unfortunately, testing the facility of outflow with tonography has been all but abandoned even in academic centers because the machine is expensive, it has poor accuracy, a technician must perform the test, some technicians can never learn the technique, and the set up time and the test time is long.

(Research project: In an attempt to simplify tonography and restore its usefulness I studied the literature, studied the graphs, obtained a tonographic machine, performed tonography, and talked with doctors who had used the test extensively. It soon became obvious that to simplify the test and make it much more accurate, the machine had to be eliminated. Eventually a highly accurate, simple, fast, and inexpensive method of learning facility of outflow was developed. My method is called "SOFT", meaning Simplified Outflow Facility Testing. It takes six minutes to perform the test. It utilizes only the Schiotz tonometer, an inexpensive timer, a miniature voice recorder, and the usual tonography charts. The method is described in Appendix L.)

PREVENTING RETINAL DAMAGE

The combination of thermal effects, mechanical effects, and electromagnetic field effects can produce retinal damage[3] that could be a source of complications. But we have not seen significant retinal damage after placing over 150,000 laser shots into the vitreous. Our review and our hospital library's review of the world literature of this operation did not reveal any case of significant retinal damage (see Appendix F. World Literature). I am familiar with 11,000 cases of laser treatment of vitreous floaters done in the United States and Taiwan, and there was no incidence of significant retinal complications in any case.

Lack of significant retinal complications is due to a combination of (a) eight ways we protect the retina on each shot (see details in Chapter 20), and (b) each time the laser is fired, it severs vitreous strands that can pull on the retina. This is protective of the retina since one of the main causes of retinal tears and detachments is vitreous traction on the retina.

In your first cases you may feel a need to measure how close the floater is to the retina or the lens. For this, we have modified an idea presented by Doctor Hunter Little.[4] To take this measurement, tape a piece of paper onto the table of the slit lamp directly underneath the horizontal round bar that rolls backward and forward as the slit lamp is moved. Then place a flat faced examining contact lens having no magnification, such as the Karickhoff Laser Lens made by Ocular Instruments Inc. on the eye. Hold a pencil perfectly upright with the shaft of the pencil against the round bar. Focus on the iris since you can't see the cornea with a contact on the eye and make a mark on the paper. Keeping the pencil perfectly upright, focus on the retina and make a second mark on the paper. Then focus on the floater and make a third mark on the paper. You then measure your marks with a millimeter ruler. If you double the numbers obtained, you get a rather accurate measure of at least the relative distances in the vitreous. Of course the power of the patient’s lens is not neutralized by the contact lens, so the numbers obtained are only an approximation of the distances.

After gaining some experience with the operation, the above measurements are totally unnecessary. The safety of the procedure does not lie in such measurements. It lies in clinical experience and judgment.

The best indicator of retinal safety when firing the laser is how much out of focus the retina is when you are focused on the floater. This indicator is especially good because it is affected by not only the distance to the retina but also on the coning power of the contact you are presently using. Naturally, the more out of focus the retina is, the safer it is to fire the laser. In all work in the mid and posterior vitreous, the illuminating beam should be in the central position between the slit lamp oculars, so the retina will always be illuminated and seen if you come close to it. This is a major advantage of the Laserex LQP 4106 laser. Also by having the illumination in the central position, you can also always find the aiming beam because it is within the illuminating beam. The only time this safeguard could fail is if you are treating an off-axis floater in a post retinal detachment patient that has a high buckle. In this situation you could be unaware that you are treating near the elevated retina overlying the buckle. If the illuminating beam is off to the side, finding the aiming beams in the transparent vitreous can be difficult. If the retina is out of focus when the floater is in focus, no harm can result. As you get closer to the retina and its clarity increases, the chance of injury also increases.

You should use the strongest contact lens that allows you to get a pinpoint focus of the aiming beams on the floater, and allows you to see the retina when you move the slit lamp joy stick all the way forward. You need to be able to see the retina without changing contact lenses so you can check for retinal damage if it is suspected. The only way a beginner can learn how near the retina he can fire the laser is to gradually work closer to the retina. Several parameters determine whether there will be damage when working near the retina. These parameters are the power being used, the distance to the retina, whether the floater is big enough to block the shot, how much coning the contact lens provides, whether your aim is good, and whether optical breakdown is achieved.

If the aiming beams are somewhat doubled in the anterior-posterior axis because the floater is off the central axis, a retinal hemorrhage is especially likely to occur because one of the two beams may be near the retina.

At some point you will have to learn how close to the retina you can fire the laser. To prevent a "curiosity killed the cat" situation in your learning, try it the following way. If you are not certain whether it is safe to fire the laser, choose a spot on the retina where there are no blood vessels in the back- scatter area of the laser beam and that is also away from the macula. Then reduce the power down to about 4 mJs and fire the laser. Then gradually increase the power. With this method, you can learn the limits. When I went beyond the limit, instantly a perfectly round hemorrhage appeared in the choroid about one-half a disc diameter in size (color page 103, Figure 19, 20, 21 showing the same retinal hemorrhage at 1 day, 14 days, and 2 years). It did not spread. It absorbed within a week and the patient was never aware of it. Probably this could happen repeatedly without harm as long as the beam did not hit a retinal vessel or the macular area. With a harder hit, a choroidal hemorrhage can occur that will spill into the vitreous slightly. Here the surgeon should press on the eye with the contact lens for 20 or 30 seconds until the hemorrhage stops. The resultant hole in the internal limiting membrane does not seem harmful and is indeed helpful in releasing the blood into the vitreous where it is absorbed.

Theoretically the shock wave from optical breakdown that is transmitted through the vitreous could harm the retina. But at the powers we use, it does not. The shock wave definitely reaches the retina. If you fire a 7.0 mJ shot into the anterior vitreous (higher power than we normally use in the anterior vitreous), you will feel the shock wave through the housing of the contact lens you are holding.

Since starting this operation I've had five retinal hemorrhages, and they were all harmless. Although the hemorrhages were harmless and semi-intentional, they would not give a positive image to my work if discovered, so I decided in February 2004 to not fire the laser in a situation where I might get a hemorrhage even if the patient was complaining about the floater near his retina. In thousands of laser shots since, I have never had a hemorrhage.

Two hemorrhages occurred during our 200 case Formal Study. These occurred intentionally treating a floater very near the retina while trying to learn how close one could fire the laser to the retina using two different contact lenses. In each case a perfectly round hemorrhage, about 1/3 disc diameter instantly appeared in the retina or choroid. It did not spread and healed with little or no scar. The patients were unaware of the hemorrhage.

The three pictures here (colored page 104, Figures 19, 20, 21) (same patient) show that the hemorrhage is close to the optic nerve. It looks as if a surgical disaster of hitting the optic nerve almost occurred. That was not the case. These shots were a calculated risk. Time was spent lining up this shot. In fact, almost all retinal hemorrhage that occurs is located close to the optic nerve. Why so? Retinal hemorrhages almost always occur while treating a Weiss ring since these rings have the characteristic of migrating toward the optic nerve during treatment. At the beginning of treatment the Weiss ring is usually in the mid vitreous due to the posterior vitreous detachment. But with treatment, it moves posterior.

During treatment the Weiss ring is shoved backward toward the optic nerve from the shock wave of the optical breakdown, and because there is no formed vitreous behind the posterior vitreous detachment to retard the migration of the ring toward the optic nerve. Frequently some of the ring will remain when it approaches the optic nerve. Then the choices are: leave it there and hope for absorption, come back another day, or fire on it. If I decide to fire on it, it is a planned shot, it is a calculated risk, and a retinal hemorrhage is not a surprise. In the rare event that I think a retinal hemorrhage might occur, I discuss it with the patient before making that shot and ask them of they are on any anticoagulants. If they are, the questionable shot is not done.

Of course, producing any retinal hemorrhage is undesirable, but such a hemorrhage can be kept in perspective by comparing it to the lesions of panretinal photocoagulation. Consider these facts about a hemorrhage that can occur during laser treatment of floaters: a) no hemorrhage has ever been harmful, b) at most there would be one hemorrhage in an eye, c) none had any effect on the vision, d) all healed rapidly with a minor scar, and e) such a hemorrhage is extremely rare. (There were two retinal hemorrhages in our Formal Study of 200 cases. There was an average of 125 shots per case x 200 cases giving a total of 25,000 shots for the study. Thus, the incidence of retinal hemorrhage was 0.008 per cent per shot). Contrast that to the scars of argon laser panretinal photocoagulation where a thousand lesions are placed in a single eye and each heals with a prominent scar (color page 103, Figure 22). Because the retinal scarring of hundreds of PRP lesions are planned, they are not classified as complication, but are rather the expected result of a universally accepted, helpful treatment. In contrast, the tiny scar of one retinal hemorrhage in the treatment of floaters is considered a complication.

Doctor Douglas Gaasterland told me of his research on monkeys on YAG laser damage to the retina, where they intentionally produced retinal hemorrhage that spilled into the vitreous.[5] He said that all of these retinal lesions healed nicely.

Why would a retinal hemorrhage that spills into the vitreous always heal so well? The two probable reasons are: (1) When you produce such a hemorrhage, you also accidentally and simultaneous administer the treatment of choice, i.e., a perforation of the internal limiting membrane. For example, large pre-retinal hemorrhages such as from leukemia and especially ones that cover the macula, can be effectively drained into the vitreous with a small hole made in the internal limiting membrane at the bottom of the hemorrhage.[6] (2) At the time of the hemorrhage the YAG laser would also sever the vitreous and release any vitreous traction in that area.

If you feel that there is a possibility that you may get a retinal hemorrhage on the next shot, be sure to line up the shot so that the macula and no vessels are in the back-scatter area.

Why might a hemorrhage occur? (1) You are simply too close to the retina. (2) You missed the opacity when you fired the laser, meaning the opacity was not there to block the energy from going to the retina. (3) You hit the opacity but it was too thin to block the energy from going beyond it. Remember you judge the floater to be dense enough to block the shot from going to the retina by illuminating it with a tungsten light from the slit lamp. However, the near infra-red treatment beam may penetrate through the floater better than the tungsten light. (4) The power was too high. (5) You forgot to reduce the power when you switched to the Peyman 25 mm lens. There is little coning of the beam with this contact lens, meaning that the back-scatter is confined to a smaller area which increases the power density. With this lens the safety margin is low near the retina. (6) You did not get optical breakdown and its accompanying plasma shield. At the instant of optical breakdown the plasma becomes dark and dense and is a very effective shield in preventing the energy from going to the retina. (7) The patient's stool was too low. Because of this the patient's forehead came off the forehead rest. As you fired the laser, the patient brought his head forward onto the rest and you hit the retina. (8) The patient moved a lot. Just don't shoot near the retina if the patient has a lot of movement. And last but far from least, (9) the patient wanted the last speck of the floater removed. In the case of the three retinal hemorrhage pictures (colored page 103, Figures 19, 20, 21) (same patient), it was a Weiss ring, the only floater that almost always moves posterior as you treat it. I was fairly well satisfied after the first treatment, but the patient wanted more of the floater removed. We did a second treatment, and I was satisfied then with removing 99 per cent of the floater. The next week the patient called up complaining of the last 1 per cent. On the third session the tiny remains of the floater were found near the retina. I explained there was about a 40 per cent chance that we would get a retinal hemorrhage if I shot, but I could line it up so the shot would not affect his vision. I shot, reduced the floater to almost nothing, and got the hemorrhage. I decided that day that I would never have another retinal hemorrhage. Not that a hemorrhage is a medical problem, but a colleague who sees the patient might assume it was an accident rather than a calculated risk. The point is, retinal hemorrhages are totally avoidable, but you must be firm and explain to an occasional persistent patient that their tiny floater probably will absorb.

If a retinal hemorrhage occurs, the contact lens should be used to press on the eye for about 30 seconds until the hemorrhage stops.

PREVENTING MACULAR DAMAGE

There is no case of macular damage in the literature or in the 3,000 unpublished cases of which I am aware. But the importance of protecting the macula can not be over emphasized. Macular damage is prevented by simply being aware of its location when working near the retina.

ABSENCE OF RETINAL DETACHMENT

In all the cases in the literature, in the 9,000 unpublished cases with which I am familiar, and in my series, there are no cases of retinal detachment. In YAG laser posterior capsulotomies there is a 0.5% to 4.16% incidence of retinal detachment.[7] Retinal detachments are associated with posterior capsulotomies probably because with that procedure, vitreous can herniate through the created capsulotomy into the anterior chamber and thereby increase vitreous traction on the retina. However, in treating floaters, the vitreous can not herniate into the anterior chamber. In fact vitreous traction can only be decreased with laser treatment of floaters. Each laser shot destroys vitreous strands and architecture that can cause vitreous traction. Light flashing from vitreous traction of long duration is frequently immediately stopped by laser treatment of floaters. When a vitreous strand across the eye is hit with the laser beam, the severed ends immediately separate relieving vitreous traction. Probably the most common cause of retinal detachments and peripheral pathology is vitreous traction. So it could be argued that laser treatment of floaters decreases, not increases, the incidence of retinal detachment by directly reducing vitreous traction. Actually the YAG laser has been successfully used to treat pre-retinal macular fibrosis by severing the vitreous adhesions from the retina.[8]

PREVENTING CATARACT FORMATION

Here is how to protect the lens during surgery. With the illumination in the central position it is difficult to know how close you are to the lens. Therefore, when working near the lens, place the illuminating (slit lamp) beam a few degrees to the side so the lens is seen in profile and the contact lens reflexes are reduced. This is a happy coincidence because only in the anterior and mid-vitreous can the beam be put to the side and its illumination not be blocked by the iris.

I am aware of two cases in the approximately 4,500 cases done in the U.S. where visually insignificant cataracts were a complication of the procedure. One was a peripheral spot cortical cataract. In a second case some Elschnig pearls developed on the lens capsule in the location of the laser hit. And I had one case of a micro rupture of the posterior lens capsule (the incidence of this complication was 0.05 per cent in my 2,000 cases). At that spot the lens became somewhat cloudy. The vision months later was 20/25.

Also, to avoid lens damage Doctor Aron-Rosa advises not using the burst mode in phakic patients at less than 4 mm from the lens of the eye.[9]

NO ACCELERATED SYNERESIS OR PVD PRODUCTION

We are aware of no cases where treatment caused collagen clumping and formation of more floaters, early liquefaction of the vitreous, or a posterior vitreous detachment.

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[9] Aron-Rosa and Greenspan: Neodymium: YAG laser vitreolysis. Int. Ophthal Clin 25:125-134, 1985

CHAPTER 21. FOLLOW UP, AND RETREATMENTS

EXAMINATION IMMEDIATELY AFTER TREATMENT

If the patient was treated for one floater that was central and located on a detached vitreous face (Weiss ring or similar), they frequently are aware of marked improvement almost immediately. If they were treated for multiple floaters, they will not be aware of improvement until that night or the next morning when the pupil returns to normal size and the gas bubbles are gone.

Immediately after treatment, look at the fundus with the indirect ophthalmoscope. This brief examination is done only because the patient is then fearful and in need of reassurance. They are told that every thing looks perfect, and what to expect until they see you the next day. Let them know their vision will be blurred for about six hours because of the dilation, the grease on the eye, and the dazzle of the treatment. Also tell them they will see some debris, and if they see anything perfectly round, those are gas bubbles from the treatment and they will be gone tomorrow. Then say, “Call me if you have anything unusual like a lot of redness, pain, or marked decrease in vision. But I never get any phone calls.” We also provide the above information as a handout (see Appendix C).

Finally say, "I'll check you tomorrow, and if you need a touch up, I'll do it tomorrow at no charge." That way they don't worry if they see a floater that night.

THE DAY AFTER TREATMENT

Most patients are aware that they are much better than before the operation. Usually the patients know that their big opacities are gone. Many are very grateful. Those who had a Weiss ring or a very posterior opacity removed may feel that a miracle has been performed.

If they are uncertain of their status, they seem very easily reassured after examination. After reassurance they frequently say something like, “I thought everything was fine but I just wanted to hear it from you.”

With the indirect scope, usually no opacities are seen. With the direct scope, usually just wispy waves of the vitreous or the tiniest floaters are seen. If they have and are seeing clear folds of vitreous, this needs to be explained. They need to be told you can get rid of floaters but the clear vitreous folds don't react to the laser energy, so there is nothing you can do about them. Fortunately these folds are only a minor annoyance. These clear vitreous folds should also have been explained before surgery.

On the day after the initial treatment, the best evaluation is done with the direct ophthalmoscope with the +10 lens. The only decision to be made in this short examination is, do you want to take them back to the laser or not. If you try to map out individual floaters, you will lose them by the time you take the patient to the laser. If you decide to take them to the laser, the real examination is done there along with the re-treatment.

The purpose of the operation is to rid the patient of their symptoms of a moving shadow on the retina. However, up to three lines of improvement in visual acuity may be found the first day post-operative. This can be expected when the opacity is situated in the central visual axis. This improvement in visual acuity always surprises and pleases the patients. This possible improvement in visual acuity should not be mentioned to patients preoperatively because it varies from patient to patient.

RE-TREATMENTS

If there are any significant floaters remaining, additional shots are given on the first day post-operatively. The most common indication is a tiny particle that went peripheral during the treatment and was lost, or a floater that went so far posterior that it was not safe to continue. The next most common indication is a fibrous floater that was difficult to break up. This type of floater is usually recognized on the initial examination, and the patient is told to expect more than one session.

The first re-treatment is almost always helpful, but let the patient know that additional re-treatments yield diminishing returns. Seldom is there pronounced improvement on a second re-treatment unless it is that rare, very fibrous floater that breaks into small pieces rather than disappearing.

FOLLOW UP EXAMINATIONS

A one year follow up examination is done on local patients. If the patient is from out of town, they are given a form which their local ophthalmologist fills out at their one year examination. The patient sends it as a FAX to our office (see form in Appendix J).

CHAPTER 22. SELECTION OF A LASER

The secret to treating floaters with a YAG laser is having the illumination beam nearly coaxial with the treatment and observation beams (see Chapter 9, Laser Optics for Floater Treatment). This allows for viewing and treatment of the floater in the posterior vitreous. In many YAG lasers, the illumination beam originates from far below to reduce reflexes during capsulotomies. This type of laser will not work for posterior floaters.

You can test your YAG laser to see if it is suitable for treating floaters. With a dilated pupil and using a flat faced contact lens, see if you can simultaneously shine the two red aiming beams of the laser and a small white illumination beam of the slit lamp on the optic nerve head. If you can, your laser passed the first test. Then do the same thing using a convex faced contact lens like the Karickhoff 21 mm lens. If the illumination beam passes too low through the lower half of the contact lens, the contact will act as a base up prism and the illumination beam will go too high in the eye and will not coincide with the treatment beam. If that happens, your laser will not work for floaters.

Most YAG lasers have a cone angle of 16 degrees. That angle gives a short working distance, makes it difficult to see to the retina with some of the surgical contact lenses and difficult to have room to hold the lenses on the eye. The Laserex LQP 4106 has a cone angle of 14 degrees that prevents these problems.

Learning whether a laser on the market had the above capabilities was a formidable task for me. On some we consulted with their engineers; two lasers were sent to us; we had to buy one laser on trial to test it; and on one we traveled to the nearest owner of the laser and examined it there. I did not perform surgery with some of them. I can verify that the operation can be done with the Lasag Microruptor II and the Laserex LQP 4106 lasers. Your purchase of any other laser for floater treatment should contain an agreement that it can be returned if the buyer is not satisfied. Probably several other lasers can perform the operation.

Laserex, (800) 824-7444, stopped manufacturing a small, portable laser, model LQP 4106 (it should be available on the used market), that the doctor attaches to the Haag Streit 900 BM (basic model) slit lamp. I tested this laser also on the Marco V and the Topcon copies of the Haag Streit slit lamp. The laser works with these slit lamps. This is the only Laserex laser in which all beams are nearly axial. The manufacturer was kind enough to loan this laser to me, and I eventually bought it. Nearly all of my experience treating floaters is with this laser.

The slit lamp used must have the feature that allows the housing containing the bulb to be tilted forward at least one notch. Otherwise, when the slit lamp illumination arm is moved from side to side, it collides with the laser. The joy stick on the slit lamp should have both the vertical and horizontal adjustments on one knob so you can control it with one hand. Your other hand is needed to hold the contact lens.

Laserex LQP 4106 laser.

To install the laser, the head of the slit lamp which contains the objective and ocular lens is removed, and the laser with its own oculars is attached. This laser uses a special mirror to make the illuminating beam almost coaxial with the treatment beam. If the standard slit lamp mirror is used, the lower beam of the two aiming beams is blocked by the top of the mirror when the mirror is brought into the central position between the surgeon's two eyes. If one moves the standard mirror just enough to the side so that both aiming beams are seen, then one of the surgeon's oculars is blocked. However, Laserex will provide you with a shorter rectangular mirror that does not block the aiming beam or the surgeon's viewing. In setting up the laser, one needs to focus the laser onto the same spot as the slit lamp light. This laser works only in the desired fundamental mode.

Laser on the slit lamp.

The advantages of this laser are: (1) It is small. The laser fits onto the slit lamp and the power supply which is the size of a small brief case sits nearby (in the photo it is to the left of the laser on a shelf) or can be attached to the slit lamp table. (2) It is suitable for floater work and available. (3) The laser is suitable for posterior capsulotomies but has a few more reflexes than lasers that have the illumination coming slightly from below. (4) Because this is a recently designed laser, the focal spot size is very small, that is, 8 microns. The smaller the spot size, the less energy it takes to get optical breakdown. The spot size is reduced further by the optics of the patient's eye and the surgical contact lens. But at explosion, the spread of the energy is wider than 8 microns. (5) The laser when set up with coaxial illumination as described below, is also excellent for cutting vitreous strands to a cataract wound. The best contact lens for cutting strands to a cataract wound is the Lasag chamber angle lens or the Ocular Magna View Gonio Lens from Ocular Instruments Inc. (Product OMVGL, phone 800-888-6616). And (6) since it has near coaxial viewing, one can monitor the retina directly behind the floater during treatment.

The disadvantages of this laser are:

(1) It does not have the multiburst mode. Multiburst mode significantly speeds the surgery, but there is also a much more rapid accumulation of total shots and energy when using the multiburst mode. This excessive energy may rarely lead to elevated pressure post-operatively.

(2) The earlier Laserex LQP 4106 lasers did not have a shot counter. So I made one from Radio Shack parts for $15. The laser now comes with a software modification that provides a read out of the total number of shots used.

(3) Centering the aiming beam into the center of the smallest (2mm) illuminating beam is absolutely essential but requires patience. This centering makes certain that the aiming beam spot is located exactly in the center of the illuminating beam. The vertical alignment is accomplished by tilting the illuminating mirror slightly. One can use tiny strips of Scotch or bandage tape beneath the edge of the mirror and its housing to shift the angle of the mirror slightly. The horizontal alignment is accomplished by loosening the housing screws, moving the laser slightly, and retightening them. Once it is aligned it usually stays aligned for months.

(4) Sometimes one has to work at seeing the floater because the source of the illuminating beam and the treatment beam are not perfectly coaxial. I calculated that the angle of the treatment

beam from the illumination beam as 6.5 degrees (see Appendix N for method of calculation). This is not a wide separation but it is enough so that occasionally one can see the floater with the red aiming beams but there will be no white light from the slit lamp shining on the floater. To correct the problem, one needs more pupil dilation or to turn the eye down slightly.

(5) Finding the aiming beam during floater surgery can be difficult. When doing a posterior capsulotomy, there is never a problem finding the aiming beam because one moves the slit lamp slightly and the aiming beam is seen hitting the remaining capsule. But when looking at an isolated small floater in the middle of the vitreous, one is using a small illuminating beam (usually 3 mm diameter) to find the floater. When you find the floater you may not be able to find the aiming beam because it is passing through clear vitreous with nothing to reflect it back into your eye. It helps here to switch to the 2 mm diameter slit lamp beam. This greatly reduces reflexes and if you have previously perfectly aligned the aiming beams in the middle of the 2 mm illuminating beam, you will soon find the aiming beams and can center them on the floater.

(6) For the neophyte the perfect aim can look somewhat similar to the disaster aim. The perfect aim is when the two red aiming beams are brought together on the floater to appear as one red spot. The disaster aim is when only one of the beams is centered on the floater looking somewhat the same as the perfect aim, but actually it and the other aiming beam are focused on the retina. This is mainly a theoretical problem because you will soon learn that the floater will be out of focus somewhat (especially when using a magnifying contact lens) if the beams are not focused on the floater. The way the disaster is prevented is to see the floater, put the aiming beams on it, then always pull back a little with the joy stick to be sure you have two aiming beams on it, then go back into focus and fire. This danger of hitting the retina should not discourage anyone from adopting the procedure, or this laser, or other lasers with non-rotating aiming beams. These are just precautions. The incidence of hitting the retina is extremely low. The five times that I produced a lesion on the retina were a calculated risk and were harmless.

(7) With this laser the aiming beam is found best if the illumination is in the center position between the oculars. But this position makes for slightly more reflexes than when the illumination is off to the side some.

(8) Like almost all YAG lasers made for posterior capsulotomies, there is a depth offset between the aiming beam and the treatment beam to protect the intraocular lens. That is, the treatment beam fires slightly posterior to the aiming beam. This is not desirable for vitreous opacity disruption and you may want to compensate for it. This is done by focusing the aiming beams on the opacity, then moving the joystick slightly toward the surgeon before firing. In addition to this manufacturer's offset of the beams, chromatic aberration also causes the red aiming beam to focus closer to the surgeon than the YAG beam. And this difference is increased as one works deeper in the vitreous. So when working deep in the vitreous, one must focus more anterior from the opacity than when working in the anterior vitreous.

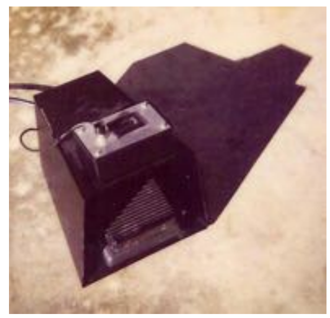
(9) There is only one magnification setting with the slit lamp. Having a second weaker power might make is easier to find floaters that are temporarily lost.

(10) If the chin rest of the slit lamp is set a little low, the inferior aiming beam does not get into the eye because it is blocked by the top edge of the mirror. In this situation raise the chin rest.

(11) And, the upper part of the illuminating beam is not reflected into the eye because the mirror on the slit lamp is not full length. This is rarely a problem.

(In spite of the disadvantages above, this is a beautiful little laser that gave excellent visibility. The only way to see better than with this laser would be to have the illumination and the treatment beam perfectly coaxial using a beam splitter. But with that arrangement the reflexes from the contact lens and the cornea probably would be directly in line with the floater, thereby reducing visibility.)

(<u>Research project</u>: A problem was the early Laserex LQP 4106 lasers did not come with a shot counter. Of course one can write down an approximation of the number of shots used but that is far from ideal. It took two or three planning sessions to come up with a design of my homemade shot counter because I had to add the shot counter without making any modification to the laser which would have disqualified it as an FDA approved laser.   One weekend I built and installed my shot counter on the foot switch of the laser in two hours (see photo). The cost was $15. It consisted of a Radio Shack digital counter that counted when a small burst of electricity was sent through it. A new, separate foot switch was purchased and taped on top of the laser foot switch so that when the top foot switch was pressed, both the top and the bottom switch closed. The top switch was wired in series to a battery and the digital counter. The counter was taped on top of the laser foot switch housing. It worked perfectly. My plans and photos were sent to the manufacturer. A few months later Laserex modified their laser so it had a shot counter. Their counter was just a software change. My laser was sent to them for a retrofit of their counter. The laser was returned to me looking just like I sent it. Now, after treating a patient, one presses the Ready/Standby button and the number of shots used appears in the read out.)



Homemade Shot Counter

Laserex did not design this modern laser with floater disruption in mind. It was designed to be a portable add-on laser for capsulotomies. Its having the needed floater disintegration design features of all beams being nearly coaxial and having a large working distance was entirely fortuitous. When they submitted the laser for F.D.A. approval, they again did not consider using it for the unknown operation of floater disruption, but on the application they listed capsulotomies, and also listed everything else under the 67031 code which just happened to contain vitreous opacity disruption.   The F.D.A. approved this laser for all of those procedures. I suspect that the same fortuitous events happened to some of the other laser manufacturers that made a laser suitable for floater obliteration.

To get the laser in focus, first, tape the top of a piece of paper to the forehead strap and tape the bottom of the paper to the chin rest. Then bring the aiming beams into perfect focus on the paper. Then focus the oculars so that the paper is in perfect focus.

The Ellex Ultra Q laser was evaluated by me for the manufacturer, and I did floater cases with it. The laser itself is adequate, but the focal distance (distance from the laser exit to the point of focus) is about 9.2 centimeters which is too short to easily hold and manipulate the surgical contact lens on the eye. A more concerning problem is that the Ultra Q has an aiming system that is visually confusing and, I think, unsafe. The aiming system has two flip-down mirrors that partially block the surgeon's stereopsis (3 D). This blocking makes it more difficult to know exactly where the laser beam and the floater is in the vitreous and could lead to hitting the patient's lens. The laser beam diameter has been reduced slightly by reducing the diameter of the aperture where the beam exits from the laser cavity. This may have an advantage for working on floaters that are near the patient's lens.

The Lasag Microruptor II was designed by Franz Fankhauser, M.D., Professor of Ophthalmology, Universitats-Augenklinik, Bern, Switzerland specifically for working in the vitreous. This laser was first produced in 1983 and was taken out of production in 1993. This laser is still available on the used market, and parts and service are still available. I have not treated floaters with this laser, but thousands of floaters have been treated using it.

This laser featured a foot and finger firing switch and will fire in the single or multiburst mode (2 to 9 shots). The laser works in both the fundamental mode and the multimode. The fundamental mode is the essential one for floater disruption because that mode uses the strong central peak of power of the beam, and it has more precise aiming than the multimode. Unfortunately this laser is physically large, requiring 2 by 3 meters of floor space.

Microruptor II laser.

This is a Q-switched laser with a 12 nanosecond duration of the impulse. Its maximum power in the free running mode is 7 joules (not millijoules). This laser is older and out of production, but from a technical standpoint it works quite well. The laser is built onto a Zeiss slit lamp. When the illumination mirror is brought into the central position between the two oculars, the laser beam is partially blocked. With the mirror in this position the laser can be fired but the power seems to be reduced by about one half. Therefore, it is essentially never used in this position. Nearly all treatment is done with the illumination mirror placed at an angle wider than the oculars. The aiming system of this laser is unusual. Its two constantly rotating red aiming beams are superior to any other aiming system.[1] These aiming beams are easy to find in the vitreous because they are always moving (rotating). If only one of the aiming beams is hitting the floater, it is seen only when it hits the floater, so it appears as a flashing red light as it rotates over the floater. When one gets both aiming beams on the floater, they are then seen continuously because they are always reflecting from the floater although they are still rotating. The mirror of the slit lamp that reflects the illuminating beam into the eye can be screwed up and down.

The Meridian Microruptor V YAG laser (sold by Iridex (650) 940-4700) (manufactured by Meridian, www.meridian.ch) seems to be a new, modern, smaller, air cooled version of the Microruptor II. It uses the Haag Streit Original 900 BQ slit lamp. The Microruptor V has the rotating aiming beams. The speed of rotation is adjustable. This aiming system indicates accidental beam obstructions and perfect focus on the floater. The manufacturer chose to place the illumination mirror of the slit lamp on the same horizontal plane as the viewing oculars and the treatment beam as in the Microruptor II. Thus the illumination comes from an angle wider than the oculars (I measure this to be about 12 degrees). The laser beam is partially blocked when the illumination mirror is placed centrally between the two oculars. Having the illumination coming from a position wider than the oculars in this laser has the advantage of reducing the corneal and contact lens reflexes, but makes working with small pupils more difficult when compared to the Laserex LPQ 4106 where the illumination is placed just slightly below the treatment beam. But perfect coaxial illumination may not be a legitimate goal because that would put the reflex of the slit lamp bulb from the contact lens surface directly in

Microruptor V laser.

front of the floater. This laser does have a single shot and adjustable 1 to 3 burst mode which can speed the treatment. The depth of focus is good, meaning that one can see using a flat faced contact lens all the way back to the retina even in myopic eyes. The repetition rate is less than 1.3 Hz. I have examined this laser twice but have not treated floaters with it. Therefore, I can not verify that it will perform the floater procedure.

The Nidek YC-1300 has been used extensively in floater treatment. Doctor Wu-Fu Tsai of Taiwan (now retired) did about 5,000 cases with the Nidek YC-1300 laser (personal communication). The Nidek YC-1400 has also been used for floater obliteration. The YC-1300 has only the single burst mode. The YC-1400 has the single and multiburst mode (selectable between 2 or 3 pulse). The multiburst mode is helpful in floater work. The laser operates in the desirable fundamental mode, has power of 0.5 to 10 mJ/ pulse, a 16 degree cone angle, and a 2 Hz repetition rate. I have not treated a floater with this laser, but I did look at a 25.3 mm axial length eye with it. Using the Peyman 25 mm vitreous lens, the slit lamp could barely focus clearly to the retina. Of course it is not essential to see the retina during treatment, but it is desirable. A possible homemade adaptation would be to loosen the forehead strap so the patient's head could be brought closer to the laser. The Laserex LQP 4106 laser and the Microruptor II allow for clear focus to the retina. The owner of the laser I saw had treated a few floaters with it. The Nidek YC-1800 has the same optical setup as the 1300 and 1400.

The optical arrangement for the Lumenis Selectra 1064 YAG, the Aura, the Selectra Duo (YAG+532 nm photocoagulation), and the Selectra Duet (YAG+SLT) appears to be satisfactory for floater work. I have not tested the lasers.

The Alcon Nanolas 15S has also been used for floater disruption[2], but I have not done surgery with it.

The Coherent Epic laser was evaluated in my office for several weeks. It has a beam splitter to make the illuminating beam coaxial with the treatment beam. This laser gives a better red reflex than lasers using a mirror placed slightly wider than the oculars. The viewing is excellent, but this laser has significant drawbacks. The most important is the short working distance to the patient. Some posterior floaters can not be brought into focus because the laser's movement toward the patient is blocked by the patient's forehead. Also the illumination light can not be moved to the right very far, and when the illumination is moved to the left, the aiming beam is not in the center of the illumination. Most doctors would desire to have only one YAG laser in their office that can do floaters as well as capsulotomies. For posterior capsulotomies, this laser had more red reflex than I desired when the illumination was central or slightly off center. When the illumination is moved further to the side, the illuminating beam is blocked by the support pillar of the illumination housing. When moved further to the side, the beam is blocked by the iris. Again, this laser was never intended for floater treatment and, for me, presented significant difficulties.

The first pulsed laser I ever used was a mode-locked picosecond laser made by Meditec. Picosecond lasers can be used for floater disruption, but several years ago their production was stopped due to the difficulty and high cost of maintenance. In contrast, the maintenance of Q-switched lasers is very low. The duration of a mode-locked picosecond laser pulse is typically 30 picoseconds and those impulses are released as a train of perhaps 7 impulses. This shorter pulse tends to move the floater somewhat less that when hit with the Q-switched YAG laser. This movement of the opacity during treatment has raised the theoretical question of whether the shock wave of a Q-switched YAG laser could cause a retinal detachment. But, in practice, this never happens. The movement of a floater from a laser hit is insignificant when compared to movements caused by normal change in the direction of gaze. Although the picosecond mode locked laser probably moves the opacity less than a Q-switched laser, the back scatter to the retina is considered to be more from a picosecond laser because its power is delivered as a train of pulses. Mode-locked lasers function better as a laser knife, and Q-switch lasers function better for disruption.

As can be seen from this discussion, there is no laser setup yet completely satisfactory for performing this procedure (see Appendix N for Designing the ideal laser for floater treatment). I prefer lasers that allow firing with the illumination mirror placed between the oculars rather than lateral to one of the oculars.

[1] Pol P, Fankhauser F: Aiming accuracy in ophthalmic laser microsurgery. Ophthalmic Surgery 17/5: 278-282, 1986

[2] Vandorselaer: Eligibility criteria for Nd-YAG laser treatment of highly symptomatic vitreous floaters. Bull. Soc. Belge Ophtalmol, 280:15-19, 2001

CHAPTER 23. SELECTION OF DIAGNOTIC AND SURGICAL CONTACT LENSES; DESIGNING A SURGICAL CONTACT LENS

(All contact lenses mentioned here, except the Lasag lens, are available from Ocular Instruments, Inc., 2255 116th Avenue NE, Bellevue, Washington 98004. Phone 1(800) 888-6616. The author has no financial interest in the Karickhoff lenses or any others.)

DIAGNOSTIC CONTACT LENSES

Every floater should be examined with a contact lens at the slit lamp as well as with the direct and indirect ophthalmoscope prior to discussing the floater with the patient and taking the patient to the laser. The contact lens is the best instrument to reveal the relationship of the floater to the patient's retina and lens. If you omit the contact lens examination, on a few patients the permit will be signed, the fees collected, they will be taken to the laser, and only at that late stage will you learn that their floaters are too far posterior to allow the procedure.

Any flat faced lens you already own, such as the Karickhoff Four Mirror lens with a flange[1] (Ocular Instruments Inc. order OJKFA), will suffice for the examination. With a flat faced lens the retina can be brought into focus on all eyes, regardless of long axial length and relationships of structures are true. This particular lens has four mirrors the fields of which overlap exactly so that a retinal lesion can be seen or treated from the central area to the far periphery by simply rotating the lens. Each mirror is identified at its base with 1 to 4 unique "depth dots" which eliminates mirror and orientation confusion. It has a serrated front edge for easy and sure rotation. The flanged base makes it impossible for the patient to squeeze it off the eye.

Karickhoff 4 Mirror Lens

But the mirrors of the above lens are not needed for floater evaluation and the posterior diameter is a bit large for easy insertion in small eyes, so I prefer for floater evaluation a little known lens called the Fundus Laser Lens[2] (Ocular Instruments Inc. order OGFA). The front face is flat which is needed to be sure the retina can be brought into focus and the relationship of the floater and other eye structures are true. A flat faced lens is best for hunting floaters in young patients because most often their floaters are near the retina. The posterior diameter of this contact lens is small, making it easy to insert. It has a tiny flange so it can not be squeezed off the eye.

Fundus Laser Lens

Occasionally during the evaluation the Karickhoff Off-Axis Lens (described later) is also placed on the eye to see if an off-axis floater is within the treatment area seen by this lens.

GENERAL CONCEPTS OF TREATMENT LENSES

The floater operation should be performed with a surgical contact lens that has a convex front surface, not a flat-faced lens.

A contact lens helps in several ways

a) It neutralizes the optical power of the cornea so that the middle and posterior vitreous can be viewed with a slit lamp.

b) It slows down any movement of the eye.

c) It neutralizes most corneal astigmatism and any optical aberrations of the cornea that may degrade the focus of the laser beam. A tiny, discrete focus of the laser is essential to obtaining the necessary plasma formation and optical breakdown at a low power on each shot. This discrete focus is also aided by using the fundamental mode (using only the central rays of the laser). Utilizing the fundamental mode and an appropriate contact lens reduces the focal spot diameter from 65 microns down to about 5 microns (in air)[3].

d) A contact with a positively curved front face increases the coning of the laser beam and thereby reduces the laser power needed and decreases the chance of retinal damage. The procedure can be done with a contact with a flat front face, but this type of contact is not recommended because it does not give any coning of the laser beam. In most commercially available YAG lasers, the YAG beam does not exit as a parallel beam but instead exits as a broad circular beam that is usually coned down (converges) at a 16 degree angle. Increasing the cone angle with a contact reduces the diameter of the focal spot. This increases the focal power and energy density. And the more the beam is coned (converged) with a contact lens before it strikes the floater, the more the beam spreads posterior to the floater. This spreading (divergence) of the beam posterior to the floater delivers less power per unit area to the retina. Thus, coning from the contact lens provides a major safety factor. Therefore, for each floater the strongest contact lens, that is, the strongest diopteric power (the shortest focal length) should be used that still gives a clear, precise focus of the aiming beams on the floater. This coning also increases aiming and focusing accuracy.

(Research project: The image of the slit lamp illumination mirror off the surface of the surgical contact lens interferes some with seeing the floater during treatment. The size of this reflex off the face of a flat versus a curved faced contact was measured. The difference was found to be minor and of no consequence in treatment.)

Excessive shoving of the contact lens toward the cornea should be avoided. Some floater operations last 25 minutes. Continued, excessive, posterior pressure for that amount of time might be harmful. The lenses listed below with the exception of the Lasag lens are not easily squeezed off the eye and require little posterior pressure.

The front surface of the contact lens must be clean. Surprisingly, a fingerprint can make it more difficult to attaining optical breakdown.

We utilize seven surgical contact lenses for floater disruption, but almost all cases are done with only two lenses- the Karickhoff 21 mm Vitreous Lens and the Karickhoff Off-Axis Vitreous Lens.

USES OF SEVEN TREATMENT LENSES

The Karickhoff 21 mm Vitreous Lens (Ocular Instruments Inc. order OJKY-21) (see Appendix M) is the most useful lens for laser treatment of floaters and is used for all floaters except off-axis ones and floaters that are very near the lens of the eye. The advantages of this lens are:

Karickhoff 21 mm Lens

(a) it provides good coning of the laser beam;
(b) it has a small flange that prevents the patient from squeezing the contact off the eye;

(c) the lens will stay on the eye a few moments without holding it there;
(d) the posterior face has a small exterior diameter so it can be easily placed on an eye with small lid fissures;
(e) it is made from plastic, so it is light weight and doesn't tend to fall off the eye;
(f) it has a serrated edge so it will not slip from your fingers; and
(g) unless the eye is very long, the surgeon can see the retina clearly during the procedure to check for hemorrhage. By comparison, the shorter focal length Peyman 18 mm lens does not allow monitoring the retina in many patients.

(The lenses above and below were developed while using the Laserex LQP4106 laser. The focal point of the lenses in the vitreous is somewhat different with other lasers.)

The Karickhoff Off-Axis Vitreous Lens (Ocular Instruments Inc. order OJKPY-25) (see Appendix M) or my newer (OJKPY-30 lens)(the same lens but a longer focal length) is used at some point in many cases. I now prefer the OJKPY-30 lens for most peripheral floaters.

The advantages of the Karickhoff Off-Axis Contact are as follows:

Karickhoff Off-Axis Lens

(a) it allows for easier viewing and treatment of off-axis floaters. With this lens the eye does not have to be turned as far. Turning the eye produces corneal striae that degrade the image. It allows surgery on some off-axis floaters where a discrete focus and optical breakdown could not be obtained with the Karickhoff 21 mm Vitreous Lens.
(b) The focus is more posterior than the Peyman 18 and allows monitoring of the retina during treatment in nearly every patient. The focal length of the Off-Axis lens is about the same as the Karickhoff 21 mm lens.
(c) There is a prism incorporated in the lens and there is a black mark deep inside to indicate the location of the base of the prism (see photograph). To best see off-axis floaters, the lens is rotated so the black mark is nearest the floater.
(d) By rotating the lens, its prism helps shift the surface reflexes normally seen with any contact lens away from the central area and over toward

the mark that indicates the base of the lens' prism. This shift of reflexes is especially helpful when looking for faint floaters.

(e) Rotating this lens allows the surgeon to observe and treat all around the main floater without having to stop and move the fixation light or ask the patient to move their eye. In other words the position of the patient's eye is not very critical with this lens because you are moving the slit lamp illuminating light and the laser aiming beam by rotating the lens rather than asking the patient to move his eye. When you ask a patient to move their eye, frequently the patient moves their eye too far, and you lose the floater. This ability to move the illuminating and laser beams by rotating this lens without moving the eye was totally unplanned when I was designing the lens, and it is the best feature of the lens.

(f) The front surface of the lens is designed so that the image does not degrade when the lens is tilted to view off-axis floaters. Flat surface lenses degrade the image when tilted and can cause oblique astigmatism and two areas of optical breakdown when fired.

(g) The patient can not squeeze this lens off the eye due to the flange. (This lens is not helpful in hunting floaters during the pre-operative examination. Use a flat-faced lens there.)

(h) The lens is helpful in treating off-axis floaters in LASIK patients. It allows treating more through the central cornea rather than the knee.

There are three Peyman contact lenses[4] for vitreous work- a 12.5 mm lens for the anterior vitreous, an 18 mm lens for the mid vitreous, and a 25 mm focal length lens for the posterior vitreous. The only difference in the three lenses is the curvature of the anterior surface. Their appearance is the same as the Karickhoff 21 mm Vitreous Lens shown above.

(<u>Research project</u>: I evaluated the 12.5 mm Peyman lens on several cases and found it unnecessary to own. Instead, by rarely using the two Abraham lenses which most surgeons already own and routinely using the Karickhoff 21 mm Floater Lens, all the floaters in the anterior and mid vitreous could be treated. I also evaluated the Peyman 18mm lens and now rarely use it. It is very similar to the Karickhoff 21mm Vitreous Lens, but the Peyman 18mm with its shorter focal length did not allow me enough monitoring of the retina during treatment. The Peyman 18mm lens is a very satisfactory lens for treating central axis floaters in the anterior and mid vitreous, but when the floaters move posterior during treatment, which they almost always do, I had to switch to the Karickhoff 21 mm lens. When the floater moves posterior using the Peyman 18 mm lens, the aiming beam on the floater may become fuzzy. Usually it will become discrete in switching to the Karickhoff 21 mm Vitreous Lens. (The beginning surgeon should be reassured that when focused directly on the floater and you note the retina is significantly out of focus, there is no danger to the retina.)

Many floaters, especially Weiss rings, move posterior during the disruption process. If you are using a contact with too short a focus, as the floaters move more posterior, the focus of the aiming beams becomes hazy (defocused) and you have difficulty achieving optical breakdown (the flash of light and the audible snap). If you switch to a longer focal length contact such as the Karickhoff 21mm Vitreous Lens, the aiming beam again becomes a discrete point and optical breakdown is again achieved.

The Peyman 25mm lens with its longer focal length is usually the first lens used to treat very long, myopic eyes (including eyes that have had LASIK and RK and are now emmetropic). However, if this lens is used in normal length eyes, the possibility of producing a retinal hemorrhage is increased. This is because the Peyman 25 mm lens has less coning than the Karickhoff 21mm Floater Lens and the laser back scatter will now be confined to a smaller area. Ideally you should reduce the laser power when switching to the Peyman 25 at least for a test. If the posterior floater you are attempting to disrupt is solid, there will be no problem because the floater will block the backscatter of the shot. But if the floater is vague and thin, beware because it may not block the backscatter. When working close to the retina, it is important to get plasma formation and optical breakdown with each shot because plasma formation (the plasma shield) is a very effective, instantaneous backscatter shield for the retina. The chance of achieving plasma formation and optical breakdown is high if the aiming beam image on the floater is quite distinct. If the eye must be turned off axis to see the floater and corneal striae are present, usually the aiming beam image will be of poor quality and you will not get optical breakdown. If the aiming beam image on the floater is of poor quality, don't fire the laser. To try to move the floater forward, you can have the patient move their eye around with the contact still on it, or you can see the patient on another day. Either method usually brings the floater forward.

The Lasag CGV contact is rarely used because its physical design is poor. However, its optics are the gold standard for vitreous work. It would be only a slight exaggeration to say that you have never really seen the vitreous until you have seen it with this lens. It seems to collect light slightly better than the other contacts. It was designed by Pascol Rol and was the first lens designed for disruption of vitreous opacities. It gives a beautiful view of most floaters, but frequently its focus is not deep enough to work in the posterior vitreous. The focal length of the anterior curvature of this CGA lens is given as 18.5 mm by the designer.[5] This is similar to the Peyman 18mm lens. Because of this rather anterior focus, a precise pinpoint focus of the aiming beams on the floater is lost as the floater moves posterior during the treatment. This necessitates changing to a longer focal length lens which usually means hunting for the floater again. The biggest problem with the Lasag CGA lens is it is very easily squeezed off the eye during the surgery because its sides are not perpendicular to the eyelid margins and there is no flange.

Lasag CGV lens.

In contrast, the Karickhoff and the Peyman lenses can not be squeezed off the eye and are self-retaining on the eye for a few moments. The lens seems to be especially poor for off-axis floaters because it tends to slip off the eye. The lens requires more posterior pressure in general, has a 1 mm larger posterior diameter than the Peyman and Karickhoff lenses, is more apt to cause a corneal abrasion, and produces more striae. And the lens tends to slip out of your fingers because the lens is made of glass (making it too heavy), plus the rim where you hold is smooth metal. I had to put rough tape on the rim of the lens to prevent it from slipping out of my fingers (see photo). Finding the lens for purchase can also be difficult.

The Abraham posterior capsulotomy lens[6] can be used to disrupt floaters or cut a strand only if an intraocular lens is present. Because of the great power and coning of this lens, if there is a small space between the IOL and the floater, the floater usually can be disrupted.

Abraham capsulotomy lens.

Because the spaces here are small, be sure the patient is comfortable and their forehead is firmly against the forehead strap before firing the laser. This lens has great power, so be sure the anatomical landmarks are clearly in mind. Of course in this situation, start with a low power test shot of perhaps 2.5 mJ and gradually increase the power.

The Abraham iridotomy lens[7] can be used to disrupt a floater, or a vitreous strand that is suspending a floater, where the strand or floater is peripheral to the central optical pathway and close to an intraocular lens. But be aware when working in this peripheral area of the possibility of damaging the haptic of an IOL accidentally or creating a posterior capsulotomy allowing vitreous to enter into the anterior chamber. The margin of error is small here, so start with a low power test shot.

Abraham iridotomy lens.

(Research project: The question was, are there any other contact lenses that might be useful for floater disruption that no one has yet tried? The catalogue of Ocular Instruments Inc. displayed about 50 lenses. The only lens that seemed to be a possibility was the Mainster Wide Field lens. I obtained one and evaluated it. It is not useful for viewing vitreous opacities. It provides an inverted, aerial image so the slit lamp must be further back from the contact than usual. With it you see only the retina and just a few millimeters anterior to the retina. The mid or anterior vitreous could be viewed.)

Here is the strength (focal length) of each lens discussed above:
Peyman 12mm lens---------------------12mm
Lasag CGV lens-------------------------18.5mm
Peyman 18mm. lens---------------------18mm
Karickhoff Off-Axis Vitreous Lens---21mm
Karickhoff 21 mm. Vitreous Lens-----21mm
Peyman 25 mm. lens--------------------25mm
Abraham iridotomy lens----------------66 diopter
Abraham capsulotomy lens------------66 diopter

I have found surgical contact lenses with a mirror not useful in floater treatment.

(Research project: An attempt was made to learn the exact powers of the above contact lenses by filling the inner cup of the contact that rests against the cornea with gonio fluid, then placing the posterior surface of the lens against a glass slide, and then putting the contact and slide under the lensometer. This was unsuccessful. Likewise, trying to read the front curvature of the contact with the keratometer using +5 to -5 diopter lenses in order to put the curvature within the range of the keratometer was also unsuccessful.)

Seven lens case.

If you perform this laser procedure, probably you will have at least four surgical contact lenses. Individual lens boxes are confusing. Ocular Instruments Inc. makes inexpensive custom walnut lens cases that hold several lenses with the storage hole drilled specifically for the lens to be stored. With it, one box holds all of your lenses.

Two final words about these contact lenses:

(1) Throw away the shipping cotton on top of the lens in the case. It serves no purpose after arrival of the lens.

(2) Frequently you change lenses during the procedure. To avoid bubbles in filling the lenses always store the Gonio fluid upside down. As soon as you screw the cap onto the gonio bottle after each usage, shake the bottle twice like shaking a thermometer. The first shake gets rid of the big bubbles, and the second shake gets rid of the tiny bubbles. This works using the less viscous ethylcellulose. It may not work using methylcellulose.

DESIGNING A SURGICAL CONTACT LENS

I have designed three surgical contact lenses--the Karickhoff Four Mirror Laser Lens for general office use, the Karickhoff 21 mm Vitreous Lens, and the Karickhoff Off-Axis Vitreous Lens. For those who might find the need to design a lens, here is the process.

(Research project: Let's use the Karickhoff Off-Axis Floater Lens in order to illustrate the specifics of the design process. First one submits to the manufacturer the proposed use of the lens and a drawing. The manufacturer then makes a prototype. This Off-Axis lens has a central viewing area that has a prismatic tilt and also has a mark to show the location of the base of the prism. The posterior curvature of the lens is made to match or be slightly flatter than the curvature of the average cornea. The anterior curvature determines the depth of focus. This has to be calculated and then tried with a prototype to be sure it is correct for your use, then modified if needed. The prism of the lens is obtained by simply tilting the anterior surface. The strength of the prism had to be determined empirically also. Unfortunately, the presence of a prism brought one side of the anterior surface further from the eye than the other side which in turn affected the focal length. So the focal length was readjusted via another prototype. Different types and locations of the mark that indicates the location of the base of the prism was tried via prototypes. The mark needed to be as posterior as possible in the lens so that the mark could still be seen when the slit lamp was focused on a floater. A total of five prototypes and five evaluations were required for the finished product. Ocular Instruments Inc. charged nothing for producing the prototypes and a finished product. The designer receives no compensation other than his name being placed on the lens.)

[1] Optometric Management, Vol. 35, No. 6, June 2000

[2] Retina, Vol. 4:126-128, 1984

[3] Trokel S L: YAG Laser Ophthalmic Microsurgery, Norwalk, Connecticut, Appleton-Century-Crofts, p. 108, 1983

[4] Retina, Vol 4, No. 2, pp. 129-131, February 1984

[5] Rol P, Fankhauser F: A new contact lens for posterior vitreous photodisruption. Invest Oph & Visual Science Vol. 27, p. 946-950, June 1986

[6] Ocular Surgery News, Vol. 14, No. 17, p. 36, 1996

[7] Ophthalmic Surgery and Lasers, Vol. 27, No. 3, pp. 209-227, March 1996

CHAPTER 24. DILUTING, SELECTING, AND MAKING GONIOSCOPIC FLUID

DILUTING METHYLCELLOSE

Recently we learned that the commercially available 2% and 2.5 % methylcellulose can be diluted with Dacriose to make a suitable gonio fluid for this procedure. Use about 40% by volume of methylcellulose and 60% by volume of Dacriose. We have used it in about 100 cases without any superficial punctate keratopathy. This is the gonio fluid we now recommend for this procedure. Below is the clinical complication and our research that led to this recommendation (and why we don't follow this recommendation).

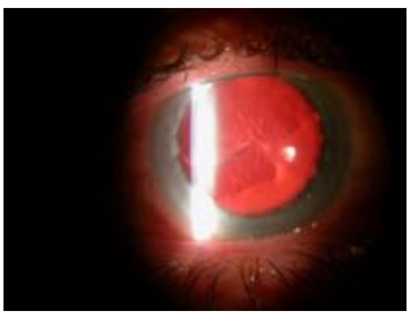
METHYL VS. ETHYL CELLULOSE FLUID

Using the proper gonioscopic fluid is important in laser treatment of floaters. If the gonioscopic fluid is too viscous, it can cause superficial punctate keratopathy with pain and blurred vision. If it is too fluid, air bubbles get under the surgical contact lens and one gets minor abrasions from repeat insertions of the contact lens.

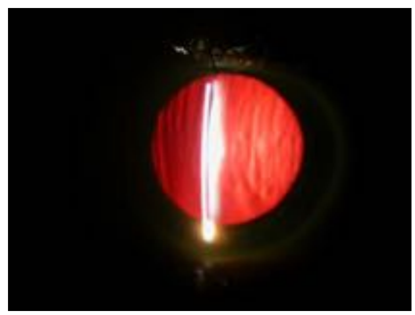
Methylcellulose gonio fluid.

In my first 50 cases of laser disruption of floaters when using the popular 2% and 2.5% methylcellulose, there were a few cases of moderate pain and tearing in the first 24 hours post-operatively. These cases were usually long ones, lasting perhaps 20 to 30 minutes. Examination revealed superficial punctate staining of the cornea in these patients. The staining was generalized and perfectly even. It seemed that the gonioscopic fluid was so thick that it deprived the cornea of oxygen and damaged the epithelium. The corneal epithelium gets most of its oxygen from atmospheric oxygen dissolved in the tear film. There is no tear film or oxygen when a viscous gonioscopic fluid and a surgical contact lens are on the eye. We now use 2% and 2.5% methylcellulose only when getting air bubbles under the contact lens becomes a problem. This is seen mainly in LASIK or radial keratotomy patients whose corneas are so flat that they do not match closely the posterior curvature of the contact lens. This mismatch invites air bubbles. Also air bubbles frequently get under the contact because the patient squeezes their eyelids upon insertion or something else delays a quick insertion of the contact.

The other major problem with methylcellulose gonio fluid was the patient could not drive home after using it in both eyes. Methylcellulose 2% and 2.5% is quite thick and blurs the vision (see photographs below). There are several companies that sell methylcellulose. One of these products, Methocel made by Ciba Novartis, is unique in that the cap has a flat top so that the bottle will stand upside down without support. Because of this feature, the label is printed upside down (see photo previous page). It is available from Wilson Ophthalmic (800) 329-9133.

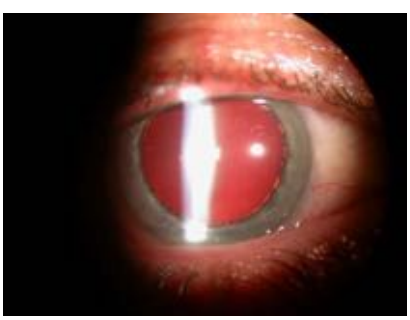


Methylcellulose on eye.



Methylcellulose on eye.

Encountering this problem of occasional pain and blurred vision, I obtained some of Alcon's Gonioscopic fluid. This fluid is hydroxy*ethyl*cellulose and is preserved with Thimerosol. It is less viscous than methylcellulose.



Ethylcellulose on eye.

(<u>Research project</u>: The effect on vision and the chemical irritation of methyl versus ethyl cellulose was compared. This was done at no cost using very sensitive and valuable equipment (my body). A drop of the ethylcellulose fluid was placed on my tongue. It had no taste or after taste. An hour later a drop of the methylcellulose fluid was placed on my tongue. The methylcellulose fluid left an unpleasant, long lasting after taste. Then one drop of the ethylcellulose fluid was placed in my right eye and a drop of the methylcellulose fluid was placed in my left eye and I started watching television. It took five minutes for clear vision to return in the right eye (ethyl). It took 50 minutes for clear vision to return in the left eye (methyl). This very informal testing seemed to indicate that the methylcellulose fluid was the more likely to cause direct chemical irritation to the corneal and to deprive the cornea of oxygen absorbed in the tear film for an extended period.)

Since completing these experiments in July 1993, only Alcon's (ethylcellulose) gonio fluid was used for procedures until February 2005. Its advantages were quite significant:

- The patient can drive home in a few minutes even if used in both eyes.
- You can take a post-operative photograph in a few minutes after the surgery rather than waiting until the next day.
- Surgical contact lenses come off the eye more easily with this fluid.
- If an air bubble comes out of the bottle while filling a contact lens, the air bubble quickly rises to the surface and can be wiped off with tissue. If an air bubble comes out in methylcellulose, you must wipe away all the fluid completely and start over.
- During the case if an air bubble gets under the contact lens, it is fairly easy to expel it with the Alcon fluid by having the patient look down and pressing the contact a bit. You can not expel air from under a contact lens when using methylcellulose.
- You can remove the Alcon (ethylcellulose) fluid from the eye by dripping a few drops of saline on the eye and having the patient blink. To try to remove the methylcellulose fluid, you must send the patient to the sink and have them splash water on their eyelids and eye. And this is only partially successful.

With the ethylcellulose fluid, there have been no cases of postoperative pain.

Unfortunately, in April 2003 Alcon discontinued the manufacturing of their gonioscopic (ethylcellulose) fluid. Currently there is no ethylcellulose gonioscopic fluid available on the U. S. market. Alcon does make a single use gonio fluid called Gelaser, which is sold only in Europe. It is my understanding that ethylcellulose is FDA approved for indirect food applications, such as food-packaging adhesives and can and paper coatings. It is also my understanding that it has not been approved for direct use as a component of food products. Use as an eye drop does not fall exactly into either category above.

GONIOSCOPIC FLUID SUBSTITUTES

(Research project: Upon learning there would be no commercial ethylcellulose available in the future, substitutes were tried.

- KY Jelly worked poorly.
- Genteal Gel is easily irrigated off the eye and the patient sees clearly in a few minutes. But it is so thick that any air bubble in the gel placed on the contact does not come to the surface to be wiped off. You have to start over.
- Bausch and Lomb Liquid Gel (over the counter at drug stores) works quite well. The active ingredients are Dextran 70 (0.1%) and Hypromellose (0.8%). But, if there is any hesitancy in getting the contact onto the eye, an air bubble will be found under the contact. Currently I use this solution for most examinations but it is not adequate for some laser treatments.

MAKING A SUPERIOR GONIOSCOPIC FLUID

(Research project: Ethylcellulose is my preferred gonio fluid for general ophthalmology, but it is not available. I contacted a major chemical company and received from them three quart jars of different density ethylcellusose powder (QP-40, QP-300, and QP-4400). Only the QP-300 powder would make a nice, clear gonioscopic solution. Initially the solution was made by placing a small amount of powder into water, waiting a day until that was in solution, then adding a little more, waiting a day until that was clear, and doing this until the solution was the proper viscosity for gonioscopic fluid, that is, it doesn't run out of the contact before it is on the eye, yet the contact comes off the eye easily. This method was very time consuming and there was always some clear gel in the bottom of the final vial. The solution was then made using Dacriose so it would be in saline and have a preservative. This home-made gonioscopic fluid

Ready to make gonio fluid.

was tested in my mouth and my eyes many times, and it worked better than five methyl-cellulose solutions I was able to purchase. When making this solution, placing it in a clear bottle is important. In that way any contamination will be revealed by clouding of the solution.

Here is the way I learned to make a clear solution without any clear gel residue: To make a 2% solution, use 100 ml. of fluid (Dacriose) and weigh out 2 grams of ethylcellulose QP-300 powder. Warm the solution in the microwave; place the powder little by little into the solution over about a two minute period while agitating the fluid constantly. Do not stop the agitation until the fluid becomes perfectly clear. With this method you will find no clear gel in the bottom of the fluid. This homemade gonio fluid was superior to the methylcellulose fluids. It was tested with a drop on my tongue and later a drop on my eye.)

Warning:

We are informing readers how to make this solution, but the responsibility of using it rests with the maker because:

1) It seems that the U. S. Food and Drug Administration status of the ethylcellulose used for making this solution is uncertain since gonioscopic fluid is neither a food nor a container coating.

2) The ethylcellose dust used to make the gonio fluid can be explosive if mixed with air or other oxidants in critical proportions and in the presence of an ignition source. There will be no problem in the tiny amounts (2 grams) used to make 100 ml. of gonio fluid. But, for example, if a quart jar of the powder were scattered in the air with an ignition source, there could be an explosion as with many other fine powders.

AIR BUBBLES IN THE GONIO FLUID

Air bubbles coming out of the gonio fluid dropper can be eliminated by shaking the bottle twice like a thermometer after screwing on the cap. Store it upside down.

CHAPTER 25. OTHER EQUIPMENT

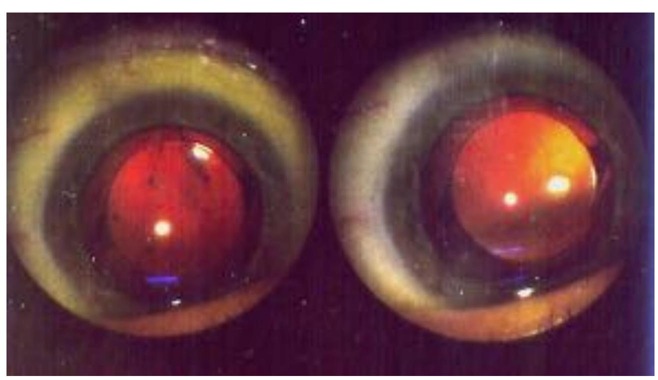
PHOTOGRAPHING FLOATERS

It is important both medically and legally to take a photograph of each floater preoperatively. The image should be made either digitally or on Polaroid film so you are certain you have the picture before starting the operation. Always show the photos to the patient, as it is important for them to understand their condition and progress.

(Research project: We have used four different cameras to photograph floaters.

Docustar camera.

The easiest and fastest camera is the Docustar Polaroid camera made by Reichert, a division of Warner-Lambert, Buffalo, NY. Unfortunately it is no longer made. This unusual camera allows sliding the film housing across the top of the camera. With this feature one can snap the preoperative picture, do the operation, then snap the postoperative picture on the other half of the same Polaroid picture. This makes for a striking demonstration of the effectiveness of the treatment. However, the problem is that resolution of the Polaroid film is low. The photographs used in this book made with this camera appear like one or two round images on a black background. In most cases the pupil and eyelids are shown.



Pre and Post-op. images on one Polaroid print.

The next camera tried was the Nidek 3-Dx stereo fundus camera. This did not seem to show the floaters well because the illumination of the camera was coaxial only. One could possibly have the same problem with any standard fundus camera**.** Most floaters are seen best with the oblique illumination of the slit lamp.

Then I tried to use a **digital camera** for floater pictures. The Nikon Coolpix 4500 (which is now out of production) was chosen because (a) it has screw threads on the inside of the lens cap so the camera could be attached to something securely, (b) the body swivels from the lens so the liquid crystal viewing screen can be seen easily, and (c) it has the macro feature needed for close up pictures.

(Research project: The question was how and where to connect the digital camera to the slit lamp. I proceeded to have built a tube that would connect my camera to a Zeiss beamsplitter on the slit lamp. With the help of a Hollywood producer floater patient, the tube was made by a machine shop in Hollywood that makes props for movies. My tube did work, but the image was too small, was upside down, and backwards. I then decided to build a Galilean telescope inside my tube to enlarge the image. Using the formula for such a telescope and an optical bench I set up, I learned the lenses needed for a telescope the length of my tube. The plus 4.50 objective lens was glued in place near the tube's attachment to the beam splitter. The placement of the minus 6.50 ocular lens was critical, so I had two ocular lenses made and cut off enough of the edge of one so that a match stick could be glued to the lens. This lens was then put into the tube. The lens was slid to different positions along the inside of the tube to find the perfectly clear image. The match stick kept the lens upright and aligned perfectly. That distance was measured, and the unaltered ocular lens was glued into that position. But, the image was still too small and, of course, still upside down and backwards.)

My camera connector.

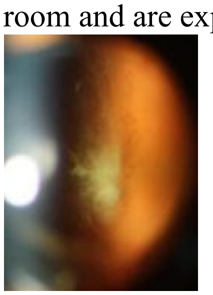
The lenses of the slit lamp were then studied and we learned why the image was too small and inverted. The reason is that the beam splitter connects before the image has been inverted and enlarged by the slit lamp lenses and the oculars. Finally it became obvious that the camera should be connected to the slit lamp ocular, not to a beam splitter that bypassed the ocular. So I had a machine shop make an aluminum ring with threads on one side for the camera and threads on the other side for a spare ocular

($147). The camera and ocular were thus united securely and put in place on the slit lamp. This produced a much larger and upright image, the same as we see in the slit lamp. This set up gives beautiful anterior chamber pictures and even movies, but for floater pictures the liquid crystal display on the camera is too small for viewing them well. Therefore, a TV monitor was connected to the to the system. If the picture is distorted, changing the video mode on the digital camera from NTSC to PAL or vice versa should give a clear image. Unfortunately with this system it is difficult to photograph anything but the largest floaters.)

Ring connects camera to slit lamp.

Unfortunately Polaroid self-developing print film is no longer made, so my Docustar camera pictured above has become obsolete. There are many fundus cameras available with digital backs, but they can take up a lot of room and are expensive ($10,000 to $25,000). We decided instead to use the **Canon Rebel XS EOS digital single reflex camera** as an attachment on the slit lamp. One can focus it using the slit lamp oculars or the viewer on the camera. It also has the necessary foot switch because one hand holds the contact lens and the other hand is on the joy stick. The camera is connected to the slit lamp with an ACCU Beam II (made for this camera) from TTI Medical (about $2,000) (phone 800-322-7373) and a Zeiss 50 beam splitter or equivalent. This device provides an upright, 1 to 1 magnification image. The pictures are of reasonable quality. The advantages of this arrangement are: no moving the patient, no floor space used, one snaps the picture during the examination when the contact lens is on, you can connect it to a monitor for patient viewing, and you can use the camera for externals or at home. It is inconvenient to put the contact back on for a post op picture, but the post op picture is not needed.

Slit lamp camera



Floater cloud with this setup

ELBOW SUPPORT

Elbow support.

Treatment for floater cases often requires up to 20 minutes. Your elbow must be elevated from the slit lamp table with a comfortable pad. A patient made the pictured elbow support for me as a present. It is covered with chamois that is soft and comfortable.

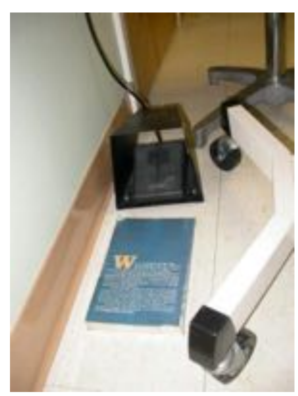
ROOM LIGHT

The goals in setting up the surgery light in the laser room are: don't put the light in front of the patient or you will get reflexes of the light from the surgical contact lens. Don't place the light in front of the doctor or he will be dazzled. An open door to an adjacent lighted room is suitable because it gives a broad light without reflexes. I use a small fluorescent light placed mid-way between the patient and myself and just high enough on the wall so my brow prevents me from seeing it directly. The surgery light should be bright enough so you can insert surgical contact lenses without turning on the overhead lights.

Room light.

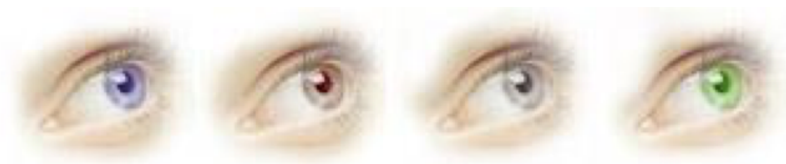
FOOT REST

To avoid holding the front of your foot off the floor between shots, I suggest creating a foot rest by using a book of proper height, and place your heal and mid-part of your foot on the book. Tape the book and the foot switch to the floor.



Book for foot rest.

CHAPTER 26. 15 MEMORABLE, ILLUSTRATIVE CASES AND PATIENT SATISFACTION



Patient satisfaction is very high. Removal of a Weiss ring that is in the posterior vitreous gives satisfaction on the level of removal of a 20/80 cataract.

The great majority of cases are routine. However, some cases were special. Here are 15.

My first surgical floater case was a young man with a long floater suspended in the optical axis by a thin vitreous strand coming from 12 o'clock. One shot from the laser was fired at that strand and then the floater could not be found. I then ended the case embarrassed that I could no longer find his floater, but convinced that I could not have cured the situation with one shot. The next morning he reported the floater gone and his vision had returned to 20/20. The floater was found curled up like a corkscrew on the anterior retina at 6 o'clock, completely out of the optical axis.

Another patient had a large floater suspended in the optic axis just behind an IOL. There were two strands above and three below suspending the floater. When the two upper strands were cut with the laser, and as I watched, the floater slowly retracted completely downward out of the optical axis over a period of about 10 seconds.

A highly intelligent young man was treated here for a dense floater caused by an old toxoplasmosis infection. At the end of the procedure he announced that he knew when I had aimed the laser properly! He said if the red aiming beam almost disappeared just before the laser was fired, he knew I had aimed perfectly onto the opacity so that the laser shot was blocked from hitting his retina. He was completely relieved of the floater.

A man came from western Virginia who had a very large syneresis cloud type floater that was suspended by one strand that seemed to come from the ora serrata at 10 o'clock down to the floater. The floater was near his lens and swung in and out of his optical axis changing the vision from 20/20 to 20/200 several times per minute. He was nearly suicidal from the floater. Using the Abraham capsulotomy lens, the strand was cut with two shots at 3 mJ power. Instantly the floater went to the bottom of the eye and has not bothered him since. In the office, he was our most "grateful" patient. Strangely enough, he never paid his bill.

A geophysicist stationed on an oil rig 200 miles out in the Atlantic Ocean found our web site via a satellite hookup. He rode a helicopter to Boston, took the train to Washington, and the subway to our office. I finally found a tiny opacity dangerously near the retina. I didn't want to do the case, but because of all his travel, I felt a special obligation to help him. It took 20 minutes to line up the opacity so there were no retinal vessels behind it. I then fired the laser one time. Thankfully there was no retinal hemorrhage. After the one shot I could not find the opacity. The next day he reported the opacity was gone and headed back to the oil rig.

A 35 year old male with high myopia said that four years ago he developed a floater in his right eye that was associated with a retinal detachment. He had retinal detachment surgery and then had a vitrectomy and eventually had to have the right eye removed. He reported that two months prior to seeing me he developed a very large floater in his only remaining eye. He saw a retinal surgeon who treated retinal degeneration in that eye. Because of the floater, he could no longer work as an engineer, and he felt he could no longer go through life as is. He had been unable to find a doctor who would perform a vitrectomy on his remaining eye in view of removal of his other eye after vitrectomy. I examined him and told him that I could help him. Both he and his mother started crying. He wasn't very well dilated, so I put in more drops and went for a very short lunch. When I returned, my receptionist said, "That patient and his mother have cried the whole time you were gone. Are they all right?" I said, "They are just happy." Because of the safety of laser treatment, I was able in a few minutes to completely remove a large Weiss ring with spreading borders from his only eye.

After acquiring significant experience with floaters, I decided to do a case with six strikes against me. The patient (1) had had radial keratotomy, (2) had glaucoma, (3) had reduced dilation, (4) the floater was located 3/4's of the way to the retina, (5) his wife was against having the procedure done, and (6) he was a physician who had come from out of state. I thought I could help him, so the case was done, without complication. They returned the next morning for examination. He said the floater was gone. A postoperative examination was not done because during the dilation his wife pulled him out of the office, saying she had to get to New York to shop.

A music professor complained of a floater in each eye blocking his reading of music. Examination revealed a large Weiss ring in each eye.

The laser completely cleared the ring from each eye, totally relieving his problem. He had a particularly blond fundus, making the rings especially visible for photography. Because of this, and his presenting with a ring in each eye, his floaters were chosen for the cover of this book.

A 55 year old female had to retire from being a librarian because of a long, thick Weiss ring remnant that was especially annoying when looking from far to near. She found our web site and came for examination. 20 minutes at the laser and the floater was entirely cleared.

A young man, about 18 years old, accompanied by his mother, described his floater in great detail. The opacity was so small that it required the direct and indirect scopes, a contact lens at the slit lamp, and finally the optics of the laser to see it. The floater was near the retina. I explained it was tiny, too near the retina for treatment, and gave him reassurance that he would be all right. Here is the conversation that followed:

Patient: "Have you heard how they dissolve these opacities at the University of Idaho?"

Dr. K.: "Yes, but I think they were dissolving hemorrhage."

Patient: "Can you take out all my vitreous and filter it and put it back inside my eye?" (His mother threw up her hands.)

Dr. K.: "That could probably be done, but the risks are extremely high."

Patient: "Can you introduce a bacteria into my eye that would eat the floater?"

Dr. K.: "That would probably destroy your vision."

Patient: "Well then, could you just spin me in a centrifuge and move the floater to the side of the eye?" That comment ended the conversation.

In another case I did four laser sessions on the right eye and three sessions in the left eye on a very nervous engineer, clearing most of his syneresis clouds. Photographs documented clearing of 90% of his floaters, but he complained that the few remaining floaters moved faster than before surgery. I returned his fees as is my practice for any patient who is not satisfied. He was planning to have vitrectomies when we last talked.

A highly intelligent Hollywood movie producer presented with a very large Weiss ring near the retina. Three fourths of it was removed at the first session but we had to stop because the floater had moved too close to the retina. The patient, whose last name was Moses, told me he would meditate about the location of his floater that night, and he would move it forward. He came back the next day and the floater had moved forward some as they all do after 24 hours of random eye movements. I told him that his floater was a bit more forward but not far enough for treatment. Then he said he would move it more forward right then. So we went to the laser and put the surgical contact on the eye. He would look downward and then rapidly back to the central position (later I named this the Moses Maneuver). Each time he did this, the floater came forward, and I was able to get off a shot or two before the floater went back to the former posterior position. Together we got rid of the floater. Since then, I have successfully used this technique that he taught to me on many patients. We have become friends and talk occasionally on ham radio.

Another patient had spotty 20/40 vision in the right eye due to an epiretinal membrane that had been operated upon twice. He had clumps of floaters in his left eye. Of course he was uneasy about having his "good left eye" operated upon by anyone, much less a stranger to him. He made two trips from New York for laser treatment, and two weeks after his second trip he reported seeing much better. He also said this: "I have been in many eye doctors' offices, but I have never seen patients leave an office as happy as your floater patients."

And then there was the case of the world's smallest "floaters." This patient complained of multiple, tiny, moving specks in both eyes. A thorough examination was done and no floaters were found. We went over the symptoms again and I wondered if he could possibly be seeing his own retinal white blood cells, not floaters. He was tested with the Karickhoff Flying Corpuscle Viewer which is a modification of the blue field entoptic test but uses the light of the slit lamp as the light source. At last he saw his "floaters" very distinctly. He actually was seeing his own retinal white blood cells.

Most of our floater patients come from out of town via the web site and most patients e-mail me a time or two before coming. We never saw this patient but his e-mail copied below was touching. Probably the writer was learning English. He seems to use the word "iller" to mean someone who is ill.

"I am the one of chinese iller who feel sorry for eyefloaters, and in China there are many many people have eyefloaters and all of them fell very bad for it, many iller even said they want to end their life, and the rest of feel hopeless for their lives, but in china there are no hospital can treat it, when we see your web, we feel exciting and hope come!!! So dear doctor please come to china because there a larger number of people need your help! And you are the only hope for us!! If you have no time to come now please know many many people is waiting for you doctor! Please come!!!"

CHAPTER 27. FUTURE USE OF THE YAG LASER IN THE VITREOUS

At present the YAG laser is rarely used in the vitreous. But there are isolated reports of it being effective to treat some diseases related to the vitreous. Below are some suggested areas for research studies that should be fruitful.

- Treating persistent vitreous hemorrhage:
  In our study no cases of persistent vitreous hemorrhage were done. One needs to be working closely with retinal surgeons to be referred this type of patient. Dr. Hunter Little found his most encouraging results with the YAG laser when treating persistent vitreous hemorrhage. He did this by performing 1-6 treatments over a period of several weeks.[1] Considering the very low complication rate of laser treatment, this approach deserves study.

- Invasive vitreous surgery for macular holes, epiretinal membranes, and proliferative diabetic retinopathy has become quite common in recent years. The purpose of these operations in general is to relieve vitreous traction. But we tend to forget that each time a YAG laser is fired in the vitreous, it severs vitreous strands and disrupts vitreous architecture, relieving vitreous traction. The evidence for the laser relieving vitreous traction is: a) there are no retinal detachments from laser treatment of floaters, b) long standing flashing frequently stops immediately with this procedure, and c) when a vitreous strand stretched across the vitreous is hit with the laser beam, the two broken ends immediately separate 3-8 mm. Indeed, it has been shown in rabbits that multiple YAG laser shots (such as is done in laser treatment of floaters) can liquefy the vitreous without producing any posterior vitreous detachments.[2] The YAG laser has been used to treat epiretinal membranes[3] and macular traction.[4] This non-invasive approach for these diseases deserves more study.

- Pre-retinal (sub-hyloid) hemorrhages are very slow to absorb and can be debilitating if they block the central vision. These hemorrhages can be drained into the vitreous by puncturing the hyaloid face with the YAG laser.[5]

[1] Little, H: Q-Switched neodymimum-YAG laser surgery of the vitreous. Graefe's Arch Clin Exp Ophthalmol 224:240-246, 1986

[2] Nasrallah et al: Can the neodymium:YAG photodisruptor liquefy the vitreous? Ophthalmic Laser Therapy 3: 63-69, 1989

[3] Tassignon, Kreissig,, Stempels, Brihaye: Indications for Q-switched and mode-locked Nd:YAG lasers in vitreoretinal pathology. European J Ophthal, vol. 1/no.3:123-130, 1991.

[4] Cohen B Z: Neodymium:YLF picosecond laser segmentation for retinal traction associated with proliferative diabetic retinopathy. Amer J Ophthal 123: 515-523, 1997

[5] ZamanF: Nd:YAG laser treatment for macular preretinal hemorrhage. Arch Ophthal 117:694-695, 1999

APPENDIX

Appendix A) **Office work up form**:

Name____________________________, ________________Age____Date__________

Address____________________________; _______________________ZIP__________

Occupation______________E-mail(for floater follow up):__________________________

Phone: office(____)________________home (____)______________Date of birth__________

EYE FLOATER EVALUATION

Rate severity of floaters in your right eye (0,1,2,3,4)__________, left eye (0,1,2,3,4)__________

Light flashes?______How long had floaters? right eye____________, left eye______________

Floaters bother you in (circle) reading, driving, computer, concentration,________________

Other floater information____Diabetes?_____

Past or present eye problems or surgery?___________________________Wear contact lenses?_____

Ever elevated eye pressure, glaucoma, or taking glaucoma drops?_______________________

History of psychiatric problems? ___________________Eye diseases in family?_______________

V OD 20 /   Tension

V OS 20 /   Tension

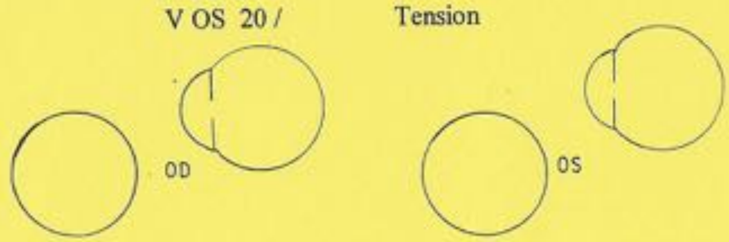
Ext:

SL:

Fundus (dil):

OD

OS



Imp:

Disp: Possible improvement: right ________%, left ________%

Appendix B) **OPERATIVE PERMIT FOR LASER DISRUPTION OF EYE FLOATERS**

Right eye Left eye

Eye floaters are dark spots that float in the vision. They are common. In some cases the floaters absorb by themselves in a few weeks or are small enough not to be a problem. However, if floaters continue to cause a visual problem, and they are not close to other eye structures, a laser can usually vaporize them, or break them into smaller less noticeable floaters that are more easily absorbed by the body, or can move them out of the central vision.

The procedure is easy on the patient, painless, and takes 10 to 30 minutes. A numbing eye drop and a special magnifying contact lens are placed on the eye. The beam of the YAG laser is then used to treat the floaters. When the laser is fired, there is a small flash of light and a snapping sound. At the same time you frequently will see something that seems to be falling down inside your eye. These are tiny gas bubbles created by the laser that are actually going upward in the eye. These bubbles will be gone the next day. There are no restrictions on activities afterwards. More than one session is frequently required, but no additional charge is made. Rarely the floater(s) can not be vaporized, broken up, or moved.

The procedure is only used to get rid of opacities within the vitreous. The vitreous itself is not removed. If the patient's vitreous face is wrinkly or cloudy, the laser does not change it**. If the patient has many floaters, all the floaters can not be removed with any reasonable number of shots. In this situation the goal is to obtain a significant improvement.** _______

Complications are quite unlikely, but can occur. Hemorrhage, retinal tear or detachment, damage to the lens (cataract), glaucoma (elevated eye pressure), and others are possible. **Very rarely floaters that are partially vaporized or broken up or untreated may move to a location where they can not be treated further and then may be more noticeable than before surgery**. Any listing of complications is incomplete. ________

The only formal research study on the efficacy and safety of laser treatment of floaters was done by Dr. Karickhoff. There was one year follow up on these 200 patients. This study was designated a Non-Significant Risk Device Study by the U. S. Food and Drug Administration, was done under FDA guidelines, and was supervised by the Institutional

Review Board of INOVA Fairfax Hospital in Virginia. The results were: success in 95% of patients and no significant complications.

The only alternative treatment for floaters is the vitrectomy procedure. In this, three tubes are placed into the eye and the floaters are cut up and sucked out of the eye. With this procedure cataract formation is very common and retinal tears and retinal detachments are seen. Therefore, this procedure is seldom recommended for isolated eye floaters.

The purpose of this form is to give a reasonable explanation of this ophthalmic laser treatment. You are encouraged to ask any questions you may have regarding your treatment. After reading this form, you are requested to sign the following statement:

THE DOCTOR HAS EXPLAINED THE DESIRABILITY OF LASER TREATMENT OF MY EYE FLOATERS. I UNDERSTAND THAT IN HIS JUDGMENT THE POTENTIAL BENEFITS OF THE PROCEDURE OUTWEIGH THE RISKS. I WISH TO HAVE THIS LASER SURGERY ON MY EYE.

Signed:____

Date: _________________________________

John R. Karickhoff, M.D.

Appendix C) **Pre-operative instructions**

This procedure is easy for the patients. There is no pain. I use an eye drop to numb the eye and then insert a contact lens. The contact lens keeps the eye open and slows down eye movements. Then I have you look in different directions while the laser is used to obliterate the floaters.

You will **see this** during the procedure:

- a white light used to illuminate the floaters
- a red light which is the aiming beam of the laser (the working beam is invisible)
- usually a light flash when the laser is fired

- particles that appear to be falling down in the eye after some laser shots. These particles are **actually gas bubbles that are going up** in the eye.

You will **hear this** during the procedure:

- my voice giving instructions
- my right hand on a joy stick constantly focusing and raising and lowering the laser between each shot
- my foot hitting the trigger
- a snap when the laser is fired.

Appendix D) **Post-operative instructions**

Your vision will be somewhat **blurred** for 4 to 8 hours. This is because the eye is dilated, there is still some grease on the eye from the contact lens, there may still be some dazzle from the laser, and there are now gas bubbles in your eye.

You may feel that there are more floaters now than before the operation. This is because you are seeing **gas bubbles** in the vitreous. These bubbles will be gone tomorrow.

Occasionally on the day of surgery, patients will have some foreign body sensation and tearing, and a little running of the nose on the side of the eye that had surgery. This comes from a slight abrasion of the front of the eye from the contact lens used during the surgery. Almost always this is fine the next morning.

If you have **any trouble**, call Dr. (name) at (phone number). What is trouble? Call me if you have a lot of pain, your vision suddenly drops significantly, you develop lightning flashes in the eye, have loss of vision in one area, the eye turns red, or if there is anything else that worries you.

On your **next visit** __________, _______________,2004 at _______(a.m.) (p.m.) we will assess everything in detail.

Appendix E) Explanation given to patients with **multiple floaters:**

When a patient has one floater, the laser treatment can usually eliminate all or almost all of it. These patients are relieved of their symptoms and their satisfaction with the procedure is very high.

However, when a patient has, let's say, 100 or more floaters, usually in the form of a cloud, the laser treatment can never eliminate all the floaters with a reasonable number of laser shots and their satisfaction might not be complete. What we are hoping for is an improvement (not a cure) so the patient does not feel the need for vitrectomy. For these patients we can usually improve the symptoms by reducing the number of floaters and sometimes by moving the cloud away from the central visual axis. These cases usually take about three times the number of shots and three times as long as when treating one floater. About 75 per cent of these multiple floater cases do have significant improvement.

Appendix F) Summary of the **world literature** on laser floater treatment:

Ophthalmology journals.

There are no studies in animals on laser treatment of vitreous opacities.

There are no laboratory studies on laser treatment of vitreous opacities.

CLINICAL STUDIES: Studies of treatment using the Nd:YAG laser for vitreous opacities (floaters) are included here; studies of cutting membranes that are attached and pulling on the retina are not included here.

Summary of Published and Unpublished Prior Investigations:

In the studies below there are reports of a total of 208 human cases of laser treatment of vitreous opacities in which an assessment could be made of success and complications. There were no significant complications, although there were 5 cases of transient pressure elevation and one case of transient vitritis. Success, although poorly defined in most of these studies, was attained in 87 per cent of cases.

Peer review literature:

Aron-Rosa, Daniele: Neodymium:YAG laser vitreolysis. Int. Ophthal. Clinics 25:125-134, 1985

This paper reported on 7 patients treated for vitreous opacities. There was one case of transient intraocular pressure rise, and one case of transient vitritis. The floaters were disintegrated in all cases.

Fankhauser, Franz: Vitreolysis with the Q-switched laser. Arch Ophthalmology 103:1166-1171, 1985

This paper consisted of mainly cutting vitreous membranes connected to the retina, but he did include 10 cases of floater disruption. There were no complications. The Neodymium:YAG laser was used. The author did separate his treatment of thickened posterior hyaloid membranes from treatment of floaters, so no assessment of success could be made.

Little, H. L.: Q-Switched neodymium:YAG laser surgery of the vitreous. Graefe's Arch Clin Exp Ophthalmol 224:240-246, 1986

This paper reported on 59 cases of laser treatment of vitreous strands, bands, and membranes. The study included 25 cases of vitreous opacities. In his results he did not separate treatment of strands to other eye structures from treatment of opacities (floaters) so no conclusions could be drawn on success or complications on treatment of opacities.

Tassignon, MJ: Indications for Q-switched and mode-locked Nd:YAG lasers in vitreoretinal pathology. European Journal of Ophthalmology Vol. 1/no. 3: 123-130, 1991

Three vitreous opacities were included in this report of cutting membranes off the retina. All vitreous opacities were severe. The Q-switched laser was used. The 3 cases were successfully treated with no complications.

Tsai, Wu-Fi: Treatment of vitreous floaters with neodymium YAG laser. British Journal of Ophthalmology 77:485-488, 1993

This report contains only cases of laser treatment of vitreous floaters (no cases of cutting membranes off the retina). It reports 15 cases of obliteration of vitreous floaters using the Nd:YAG laser. All cases were successful and there were no complications.

Veken A et al.: Nd:YAG laser posterior hyaloidotomy of a premacular vitreous floater. Bull. Soc. Belge Ophtalmol 265:39-43, 1997

This is a report of one case of a large premacular vitreous floater that was removed with the Nd:YAG laser without complication. The vision did not improve. The authors stressed that the laser procedure is much safer than the vitrectomy procedure.

Vandorselaer, T et al.: Eligibility criteria for Nd-YAG laser treatment of highly symptomatic vitreous floaters. Bull. Soc. Belge Ophtalmol 280:15-19, 2001

10 eyes were treated. 5 of the 10 eyes had success. There were no complications.

(This study is included for completeness but it is not exactly analogous to my usual purpose for the procedure. In this study they were using the laser to attempt to move the floaters out of the visual axis. I am using the laser in most cases to disrupt and disintegrate the floaters.)

Delaney, Y et al: Nd:YAG vitreolysis and pars plana vitrectomy: surgical treatment for vitreous floaters. Eye 16: 212-26, 2002

39 eyes had laser treatment. 38% had moderate improvement, 61.5% had no improvement, and 7.7% were subjectively worse.

(The maximum shot power used in this study was 1.2 mJ. This low level of power probably did not achieve optical breakdown. Therefore, as the authors state, the mechanism for treatment in their study was probably fragmentation only. The average shot power in most other studies was approximately 7 mJ which is about 6 times the power used in the above study. When using power in the 7 mJ range the primary mechanism is that of optical breakdown which means converting the floaters to a gas rather than just fragmenting them. Using the mechanism of optical breakdown should bring success in about 92% of cases.)

Non-peer review literature:

Geller, S: Nd:YAG laser treatment effective for vitreous floaters. Ocular Surgery News, Dec. 1, pg. 37, 2001

112 eyes were treated. The success rate was 85%. 5 cases had transient high IOP that was controlled with medication and returned to normal.

Karickhoff, J: YAG laser offers safe option for floaters. Ocular Surgery News, March 15, 2007

Non-published study:

Karickhoff, J.

The study consists of 61 patients. Treatment was successful in 92% of patients. Follow up averaged 10.8 months. There were no significant complications. Two patients had a tiny retinal hemorrhage. These hemorrhages were semi-intentional since I was trying to determine how close I could work to the retina. Four patients had some pain post-operatively. This problem was eliminated when I switched to a less viscous gonio fluid.

Articles related to laser floater treatment:

Bonner, FB, Sanford MM, Gaasterland DE: Threshold for retinal damage associated with the use of high-powered neodymium-YAG lasers in the vitreous. American Journal of Ophthalmology 96:153-159, 1983

In this study done on monkeys they found there was substantial risk to the retina when aiming the laser less than 2 mm from the structure.

Murakami, K, et al.: Vitreous floaters. Ophthalmology 90:1271-1276, 1983

148 cases of sudden onset of floaters were studied. The authors make the point that the sudden onset of multiple small floaters was frequently associated with vitreous hemorrhage and retinal breaks.

Boldrey, E "Risk of retinal tears in patients with vitreous floaters" Amer J of Ophthal 96:783-787, 1983

This is a study of 589 patients with vitreous floaters. They found that the most likely predictors that the patient might have a retinal tear were (1) diffuse floaters, (2) presence of vitreous cells graded +2 or more on examination, and (3) the presence of grossly visible vitreous or pre-retinal hemorrhage.

Hikichi T, Trempe C: Relationship between floaters, light flashes, or both, and complications of posterior vitreous detachment. Amer Journal of Ophthalmology 117: 593-598, 1994

This study of 902 patients attempted to determine the likelihood of having a vitreous detachment and retinal breaks if the patient's symptoms were flashes, floaters, or flashes and floaters. The greatest incidence was if the patient had both flashes and floaters.

Peyman, G: Contact lenses for Nd:YAG application in the vitreous. Retina 4:129-131, 1984

The article describes three surgical contact lenses designed by the author to focus a laser beam 12.5, 18, and 25 mm into the vitreous. Each of these lenses increased the cone angle of the laser beam which in turn decreased the power needed to achieve optical breakdown, improving safety.

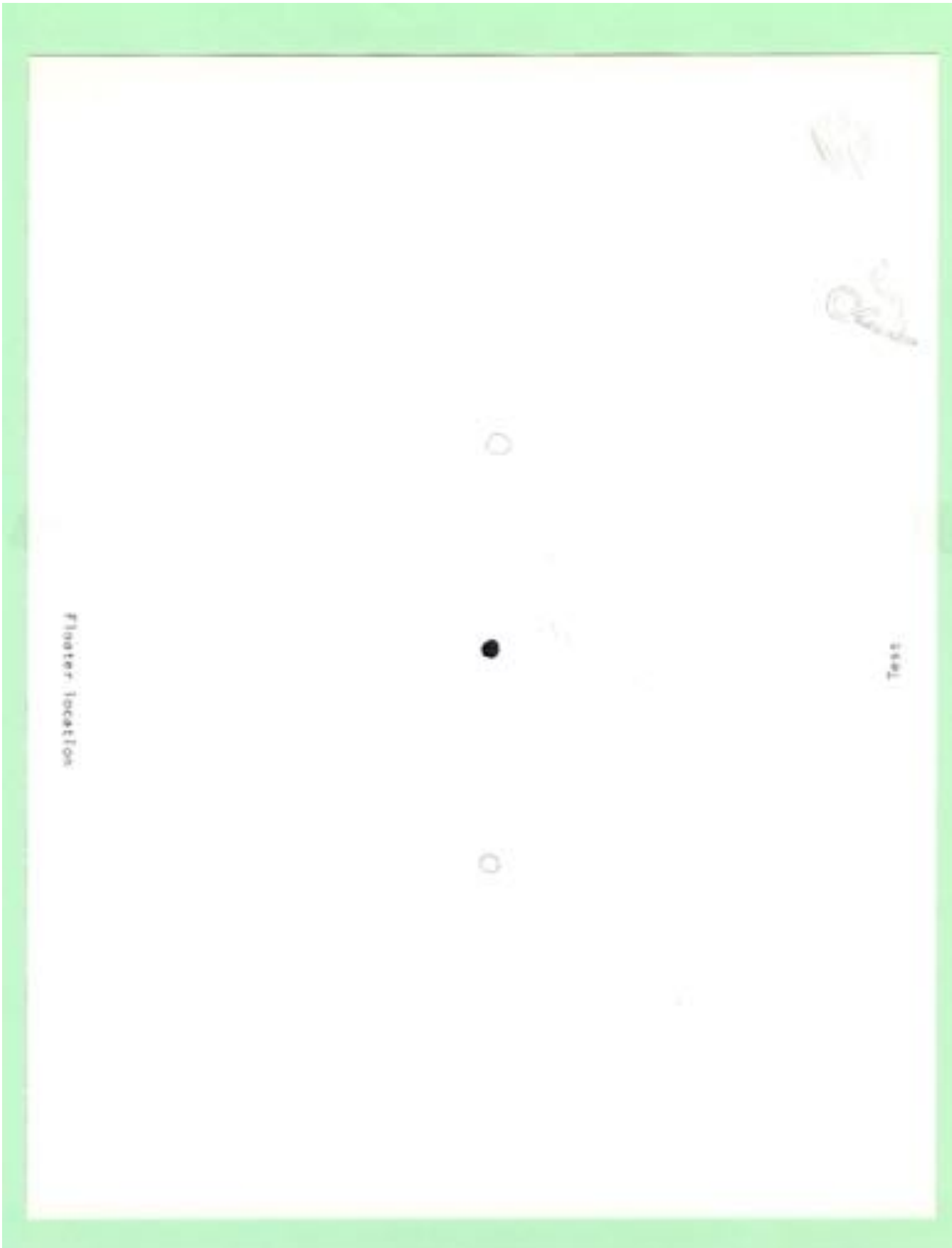
Appendix G) **Insurance codes**:

The codes involved in floater treatment are:

a new patient examination - 92004;
extended retinal examination with drawing - 92225;
photographs - 92250;
unlisted code for surgical procedure - 67299.

Appendix H) **Karickhoff Floater Finder**

(see next page)


Floater location
Test

Appendix I) **One year follow up form:**

(see next page)

313 Park Ave.
Falls Church, VA 22046
FAX (703) 536-0450

Dear Doctor:

On ______________,2003 I performed **laser treatment of symptomatic vitreous opacities** on ________________________

The patient's pre-operative examination showed:

I intend to publish this study that is being done through our hospital Institutional Review Board and with the approval of the U. S. Food and Drug Administration. To include this case, I will need **one year follow up**. Would you provide me with that follow up by mailing or FAXing this form to me?

	Right eye	Left eye
Patient's estimate of per cent reduction of floaters		
Best corrected vision	20/	20/
Tension		
Lens (presence of cataract)		
Floaters you see with the direct scope using about the +10 diopter lens. (Look behind the patient's lens and have them move their eye.)		
Any retinal laser damage?		

For your information, a detailed **analysis of our first 100 cases** showed that the procedure eliminated or greatly reduced the opacities in 92% of patients, and the rate of significant complication was zero.

Thank you for participating in this study.

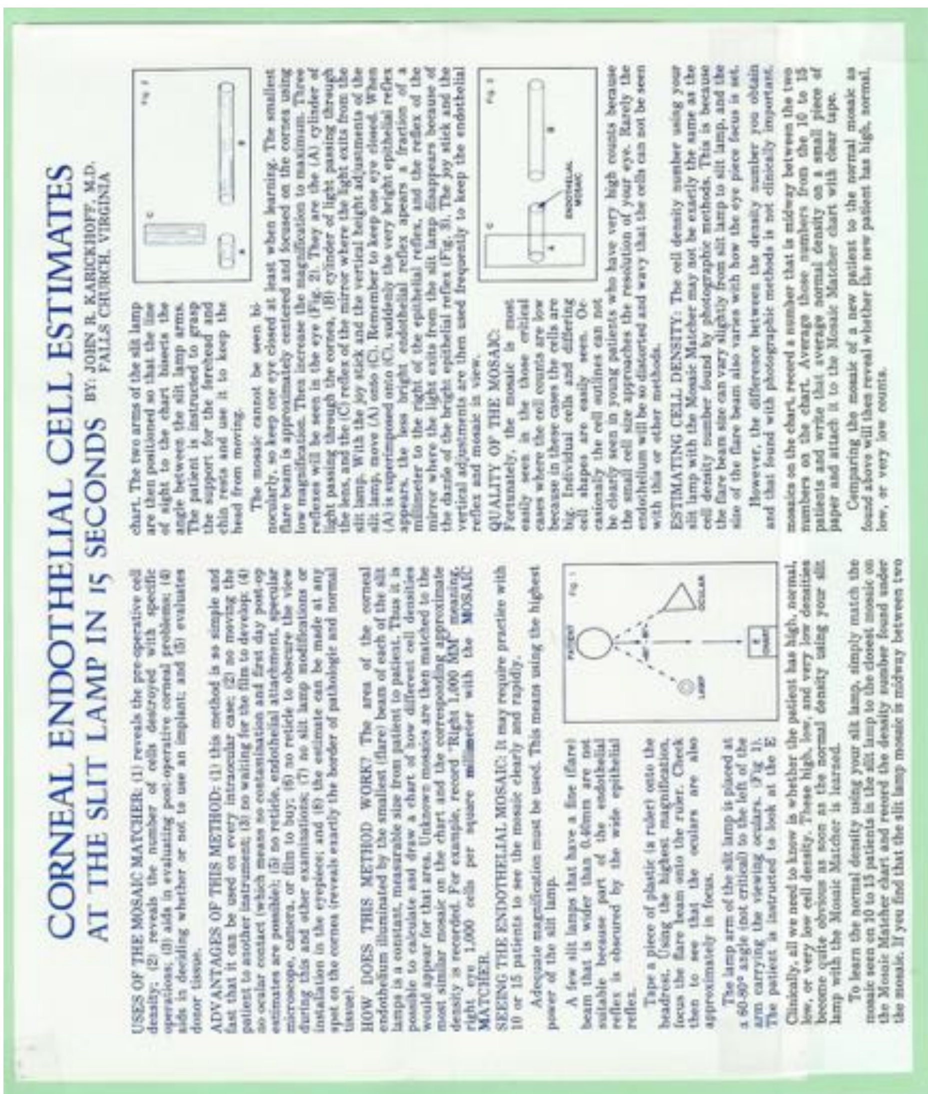
Sincerely,

John R. Karickhoff

John R. Karickhoff, M.D.

Appendix J) **Karickhoff Mosaic Matcher™**:

For performing corneal endothelial cell count estimates.
(No longer commercially available. But the instructions and needed charts are reproduced here with permission.)



CORNEAL ENDOTHELIAL CELL ESTIMATES AT THE SLIT LAMP IN 15 SECONDS

BY: JOHN R. KARICKHOFF, M.D.
FALLS CHURCH, VIRGINIA

USES OF THE MOSAIC MATCHER: (1) reveals the pre-operative cell density; (2) reveals the number of cells destroyed with specific operations; (3) aids in evaluating post-operative corneal problems; (4) aids in deciding whether or not to use an implant; and (5) evaluates donor tissue.

ADVANTAGES OF THIS METHOD: (1) this method is so simple and fast that it can be used on every intraocular case; (2) no moving the patient to another instrument; (3) no waiting for the film to develop; (4) no ocular contact (which means no contamination and first day post-op estimates are possible); (5) no reticle, endothelial attachment, specular microscope, camera, or film to buy; (6) no reticle to obscure the view during this and other examinations; (7) no slit lamp modifications or installation in the eyepiece; and (8) the estimate can be made at any spot on the cornea (reveals exactly the border of pathologic and normal tissue).

HOW DOES THIS METHOD WORK? The area of the corneal endothelium illuminated by the smallest (flare) beam of each of the slit lamps is a constant, measurable size from patient to patient. Thus it is possible to calculate and draw a chart of how different cell densities would appear for that area. Unknown mosaics are then matched to the most similar mosaic on the chart and the corresponding approximate density is recorded. For example, record "Right 1,000 MM" meaning, right eye 1,000 cells per square millimeter with the MOSAIC MATCHER.

SEEING THE ENDOTHELIAL MOSAIC: It may require practice with 10 or 15 patients to see the mosaic clearly and rapidly.

Adequate magnification must be used. This means using the highest power of the slit lamp.

A few slit lamps that have a fine (flare) beam that is wider than 0.40mm are not suitable because part of the endothelial reflex is obscured by the wide epithelial reflex.

Tape a piece of plastic (a ruler) onto the headrest. Using the highest magnification, focus the flare beam onto the ruler. Check then to see that the oculars are also approximately in focus.

The lamp arm of the slit lamp is placed at a 60-80° angle (not critical) to the left of the arm carrying the viewing oculars. (Fig 1). The patient is instructed to look at the E chart. The two arms of the slit lamp are then positioned so that the line of sight to the chart bisects the angle between the slit lamp arms. The patient is instructed to grasp the support for the forehead and chin rests and use it to keep the head from moving.

Fig. 1

The mosaic cannot be seen binocularly, so keep one eye closed at least when learning. The smallest flare beam is approximately centered and focused on the cornea using low magnification. Then increase the magnification to maximum. Three reflexes will be seen in the eye (Fig. 2). They are the (A) cylinder of light passing through the cornea, (B) cylinder of light passing through the lens, and the (C) reflex of the mirror where the light exits from the slit lamp. With the joy stick and the vertical height adjustments of the slit lamp, move (A) onto (C). Remember to keep one eye closed. When (A) is superimposed onto (C), suddenly the very bright epithelial reflex appears, the less bright endothelial reflex apears a fraction of a millimeter to the right of the epithelial reflex, and the reflex of the mirror where the light exits from the slit lamp disappears because of the dazzle of the bright epithelial reflex (Fig. 3). The joy stick and the vertical adjustments are then used frequently to keep the endothelial reflex and mosaic in view.

Fig. 2

QUALITY OF THE MOSAIC: Fortunately, the mosaic is most easily seen in the those critical cases where the cell counts are low because in these cases the cells are big. Individual cells and differing cell shapes are easily seen. Occasionally the cell outlines can not be clearly seen in young patients who have very high counts because the small cell size approaches the resolution of your eye. Rarely the endothelium will be so distorted and wavy that the cells can not be seen with this or other methods.

Fig. 3

ESTIMATING CELL DENSITY: The cell density number using your slit lamp with the Mosaic Matcher may not be exactly the same as the cell density number found by photographic methods. This is because the flare beam size can vary slightly from slit lamp to slit lamp, and the size of the flare beam also varies with how the eye piece focus is set.

However, the difference between the density number you obtain and that found with photographic methods is not clinically important.

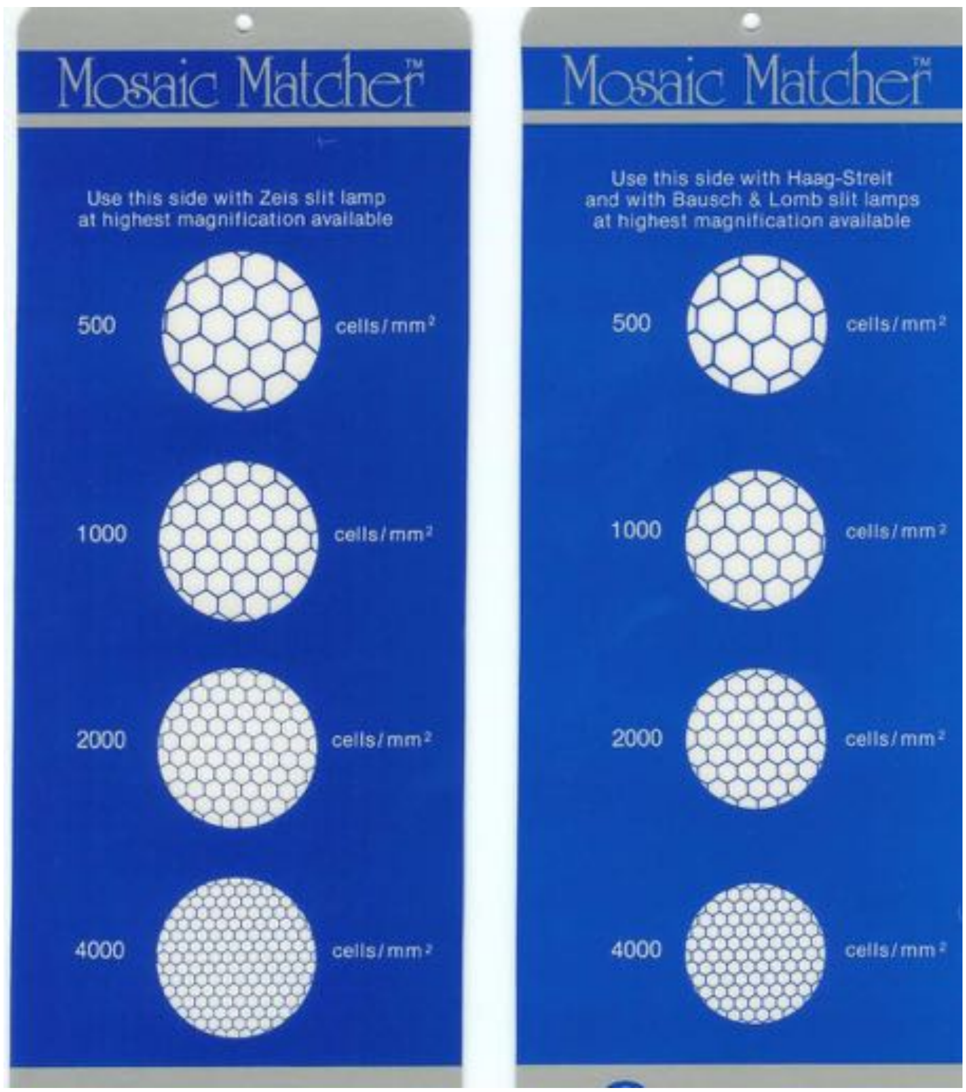
Clinically, all we need to know is whether the patient has high, normal, low, or very low cell density. These high, low, and very low densities become quite obvious as soon as the normal density using your slit lamp with the Mosaic Matcher is learned.

To learn the normal density using your slit lamp, simply match the mosaic seen on 10 to 15 patients in the slit lamp to the closest mosaic on the Mosaic Matcher chart and record the density number found under the mosaic. If you find that the slit lamp mosaic is midway between two mosaics on the chart, record a number that is midway between the two numbers on the chart. Average those numbers from the 10 to 15 patients and write that average normal density on a small piece of paper and attach it to the Mosaic Matcher chart with clear tape.

Comparing the mosaic of a new patient to the normal mosaic as found above will then reveal whether the new patient has high, normal, low, or very low counts.

Mosaic Matcher charts for slit lamps:

Zeiss | Haag-Streit (and copies)



Appendix K) **Karickhoff Flying Corpuscle Viewer™**

Flying Corpuscle Viewer™

This is the best test by far for evaluating macular function when the macula can not be seen, such as in the presence of a cataract or corneal opacities. It is a modification of the blue field entoptic test using the slit lamp as the light source rather than a special projector. This is the only test where the test object to be seen (the patient's own white blood cells) are within a millimeter of the macula. This is the only pure macular test because here floaters, cataract or corneal clouding are not between the testing target and the macula to adversely affect the test. The doctor performs the blue field entoptic test by shining the slit lamp through the filter into the eye being tested while the filter holder occludes the other eye. (This device is no longer commercially available since the original manufacturer is no longer in business. But the equipment essentials are the round filter and your slit lamp. The patient occludes the other eye. The filter is a 430 nm. narrow bandpass interference filter that can be obtained from Edmund Industrial Optics, order G43-108, for $83.50, phone 1(800) 363-1992. Below are the instruction in my original article on the test [used with permission from Cataract Surgery Now, a Surgidev publication, p. 14-15, October 1983].)

A NEW FLYING CORPUSCLE TEST IN CATARACT PATIENTS (Pre- and Post-operative use)

By John R. Karickhoff, M.D.
Falls Church, Virginia

SUMMARY

I have developed a *simplified form* of the flying corpuscle (blue field entopic) test that *uses any slit lamp* as the *source of light*. We have evaluated the device and found it most helpful in deciding whether to perform surgery since the flying corpuscle test is the only test that *accurately* (97% accurate) *reveals macular potential* when the *cataract is advanced* enough to prevent seeing the macula. Early data also shows the test to be 97% *accurate* in predicting whether poor post-operative vision will be temporary or permanent.

THE FLYING CORPUSCLE TEST & EQUIPMENT

The flying corpuscle phenomenon was first described in 1763 by Sauvages[1] and has since been found to be an accurate indicator of macular potential in cataract patients by Sinclair, et al[2]. The test, however, has not had wide use because of lack of equipment or the high cost of equipment. Much of the cost of equipment was in buying a light projector for the test to shine a beam into the eye. However, all ophthalmologists already own a device designed specifically to *shine a beam* of light *into* the human eye—a slit lamp. Therefore, we *adapted* the flying corpuscle test *for* use with the *slit lamp*. None of the inexpensive camera-filters or absorption-filters would elicit the flying corpuscle phenomenon. The slit lamp adaptation *requires* a large diameter, multilayered, dielectric interference *filter* of the proper frequency and half-band width so that the patient will have *maximum viewing* of the flying corpuscles *but not be dazzled* by the slit lamp bulb. The slit lamp adaptation in its final form consists of such a *filter*, an *occluder* for the other eye, and a *handle*. (Figure 1)

The advantages of this device over other forms of flying corpuscle tests are: 1.) *low cost*; 2.) it is the handiest and *fastest* form for the ophthalmologist because it is performed at the slit lamp; *and, 3.) no shelf space* is required.

TESTING PATIENTS

The Flying Corpuscle Viewer™ is held about one inch in front of the eye. Any slit lamp is brought to one inch from the device. The beam is shown through the filter and into the patient's eye. There is no focusing or critical alignment. The perifoveal red blood cells absorb the *pure blue light* coming into the eye from the filter. When a white blood cell courses through the perifoveal capillary net, *the blue light passes through the white blood cell and strikes the photoreceptors* immediately behind. This appears to the patient as a "*moving cell, tiny tadpoles, etc.*" When patients see their flying corpuscles, it means they have an adequate perifoveal blood supply and their *photoreceptors are sensitive enough* to see something the *size of a white blood cell*.

SENSITIVITY OF THE TEST

If patients are losing vision due to a diffuse, dry senile macular degeneration, they will usually lose the ability to see their flying corpuscles *at* about the 20/50 level. However, if patients are losing vision due to a cataract, they will *not lose* the ability to see their flying corpuscles even when the vision reaches the *count fingers level*.

PRE-OPERATIVE USE

We evaluated the device by testing 70 consecutive cataract patients prior to surgery to see if the test could predict which patients would see better, or worse than 20/40 after the cataract was removed. That is, *if* the patients *saw* the flying corpuscles, this was counted as a *prediction of 20/40 or better* post-operative vision. If they *did not see* the flying corpuscles, it was a prediction of worse than 20/40 post-operative vision. We found after surgery that the test *predicted correctly* in 69 of the 70 patients. There were five patients of the 70 that had permanent poor vision after cataract removal. Significantly, the test identified all five of these patients pre-operatively in spite of the fact that the macula could not be seen because of the advanced cataracts.

Our most important finding was that the test did retain its accuracy even in the *dense cataracts* where other tests fail and the ophthalmoscope is of no use. Of the 70 patients, there were 37 with dense cataracts in the 20/200 to hand motion vision range. In several of these the optic nerve could not be seen. The test was accurate in 36 of these 37 patients in revealing whether the post-operative vision would be better or worse than 20 / 40.

POST-OPERATIVE USE

Testing on a limited number of patients indicates that the test is accurate in predicting whether poor vision in the post-operative period will be temporary or permanent. The test can theoretically separate temporary from permanent visual loss because if the decreased vision is from corneal or retinal edema or vitreous haze, the patients will still see flying corpuscles and good vision can return in these conditions with time or treatment. However, if the decreased vision is due to damage to the perifoveal capillary network or the photoreceptors, the patients will not see their flying corpuscles, and the poor vision is permanent.

The above theory was tested in our series of 70 patients. There were 11 patients of the 70 with vision of less than 20 / 100 in the early post-operative period. The test was 100% accurate in predicting which of the 11 patients would regain foveal vision.

The test predicated that the poor vision was temporary in these patients, i.e., they saw flying corpuscles; three patients with marked corneal edema from enzyme glaucoma, two patients with cystiod macular edema, and in one with marked vitreous haze from toxic implant syndrome. All of these patients eventually recovered 20 / 20 vision.

The test predicted the poor vision was permanent in, i.e., they did not see flying corpuscles: two patients with macular degeneration, one patient with central vein occlusion, one patient with a normal appearing retina but with poor vision of unknown cause, and one patient with cystoid macular edema formerly treated with laser photocoagulation. None of these patients ever gained vision better than 20 / 100.

FLYING CORPUSCLE VERSUS OTHER TESTS

The object of a macular function test is to test the macular potential without testing the visual decrease due to the presence of the cataract.

FLYING CORPUSCLE TEST: The flying corpuscle test is the only test that tests for macular function without also testing for the amount of cataract present. It is able to do this because this is the only test in which the patient does not look through his cataract to see the vision testing object (the perifoveal white blood cells). The blue light coming into the eye in this test can be distorted, reflected, and absorbed by the cataract without affecting the test. There is no pattern or chart being carried on this beam of light. As long as some light reaches the back of the eye to light up the white blood cells, the test remains accurate. Thus the test can be 97% accurate (our study) even in cataracts in the 20 / 200 to hand motion range.

LASER INTERFERENCE FRINGE TEST: In this test a split laser pattern is projected through the cataract and onto the macula. The test is expensive and time consuming, but it is accurate if the cataract is at an early stage and the macula can be observed. However if the cataract is in the 20/200 or worse stage and the red reflex is poor, the laser pattern is severely distorted by passing through the cataract and the results are erratic[3]. Since the patient must look through the cataract to see the laser pattern, this test is evaluating both macular function and the amount of cataract if the cataract is prominent.

GUYTON POTENTIAL ACUITY METER: In this test a Snellen chart is projected through a clear area of the cataract and onto the macula. The test is expensive, can be time consuming and requires attaching the device to the slit lamp when in use. Again, the test is accurate if the cataract is in the early stage. However, if the cataract is prominent, there usually is no clear area through which the chart can be projected. Dr. Guyton found that in the 20 / 300 or worse range of cataracts, his test was 58% accurate[4]. Again, if the cataract is prominent, this test is evaluating both macular function and the amount of cataract.

CONCLUSION

From the data and experience above, we have concluded that the *flying corpuscle test* is the *only test* that *accurately reveals macular potential* when the *macula* can *not be seen.*

REFERENCES

1. Sauvages: "Acta Acad Caes Leop Carol" I:135, 1763.

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3. Goldmann H., Chrenkova A., Cornaro S.,: "Retinal Visual Acuity in Cataractous Eyes: determination with interference fringes." *Archives of Ophthalmology* 98:1778-1781, 1980.

4. Guyton D.,: "New Instrument Offers Prediction of Post-operative Vision in Mild Cataract." *Ophthalmology Times* page 1, July 1, 1982.

Appendix L) **Karickhoff Simplified Outflow Facility Testing**
(see Chapter 21, Avoiding Complications, Preventing elevated pressure)

Current thinking on treatment of glaucoma emphasizes the importance of fluctuation of pressure, that is, how high does the pressure fluctuate during the day and what is the duration of the high pressure. High pressure of sufficient duration causes optic nerve damage. The fluctuation can be learned from serial pressure readings throughout the day, but it can also be predicted by learning how open is the trabeculum to the exit of intraocular fluid (that is, learning the Coefficient of Outflow).

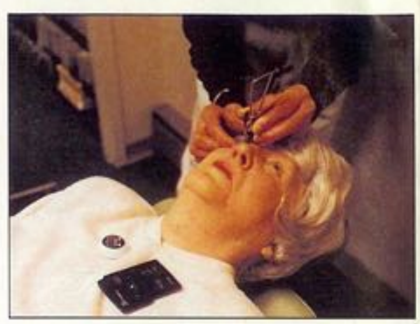
Past methods of measuring Facility of Outflow has been basically abandoned because the test was too long and too inaccurate. My method of measuring Facility of Outflow is included here because I have simplified classic tonography so that it can be done as a brief, practical office test. This simplified method measures coefficient of outflow facility ("C" value) much more rapidly, cheaply, and accurately than using a tonographic machine. To simplify tonography, I read the literature and performed Facility of Outflow testing with the classic machine.

In S.O.F.T. (Simplified Outflow Facility Testing), the doctor places the office Schiotz tonometer on the eye; directly observes the needle deflection and then speaks that reading into a smart phone voice recorder; after four minutes he takes the tonometer off the eye and writes down the closing scale reading; he then uses those two readings to find the "C" value in the charts reproduced here.

THE NEED

Each of our usual glaucoma tests has its inadequacies. Even our

Machine with electronic tonometer, standardization block and foot pedal for classic tonography.



Performing simplified tonography using the Schiotz tonometer, a digital voice recorder, and timer.

best test, applanation tension, varies from day to day, varies within the same day, and is usually sampled for only one second out of the 15,724,800 seconds of a six months treatment period. Visual field testing and viewing the optic nerve mainly serves to document past damage.

Tonography is a much longer sample than applanation testing and is, therefore, less subject to changes of the moment. Tonography specifically reveals the function of the trabeculum which is the disease site in almost all cases of glaucoma. Tonography is preeminently revealing when looking for the mechanism of increased pressured, or when elevated pressure is temporarily masked by decreased aqueous production or the mechanism of drug action is sought.

However**,** tonography's greatest value comes when the result is significantly higher or lower than you would have predicted from the previous glaucoma evaluation. When its result is surprising, the test provides a new insight into the case.

THE PRESENT PROBLEM

In spite of this clinical need for tonography, this test has almost been abandoned as an office procedure because using a machine takes too much time, is very difficult, the machine is expensive, and the test is inaccurate.

In an attempt to simplify this valuable test and restore its usefulness I studied the literature on tonography, studied the graphs, obtained a tonographic machine, performed tonography, and talked with doctors who had used the test extensively. It soon became obvious that to simplify the test and make it much more accurate, the machine had to be eliminated. Eventually I developed a highly accurate, simple, fast, and inexpensive method of learning facility of outflow. I call my method "S.O.F.T.", meaning Simplified Outflow Facility Testing. It takes four minutes to perform the test. It utilizes only the Schiotz tonometer, a smart phone (voice recorder and timer), and the usual tonography charts.

The advantages of S.O.F.T. over the machine method are: (1) no expensive machine to buy, (2) no new technique or machine to learn or teach, (3) no set-up time, (4) no technician to hire (many can not learn the machine technique), (5) no loss of accuracy due to converting the tonometer deflection to an electronic analog, converting that to a mechanical tracing, and then estimating the deflection by viewing the tracing, (6) no loss of accuracy due to inadequate warm up, setting the voltmeter at zero, setting the stylus at zero, setting the stylus for full deflection, or electronic drift during the test (drift has been improved by the change from vacuum tubes to transistors in machines), (7) S.O.F.T. is much more reproducible than machine tonography, (8) S.O.F.T. is performed in the examining chair (the machine tests are so involved that the patient needs to be moved to a back room), and (9) the doctor can monitor the quality of S.O.F.T. throughout because he can simultaneously see both the eye for centering the tonometer and also see the deflection needle to observe the decay of pressure and the ocular pulse (with machines you can not simultaneously see both the tested eye and the tracing to monitor the test).

SIMPLIFYING TONOGRAPHY

To learn "C" value you need only the opening and closing Schiotz tension of a four minute period. So why use a machine? Because if the test is to be done by only one technician, not two, there is no way to record the opening tension when one hand of the technician is holding the tonometer and the other hand is holding the lids apart. When the tonography machine was developed, an electronic recording mechanism, the galvanometer, was the only means available to record that opening tension. However, with the invention of the small digital voice recorder and timer (like in a smart phone), the opening pressure is recorded and the procedure timed while both hands perform the test.

So in S.O.F.T. the electronic tonometer and transducer of the machines is replaced by the office Schiotz tonometer.

In S.O.F.T. the galvanometer (the EKG-type moving tracing) of the machines is eliminated without any loss of function. The galvanometer had five functions. (1) It recorded the opening needle deflection. This is the only essential function and that function is replaced by speaking that beginning deflection into a miniature digital voice recorder. (2) The galvanometer also recorded the closing deflection, but that is an unnecessary function because at the end of the test the hands are free to write down that number immediately. (3) The vertical marks on the tracing paper served to define a four minute duration of the test, but a separate timer had to be used with the machine because the paper marks in the machine could not be seen while watching the tonometer on the eye. In S.O.F.T. a inexpensive separate timer is also used. (4) The galvanometer also gave an indication of the patient's ocular pulse pressure, and the slope of the curve. In S.O.F.T. these factors are monitored visually by watching the deflection needle. These factors can not be monitored during the test with machines. (5) The graph from the galvanometer was also used by the doctor to estimate quality if the test was performed by a technician. However, in S.O.F.T. that check is not needed if the tester is certain that the opening and final readings are of a steady state and the pressure decay is smooth.

PERFORMING THE TEST

Take the pressure by applanation. Choose the Schiotz weight that will give about a 5-6 starting needle reading. For example, if the applanation pressure is about 15, use the 5.5 gram weight. If about 20, use the 7.5 gram weight. If about 30, use the 10 gram weight. Start the voice recorder of the smart phone, and then start its timer set for 4 minutes and place it on the patient's chest. Put the tonometer on the eye and have the patient watch the target you have previously placed on the ceiling. The reading stabilizes in a few seconds. Usually by now about 15 seconds have elapsed since starting the timer. Note mentally that you took your initial reading with 15 seconds elapsed. That stabilized reading, read to the nearest 1/4th unit, is the one to speak into the recorder. If the ocular pulse is wide, like oscillating from 6 to 7, I use the mid-position, that is, 6.5. You can also voice record the ocular pulse on a 0 to +4 scale if desired.

Be certain not to press down or elevate the tonometer. During the test, watch the needle to be certain the lowering of pressure is gradual and smooth (the tonometer not stuck). Occasionally tell the patient to blink their eyes while you hold the lids of the tested eye more firmly to prevent their decentering the tonometer. If you have them blink occasionally, you do not need to put cellophane pasted down with methylcellulose over the other eye to prevent drying and the so-called consensual pressure drop of tonography when testing both eyes. The final reading is taken at 4 minutes and 15 seconds elapsed. Remove the tonometer and immediately write down the final deflection.

Retrieve the opening deflection reading from the recorder, and then erase all. There is a separate table for the 5.5, 7.5, and the 10 gram weights printed here. From the proper chart, read and record the opening Schiotz pressure. Rarely there is a major difference between the applanation and the opening Schiotz pressure, meaning the "C" value will be somewhat in error due to abnormal scleral rigidity.

Subtract the opening Schiotz needle reading from the final needle reading to get the change in deflection (delta) during the test and write that down. Using the chart for the weight you used, go down the R column until you come to your opening needle reading. Go to the right along that row until you come to the column of your delta. Where your opening needle reading and your delta intersect is your "C" value. For example, if using the 7.5 gram weight, with an opening scale reading (R) of 6.5, and with a final reading (P4) of 8.5, the change (delta R) is 2.0, and the "C" value is 0.12. These charts were developed by Dr. Jonus Friedenwald.

Although my Simplified Outflow Facility Testing measures the coefficient of outflow more accurately, faster and cheaper than the machines, S.O.F.T. should never be coded as tonography because no paper tracing of the pressure is created and no expensive machine is involved.

Tonography tables for the 5.5, 7.5 and 10 gram weights. (Reproduced with permission from Becker and Schaffer, Diagnosis and Therapy of the Glaucomas, second ed., St. Louis, 1965, C.V. Mosby)

Initial reading		*ΔR (change in scale reading)*										
P_o	*R*	*0*	*0.50*	*1.00*	*1.50*	*2.00*	*2.50*	*3.00*	*3.50*	*4.00*	*4.50*	*5.00*
		5.5 gram weight										
21	4.00	0	0.04	0.08	0.13	0.18	0.24	0.30	0.37	0.45	0.54	0.63
20	4.25	0	0.04	0.08	0.13	0.18	0.24	0.30	0.36	0.43	0.52	0.60
19	4.50	0	0.04	0.08	0.12	0.17	0.23	0.29	0.35	0.42	0.50	0.58
18	4.75	0	0.04	0.08	0.12	0.17	0.23	0.28	0.34	0.41	0.48	0.56
17	5.00	0	0.04	0.08	0.12	0.17	0.22	0.27	0.33	0.40	0.47	0.54
17	5.25	0	0.04	0.08	0.12	0.17	0.22	0.27	0.33	0.39	0.46	0.53
16	5.50	0	0.04	0.08	0.12	0.16	0.21	0.26	0.32	0.38	0.45	0.52
15	5.75	0	0.04	0.08	0.12	0.16	0.21	0.26	0.32	0.38	0.44	0.50
15	6.00	0	0.03	0.07	0.11	0.15	0.20	0.25	0.31	0.37	0.43	0.49
14	6.25	0	0.03	0.07	0.11	0.15	0.20	0.25	0.31	0.37	0.43	0.49
13	6.50	0	0.03	0.07	0.11	0.15	0.20	0.25	0.30	0.36	0.42	0.48
13	6.75	0	0.03	0.07	0.11	0.15	0.20	0.24	0.30	0.36	0.41	0.47
12	7.00	0	0.03	0.07	0.11	0.15	0.20	0.24	0.29	0.35	0.40	0.46
11	7.50	0	0.03	0.07	0.11	0.15	0.19	0.24	0.29	0.34	0.39	0.45
10	8.00	0	0.03	0.07	0.11	0.15	0.19	0.24	0.29	0.34	0.39	0.45
9	8.50	0	0.03	0.07	0.11	0.15	0.19	0.23	0.28	0.33	0.39	0.44
9	9.00	0	0.03	0.07	0.11	0.15	0.19	0.23	0.28	0.33	0.38	0.44

Table 29-1. Simplified tonography table for eyes of average ocular rigidity—cont'd

Initial reading		*ΔR (change in scale reading)*										
P_o	*R*	*0*	*0.50*	*1.00*	*1.50*	*2.00*	*2.50*	*3.00*	*3.50*	*4.00*	*4.50*	*5.00*
					7.5 gram weight							
30	4.00	0	0.03	0.06	0.10	0.15	0.20	0.25	0.32	0.39	0.46	0.55
29	4.25	0	0.03	0.06	0.10	0.15	0.19	0.25	0.30	0.37	0.44	0.52
28	4.50	0	0.03	0.06	0.10	0.14	0.18	0.24	0.29	0.35	0.42	0.50
27	4.75	0	0.03	0.06	0.10	0.14	0.18	0.23	0.28	0.34	0.40	0.47
26	5.00	0	0.03	0.06	0.10	0.13	0.17	0.22	0.27	0.33	0.39	0.45
25	5.25	0	0.03	0.06	0.10	0.13	0.17	0.22	0.27	0.32	0.38	0.43
24	5.50	0	0.03	0.06	0.09	0.13	0.16	0.21	0.26	0.31	0.37	0.42
23	5.75	0	0.03	0.06	0.09	0.13	0.16	0.21	0.26	0.31	0.36	0.41
22	6.00	0	0.03	0.06	0.09	0.12	0.16	0.20	0.25	0.30	0.35	0.40
21	6.25	0	0.03	0.06	0.09	0.12	0.16	0.20	0.25	0.29	0.34	0.39
20	6.50	0	0.03	0.05	0.09	0.12	0.15	0.19	0.24	0.28	0.33	0.38
19	6.75	0	0.03	0.05	0.09	0.12	0.15	0.19	0.24	0.28	0.33	0.38
18	7.00	0	0.03	0.05	0.08	0.12	0.15	0.19	0.23	0.27	0.32	0.37
17	7.50	0	0.03	0.05	0.08	0.12	0.15	0.19	0.23	0.27	0.31	0.36
16	8.00	0	0.03	0.05	0.08	0.11	0.15	0.18	0.22	0.26	0.30	0.35
14	8.50	0	0.03	0.05	0.08	0.11	0.15	0.18	0.22	0.26	0.30	0.35
13	9.00	0	0.03	0.05	0.08	0.11	0.15	0.18	0.22	0.25	0.29	0.34
12	9.50	0	0.03	0.05	0.08	0.11	0.15	0.18	0.22	0.25	0.29	0.34
					10.0 gram weight							
43	4.00	0	0.02	0.05	0.08	0.12	0.17	0.22	0.28	0.35	0.43	0.52
42	4.25	0	0.02	0.05	0.08	0.12	0.17	0.21	0.26	0.33	0.40	0.48
40	4.50	0	0.02	0.05	0.07	0.11	0.16	0.20	0.25	0.31	0.38	0.44
38	4.75	0	0.02	0.05	0.07	0.11	0.16	0.20	0.24	0.29	0.36	0.42
37	5.00	0	0.02	0.05	0.07	0.10	0.15	0.19	0.23	0.28	0.34	0.40
36	5.25	0	0.02	0.05	0.07	0.10	0.15	0.19	0.23	0.27	0.32	0.38
34	5.50	0	0.02	0.05	0.07	0.10	0.14	0.18	0.22	0.26	0.31	0.36
33	5.75	0	0.02	0.05	0.07	0.10	0.14	0.18	0.22	0.25	0.30	0.34
32	6.00	0	0.02	0.04	0.07	0.10	0.13	0.17	0.21	0.24	0.29	0.33
31	6.25	0	0.02	0.04	0.07	0.10	0.13	0.17	0.21	0.24	0.28	0.32
29	6.50	0	0.02	0.04	0.07	0.10	0.13	0.16	0.20	0.23	0.27	0.31
28	6.75	0	0.02	0.04	0.07	0.10	0.13	0.16	0.20	0.23	0.27	0.31
27	7.00	0	0.02	0.04	0.07	0.09	0.12	0.15	0.19	0.22	0.26	0.30
26	7.25	0	0.02	0.04	0.07	0.09	0.12	0.15	0.19	0.22	0.26	0.30
25	7.50	0	0.02	0.04	0.07	0.09	0.12	0.15	0.18	0.21	0.25	0.29
24	7.75	0	0.02	0.04	0.07	0.09	0.12	0.15	0.18	0.21	0.25	0.29
23	8.00	0	0.02	0.04	0.06	0.09	0.12	0.14	0.18	0.21	0.24	0.28
21	8.50	0	0.02	0.04	0.06	0.09	0.11	0.14	0.18	0.20	0.23	0.27
20	9.00	0	0.02	0.04	0.06	0.09	0.11	0.14	0.17	0.20	0.23	0.26
18	9.50	0	0.02	0.04	0.06	0.09	0.11	0.14	0.17	0.20	0.23	0.26
16	10.00	0	0.02	0.04	0.06	0.09	0.11	0.14	0.17	0.19	0.22	0.26
14	11.00	0	0.02	0.04	0.06	0.09	0.11	0.14	0.17	0.19	0.22	0.25

Karickhoff, JR: Simplified Outflow Facility Testing Is Quick, Practical. Ocular Surgery News, p. 35-38, Sept. 15, 1997

Appendix M. **Karickhoff Vitreous Treatment Lenses**

Appendix N) **Designing the ideal laser for floater treatment**

At the present time there is no ideal laser for treating floaters. None has been designed for this purpose. Here are what I consider to be the main principles for designing the ideal laser for treatment of floaters:

- Use a pulsed YAG laser. It achieves optical breakdown which is needed to convert floaters to a gas and it can fragment floaters. Furthermore it is familiar to all ophthalmologists, and it is small.

- Use Q-switching of the laser as apposed to mode-locking. Either type will disrupt floaters, but the Q-switching produces a larger shock wave which is valuable for floater disruption. And maintenance of Q-switched lasers is very low. A complete discussion of the advantages and disadvantages of Q-switching and mode-locking is given on pages 55, 56 and 148.

- Few doctors would buy a separate laser for floater obliteration. Therefore, the floater laser needs to also be an excellent laser for posterior capsulotomies and iridotomies.

- The working distance from the slit lamp mirror to the point focus of the laser should be not less than 7.5 cm. This gives room for the doctor to hold a surgical contact lens on the patient's eye and the slit lamp mirror housing not to hit the patient's nose when it is swung to the side opposite from the contact lens on the eye being treated.

- The laser should have a converging beam to protect the retina. 16 degrees of convergence is the standard angle for ophthalmic YAG lasers designed for posterior capsulotomies, but to obtain a working distance of 7.5 cm or more, less convergence is desired. 14 or 12 degrees of convergence is ideal.

- The laser should have the multiburst mode. The bursts should come so fast that you can not hear the separate shots and the floater will not have time to move before it is hit with all shots in the burst.

- The laser should have joy stick firing. This eliminates interference from the patient's legs when foot firing is used.

- The illumination beam should be nearly coaxial with the treatment beam. The closer these beams are together the easier it is to see floaters in the mid and posterior vitreous. But when these beams are perfectly coaxial, the reflexes from the contact lens, the slit lamp bulb and mirror, and the patient's cornea and lens partially block the view of the floater. I calculated the angle between the illumination and the treatment beam on my laser to be 6.5 degrees. This is quite satisfactory. (Deciding this ideal angle needs more investigation.)

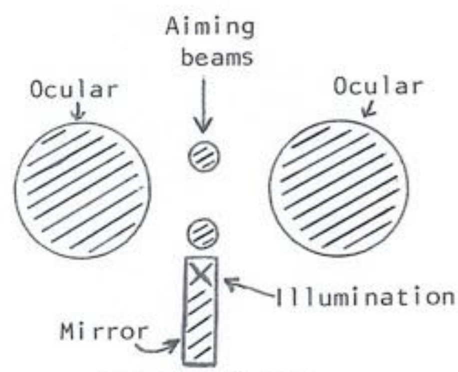
This angle between the illumination and the treatment beam can be made small in three ways:

1) The working distance from the illumination mirror to the focal point of the laser can be made longer. Extending the working distance from 8 to 9 cm., for example, decreases the angle about 1 degree. However, extending the working distance has its limitations if the standard convergence of the laser beam of 16 degrees is used.

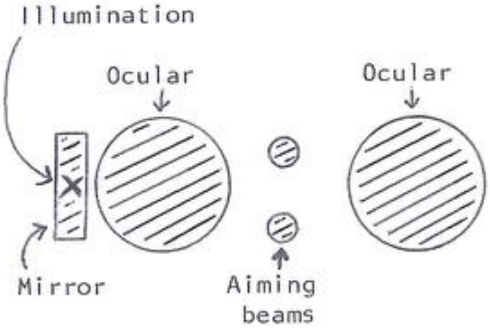
2) Another way to reduce the angle between the illumination beam and the laser beam is with a centrally placed beam splitter. This can reduce the angle to zero. This may not be ideal for floater work because the reflexes are then in line with the floater. In my experience doing capsulotomies with a centrally placed beam splitter (Coherent Epic laser), there is too much red reflex and focusing on the capsule is somewhat uncertain. Therefore, if a beam splitter is used, it needs to be mounted on the slit lamp illumination stack so that it can be swung to the outside of one of the oculars when capsulotomies are performed. This will eliminate the strong red reflex and undesired reflexes.

3) The illumination angle can also be reduced using a properly placed mirror. Here are what I consider the principles when using a mirror to get a small beam separation angle:

a) The mirror should be placed in the center position between the oculars with the top of the mirror as high as possible without cutting off some of the inferior aiming beam (see Central Mirror drawing below). This provides the same visibility of the floater from each of the doctor's eyes. In



this position the retina directly behind the floater is also illuminated. This is invaluable because it allows the doctor to know how close he is to the retina. The alternate place to locate the mirror is on the same horizontal plane as the oculars and lateral to one of them (see Side Mirror drawing below). But here the angle between the illuminating and laser beam is wider than putting the mirror in the central, inferior location, the doctor does not see the retina directly behind the floater well, and the ocular further from the illumination mirror provides a restricted view of the floater.

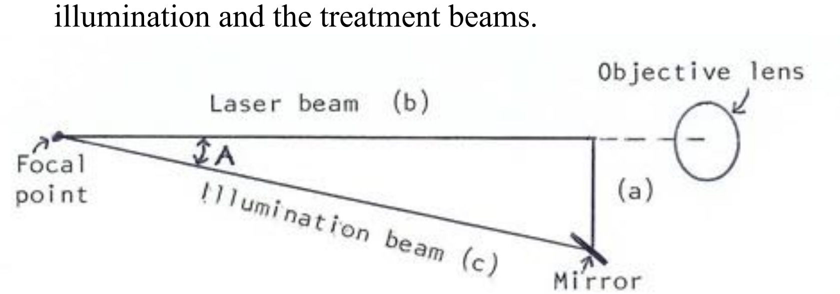


b) The illumination should exit from the very top of the mirror, not 1 or 2 mm below the top. If some of the illumination goes past the forward edge of the mirror and hits the ceiling of the room, that is fine and will guarantee that the illumination is exiting from the top of the mirror.

c) The thickness of the mirror should not be allowed to enlarge the angle between the two beams. For example, if the illumination source is below, comes up and is reflected off a mirror that is also below the laser beam, the thickness of the mirror will add to the separation of the beams. If, however, the source of the illumination is below, and the illumination passes across the laser beam to a mirror above the laser beam, the mirror can be of any thickness without enlarging the angle between the illuminating and the laser beams.

d) Using a mirror in a floater laser also works well for capsulotomies. For capsulotomies the mirror is swung to the side. This gives minimal reflexes from the illumination and reduces the red reflex.

I use trigonometry to measure the angle between the laser and illuminating beams. Measure with a millimeter ruler the distance from the center of the illumination beam where it comes out of the slit lamp mirror over or up to where it intersects perpendicularly with a line drawn from the point focus of the laser beam to the center of the objective lens of the laser (line {a} in drawing). Take that number and divide it by the distance in millimeters from the point focus of the laser in air to where the two lines above meet as a perpendicular (line {b} in drawing). Take the resultant number to the trigonometry tables under "tangent." When you find the number you derived above, go across the chart and you learn the size of the angle in degrees between the illumination and the treatment beams.



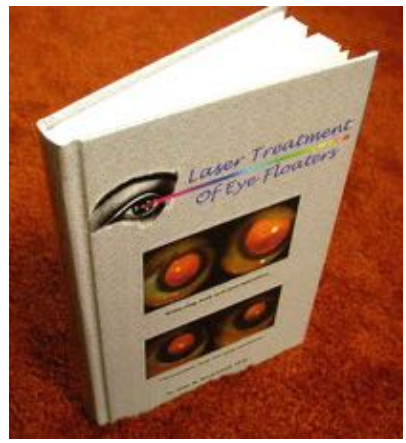
Example: Tangent of angle A=*a* divided by *b*; or, for example, 9.8/ 62, or 0.1584. From the trigonometry tables, that equals a 9 degree angle.

Appendix O) **Dr. Karickhoff's contributions to laser treatment of floaters**

- Wrote the **only book** on this procedure (<u>Laser Treatment of Eye Floaters</u>).

- Reported hundreds of **original observations and techniques** in this book.

- Wrote the **application to the United States Food and Drug Administration** that resulted in their **approval** for the first time **of YAG lasers** for this surgery without an Investigational Device Exemption from them.



Our Book.

- Wrote the **application to the United States Food and Drug Administration** that resulted in their approval of my study of Laser Treatment of Vitreous Opacities as a **Non-significant Risk** Device Study.

- Designed the Karickhoff **Four Mirror Contact Lens** used for floater evaluation.

- Designed the Karickhoff **21 mm Vitreous Lens** used for treating floaters in the posterior vitreous.

- Designed the Karickhoff **Off-Axis Vitreous Lens** used for treating floaters peripheral to the central visual axis.

- Designed the Karickhoff **Floater Finder**.

- Designed and built the first **shot counter** for the Laserex LQP 4106 laser.

- Developed the Karickhoff **Patient Assisted Method** of finding floaters.

- Developed the Karickhoff **Method of Demonstrating the Floater** to the patient.

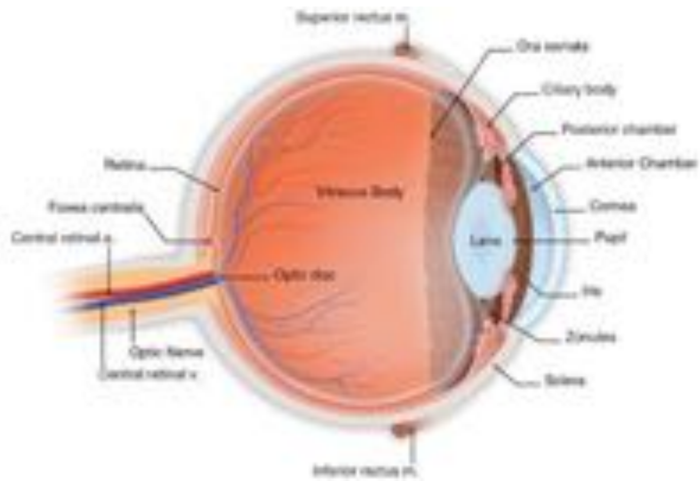
- Developed the Karickhoff **Severity of Floater Symptoms Formula**.

- Performed the **only study** on Laser Treatment of Eye Floaters that was set up under the United States **Food and Drug Administration guidelines** and **supervised by a hospital Institutional Review Board**.

- **Wrote** and supplied the graphics for an **educational web site** for Laser Treatment of Eye Floaters (www.eyefloaters.com).

Appendix P) **Dr. Karickhoff's contributions to ophthalmology**

Dr. Karickhoff's unique career goal has been to produce through clinical research an innovation or significant contribution related to each of the 14 main anatomical structures of the eyeball. The most difficult task was producing an innovation or contribution related to the zonules, the sclera, and the vitreous. Traditionally almost no research, published papers, or innovations are related to these structures. His most recent work on vitreous floaters has completed his unique 30 year goal.



©aao

(All devices, instruments, and concepts were given to the medical profession by Dr. Karickhoff with the exceptions of the Karickhoff Keratoscope (U.S. Patent) and the Karickhoff Mosaic Matcher. Only his instruments and medical devices sold internationally were listed here as an innovation or contribution.)

Dr. Karickhoff's innovations and significant contributions

for each of the 14 major eye structures.

1. Eyelids:
New treatment for oil gland deficiency (pg. 219)

2. Cornea:
New Schirmer test for dry eyes (pg. 219)
Mosaic Matcher for counting endothelial cells (pg. 215)
Two direction incision for radial keratotomy (pg. 218)
Karickhoff Keratoscope (U.S.Patent) (pg. 214)
Corneal oil layer tester (pg. 226)
Klein keratoscope modification (pg. 225)

3. Anterior Chamber Angle:
Anterior Chamber Caliper (U.S. Patent) (pg. 215)

4. Trabecular meshwork:
Simplified tonography (pg. 226)

5. Lens (cataract):
Study of Elimination of Glasses after Cataract Surgery (pg. 218)
Study of Superiority of Flexible Intraocular Implants (pg. 223)
Karickhoff Cataract Mirror (pg. 216)
Plus axis incision for cataract surgery (pg. 218)
Snowplow capsulotomy tool (pg. 226)
Karickhoff Irrigation and Aspiration Double Cannula (pg. 225)
Karickhoff Irrigation/Aspiration Double Cannula for Phaco (pg. 225)
Karickhoff Implant Positioner, Angle Assessor, and Implant Ruler (pg. 223)
Modification of the Tennant Ball (pg. 217)
Demonstration of the cataract to the patient (pg. 218)
Brightness Acuity Tester modification (pg. 215)

6. Zonules:
Concept of reverse pupillary block causing zonular rubbing(pg. 218)

7. Iris:
Concept of using transillumination to perform iridotomy (pg. 219)
Treatment of pigmentary glaucoma with iridotomy (pg. 219)

8. Ciliary body:
Simplified tonography (pg. 216)

9. Retina:
Karickhoff Laser Lens for pan retinal photocoagulation (pg. 215)

10. Macula:
Karickhoff Flying Corpuscle Viewer (pg. 215)

11. Optic nerve:
Karickhoff Flying Corpuscle Viewer (pg. 215)
Translucent occluder in visual field testing (pg. 225)

12. Choroid:
Visual field study in 600 cases of malignant melanoma (pg. 223)

13. Sclera:
Schiotz Shove Test (based on scleral rigidity) (pg. 217)

14. Vitreous:
Surgical contact lens for laser in posterior vitreous (pg. 216)
Surgical contact lens for treating off-axis floaters (pg. 216)
Principle investigator of U.S. F.D.A. supervised and hospital Institutional Review Board study of "Laser Treatment of Vitreous Floaters" (Chap. 10)
First book written on Laser Treatment of Eye Floaters

Appendix Q) **Curriculum Vitae**

CURRICULUM VITAE

John R. Karickhoff, M.D.
313 Park Avenue
Falls Church, Virginia 22046
(703) 536-2400

TABLE OF CONTENTS:

Education
Certification
Military service
Licensure
Memberships
Hospital affiliation
University affiliation
Employment
Teaching and Speaking
Inventions with United States Patents (2)
Original medical devices sold nationally (7)
Original surgical instruments (6)
Original ophthalmology concepts (11)
National advertisements authored (3)
Clinical firsts (12)
Television tapes (5)
Honors and Awards (6)
Community service
Refereed publications (19)
Non-refereed publications (22)
Patent application papers (2)
FDA application
Book

BORN:

Spencer, West Virginia. May 4, 1938

EDUCATION:

Marshall University, 1956-1960, A. B. Degree, Magna Cum Laude
Major of Zoology, Huntington, West Virginia.
Highest grade average of any student studying a science.
(Approximately 1,750 students in graduating class.)

College activities:
- President of the Student Body (senior year)
- President of the Junior Class
- President of the Sophomore Class
- President of the Freshman Class
- President of the Student Christian Association
- Varsity Debating Team
- Chairman of Campus Chapel Building Fund
- The "Outstanding Physics Student" Award
- Who's Who Among Students In American Universities and Colleges
- Sigma Alpha Epsilon social fraternity

Duke University, 1960-1964, M. D. Degree
Durham, North Carolina
Top one-fifth of class

Duke University, 1964-1965, Internship in Internal Medicine

Duke University, 1965-1968, Residency in Ophthalmology
Chief Resident, 1967-1968

CERTIFICATION:

Diplomate, American Board of Ophthalmology, October 21, 1970

Diplomate, National Board of Medical Examiners, #77822, July 1, 1965

MILITARY SERVICE:

Rank of Major in the United States Army Medical Corps:
Basic training, Fort Sam Houston, San Antonio, Texas, 1968

93rd Evacuation Hospital, DaNang, Viet Nam, 1968-1969

My primary mission was to perform emergency eye surgery on battlefield wounds. In my spare time I started a large cataract clinic in which I donated my services and performed 500 eye operations on Vietnamese civilians. I arranged for glasses to be purchased for the patients by Rotary Clubs in West Virginia. I also organized the other doctors into medical teams that went weekly to nearby hamlets. The Army awarded me the Bronze Star and the Rotary Clubs of Virginia gave me the "Best Example of Service Above Self" Award for that work.

Chief of Ophthalmology, Fort Belvoir, Virginia 1969-1970

Army Commendation Award for service there.

LICENSURE:

Commonwealth of Virginia, #20384, June 8, 1970 to present

District of Columbia, MD 25538, April 1, 1997 to present

State of North Carolina, #14229, June 18, 1964 to present

MEMBERSHIPS:

Fellow, American Academy of Ophthalmology, #000844

Member, American Intraocular Implant Society

Member, Kerato-refractive Society

Associate Member, Fairfax County Medical Society

Member, American Society of Contemporary Ophthalmology

Member, Medical Advisory Board of the Fairfax Surgical Center, Fairfax, Virginia, 1980 to 2000.

Member, Duke University Eye Center Alumni Executive Council, Durham, North Carolina, 1994 to 1997.

Member, Duke University Eye Center Advisor Board, Durham, North Carolina, 1998 to present.

Member, National Press Club, Washington, D.C. Classification of "news source for ophthalmology", 1997 to present.

HOSPITAL AFFILIATION:

Fairfax Hospital. 3300 Gallows Road, Falls Church, VA 22042
Active staff, 1969 to present.

Fairfax Surgical Center. 10730 Main Street, Fairfax. VA 22030
Active staff, 1982 to present.
Medical Advisory Board for Ophthalmology, 1987 to present.

UNIVERSITY AFFILIATION:

At the Department of Ophthalmology, Georgetown University, Washington, D.C.:

Clinical Instructor 1969-1979.
Clinical Assistant Professor 1979-1992.
Clinical Associate Professor 1992-present.

Activities at Georgetown included serving as the Attending Physician to the Resident's Outpatient Clinic every Tuesday afternoon from 1969-1976. Reorganized, obtained equipment, and headed the Low Vision Clinic, 1973-1976. Was the Attending Surgeons for the Residents in the operating room for cataract surgery for seven years.
Held Journal Club. Gave numerous lectures to medical students, Grand Rounds, nurses, and interest groups.

EMPLOYMENT:

Numerous jobs prior to medical school including a paper route for 9 years, working for the State Road Commission, and performing quantitative analysis in a chemical plant.

Was the only student in Duke Medical School to work all four years.

Private practice of ophthalmology (group practice) at the Falls Church Medical Center, in Falls Church, Virginia, 1970 until 1976.

Private practice of ophthalmology (solo practice) in Falls Church from 1976 until present.

TEACHING AND SPEAKING:

Teaching ophthalmology at Georgetown University, Washington, D.C. (see University Affiliation above)

Teaching cataract surgical techniques course at the annual Academy of Ophthalmology meeting, 1985-1989

Lectures for Surgidev Corporation at the American Academy of Ophthalmology, 1987, 1988, 1989.

Numerous lectures to medical students, nurses and interest groups.

INVENTIONS WITH UNITED STATES PATENTS

Karickhoff Keratoscope TM - U. S. Patent #4,491,398 awarded Jan. 1, 1985. This device is used by hundreds of eye surgeons nation-wide to assess the degree of corneal astigmatism and monitor corrective measures to reduce astigmatism during surgery. The device is used in cataract-implant, corneal transplant, radial keratotomy, and other corneal surgeries. Manufactured by

Surgidev Corporation.

Karickhoff Anterior Chamber Caliper - U. S. Patent #4,319,564 awarded 1982. This device is the only instrument that gives an exact measurement of the anterior chamber diameter where an anterior chamber implant fits. The device is now obsolete due to the introduction of posterior chamber implants where one size fits all eyes and flexible anterior chamber implants. Manufactured by Storz Instruments.

ORIGINAL MEDICAL DEVICES SOLD NATIONALLY:

Karickhoff Laser Lens TM - This device is a four mirrored gonioscope that directs and connects a laser beam to the eye. It is unique in that each mirror is marked with "depth dots" that prevent surgeons from making laser burns into an undesired area of the eye. This lens has become the top seller in the world for laser surgery in the back of the eye, selling over a million dollars worth of lenses. I receive no compensation from sales. Manufactured by Ocular Instruments Inc.

Karickhoff Mosaic Matcher TM - This device allows the surgeon to estimate the number of corneal endothelial cells prior to surgery. These cells pump fluid out of the cornea and determine whether it will stay clear after surgery. This device is distributed free to all ophthalmologist and is the most widely used such device in the world, owned by 7,000 ophthalmologists. The device allows the cell number estimate to be performed in 15 seconds at no charge to the patient and with no equipment for the ophthalmologist to buy. Previous devices required a $9,000 camera, regular purchase of film, required five days to obtain an answer, and a charge of $150 was usually made to the patient (refereed publication 3 below). Manufactured by Surgidev Corporation.

Karickhoff Flying Corpuscle Viewer TM - This device is an inexpensive and valuable method for determining macular function. The device is a blue field entoptic tester, but it is unique in that it uses the slit-lamp present in every ophthalmologist's office as its source of light. This greatly reduces the expense of the test and makes it more handy for the doctor (referred publication 5 and non-refereed 14). Manufactured by Surgidev Corporation.

Karickhoff Cataract Mirror - When patients have had a cataract removed but have no implant inserted, they can not see their own eye to apply make-up or to insert a contact lens. This high powered mirror allowed them to do those things. There is now little use for this mirror as essentially all patients now receive an implant.

Brightness Acuity Tester modification - My modification of this popular device allows the doctors to hang loose lenses onto the device so that the patient's best corrected vision would be tested, rather than using only the patient's glasses for testing. Upon seeing my publication (non-refereed publication 11) the manufacturers of the B.A.T., Mentor, Inc., began making and selling my modification as a standard accessory to their device.

Karickhoff Off-Axis Floater Lens. This surgical contact lens allows for better viewing and aiming on opacities not in the central visual axis. This lens contains a prism the base of which is identified with an internal black dot for easy orientation. By simply rotating the lens, the area around the opacity can be checked for small particles needing treatment. Manufactured by Ocular Instruments Inc.

Karickhoff 21 mm. Floater Lens. This surgical contact lens allows for treatment of opacities in the posterior one half of the vitreous. Previous contacts either would not focus the laser deep enough for effective floater disruption there, or they focused it too deep, making hitting the retina with the laser beam a problem.

ORIGINAL SURGICAL INSTRUMENTS:

Karickhoff Irrigation and Aspiration Double Cannula – This device is used to remove cortical material during extracapsular cataract extraction. There are similar devices now, but this device is preferred by hundreds of eye surgeons because of the gradual 45 degree curve of the body, and the "depth dots" revealing the location of the tip when it is hidden. Made by Karl Ilg Instruments.

Karickhoff Irrigation and Aspiration Double Cannulas for Phaco-emulsification - These devices, the tip of one going to the right and the other to the left, are similar to the above I. and A. devices but have an enlarged eliptical width and height that exactly fills the 3 mm phaco incision. This prevents any leakage at the wound, creating a deep anterior chamber during I. and A. Made by Karl Ilg Instruments.

Karickhoff Implant Positioner, Angle Assessor, and Implant Ruler- These 3 surgical instruments were used to manipulate anterior chamber implants. They were widely used but are now obsolete due to the advent of flexible anterior chamber implants (refereed publications 2, 4, 8, and non-referred publications 3 and 7 below). Made by Storz Instruments.

Modification of the Tennant Ball - A cyclodialysis spatula was added to the other end of the Tennant Ball so when the ball end is removed after quartering the nucleus, the spatula is handy to place in the anterior chamber to aid in the removal of the quarters. A second modification was to increase the shaft of the Tennant Ball so that the shaft completely fills the tiny incision necessary for the entrance of the ball. Made by Karl Ilg Instruments.

ORIGINAL OPHTHALMOLOGY CONCEPTS:

Schiotz-shove test - This test is performed before radial keratotomy to learn if the eye will sink during surgery resulting in undesirable shallow incisions. The Schiotz tonometer with the 7.5 gram weight is used to shove the eye into the orbit until the pin reads zero. The test tells the physician which patients need a retrobulbar injection to prevent the sinking (non-refereed publication number 8).

Demonstrating the cataract to the patient - I devised a way using the 20 diopter hand lens and the direct ophthalmoscope to allow the patient to see their own cataract. The patient can draw their own cataract and follow their cataract's development (refereed publication number 10).

Using a plus meridian incision in cataract surgery - I believe I was the first to place this astigmatism reducing concept in the modern literature for both primary (refereed publication number 15) and secondary (refereed publication number 28) cataract surgery. In my opinion this is the most reliable and simplest way to reduce astigmatism.

Elimination of distance glasses in implant patients - Other authors had written about (a) reducing astigmatism to reduce the strength of glasses and (b) performing ultrasound to reduce the strength of glasses. I believe, however, I was the first to discuss combining astigmatism reduction and ultrasound to actually get rid of distance glasses (refereed publication number 7 and non-refereed publication number 6).

Two-direction radial keratotomy incision technique - The American system is to use outward directed incisions. The Russian system uses inward directed incisions. I believe I was the first to cut both directions on all routine cases. The advantage is greater safety and more accurate placement and depth. Nine months after publishing my two direction incision method, a special blade was designed elsewhere for my method. This blade allows the surgeon to use one blade to cut both directions with little danger of entering the optical zone. My two direction method using the special blade is presently being taught in most of the courses for doctor training in the United States. (non-ref. publication number 15).

The original concept that reverse pupillary block is a principle mechanism causing classic pigmentary glaucoma (ref. publication number 17 and non-ref. publication 16).

The first published paper proposing and using laser iridotomy as a treatment for pigmentary glaucoma. (see ref. publication number 17 and non-ref. publication 16).

The original concept and first use in the world of transillumination location of laser iridotomy in treating pigmentary glaucoma (see ref. publication number 17 and non-ref. publication 16).

(The last three concepts above are now viewed as a unique and significant advance in the understanding and treatment of pigmentary glaucoma.)

The original concept of using a voice recorder to record the opening pressure for tonography. The previous concept was to use a galvanometer to mechanically record the pressure. The galvanometer is subject to many errors and is so cumbersome that tonography was basically abandoned. Voice recording is much simpler and much more accurate (non-ref. publication 18).

The original concept of using the "wrong" end of the Schirmer paper strip to adsorb any excess tears from anesthetic drops before turning the paper around and performing the Schirmer with anesthesia test. This new maneuver allows the Schirmer test to be done immediately after anesthetic drops are used, increases the accuracy by removing any excess tears, and cuts the test time by half (non-ref. publication 19).

The original concept of treating meibomian gland deficiency by placing ointment on the lower eyelid. In this disease there is an absence of oil in the tear film. Replacement with oily eye drops blurs the vision and lasts only a short time. Ointment placed on the lower eye lid below the eye works its way up to the eye and provides a non-blurry oil film over the eye for at least eight hours. The treatment prevents excess reflex tearing and prevents tears from flipping onto the back of the glasses (non-refereed publication 21).

NATIONAL ADVERTISEMENTS AUTHORED

Karickhoff Laser Lens

Karickhoff Mosaic Matcher

Karickhoff Irrigation and Aspiration Double Cannula

CLINICAL FIRSTS:

First to use all of the inventions, original designs, and original concepts above.

First in Virginia to perform surgery for radial keratotomy. April 15, 1981.

First in Northern Virginia to perform epikeratophakia ("the living contact lens") operation. December 10, 1985.

First in Northern Virginia to perform outpatient cataract surgery. January 14, 1981.

First in Northern Virginia to perform the secondary implant operation (placing the implant in the eye months or years after the original cataract surgery). April 28, 1978.

First at Fairfax Hospital to perform the anterior chamber intraocular lens operation. March 11, 1977.

First in Northern Virginia to treat chronic glaucoma with laser surgery. June 11, 1981.

First in Northern Virginia to treat acute glaucoma with laser surgery. March 2, 1977.

First to stress the importance of using flexible implants - I believe I was the first to publish a paper physically analyzing the flexibility of implants and stressing the importance of this (refereed publication number 6).

First in Northern Virginia to use the drug Mitomycin in conjunction with pterygium removal, September 30, 1988.

First in the Washington area to perform no-stitch cataract-implant surgery (February 5, 1991).

First in the world to perform iridotomy using transillumination location of the iridotomy (September 5, 1991).

First in 10 state area to regularly perform laser disruption of vitreous opacities. February 1, 1990

TELEVISION TAPES:

(I performed the surgery, wrote the script, narrated, supplied the music, and supervised the editing and production of each tape below.)

Karickhoff, J.R.: "Instruments and Techniques for Anterior Chamber Implants." Shown at the American Academy of Ophthalmology, 1979, 1980.

Karickhoff, J.R.: "Manual Extracapsular Cataract Extraction with Astigmatism Control." Shown at the American Academy of Ophthalmology, 1984, 1985, 1986.

Karickhoff, J.R.: "Astigmatism Reduction in Cataract Surgery." Shown on national Medical Education Television, 1983.

Karickhoff, J.R.: "Cataracts, Cataract Surgery, and Intraocular Implants." For office viewing by patients, 1980

Karickhoff, J.R.: "Care after cataract surgery." Placed on national sales. 1980.

HONORS AND AWARDS:

Bronze Star, U. S. Army, Vietnam, 1968.

Army Commendation, U. S. Army, Fort Belvoir, Virginia, 1969.

"Best Example of Service Above Self" Award, Rotary Clubs of Virginia, 1971.

"The Professional Service Award" given by the Washington, D.C. Metropolitan Area Prevention of Blindness Society, 1975.

Marshall University Alumni Association's, "The Distinguished Alumnus Award", 1989.

Georgetown University's Vicennial Award; for twenty years of unpaid teaching of ophthalmology, 1990.

COMMUNITY SERVICE:

Chairman of Chapel Campus Building Fund - raised $32,000 to start construction of an interdenominational campus chapel, 1958.

Started a large cataract clinic in Vietnam and did all the surgery without charge to Vietnam civilians, 1968-1969.

Member of Falls Church Rotary Club. Participated each year in numerous projects to raise money for local charities, 1970-present.

Active in the St. Matthews United Methodist Church then the Good Shepherd Epsicopal Church, 1972-1985.

Leads a band that gives free concerts in retirement homes and for charity money raising events, 1997-present.

REFEREED PUBLICATIONS:

1. Karickhoff, J.R.: "Loss of visual function and visual cells in 600 cases of malignant melanoma." American Journal of Ophthalmology. 64:268-273, 1967

2. Karickhoff, J.R.: "Director for the Choyce implant." American Journal of Ophthalmology. 87:569-570, 1979

3. Karickhoff, J.R.: "Corneal endothelial cell estimates at your

slip lamp in 15 seconds." Ophthalmology. Vol 87 #85, pg. 132, 1980

4. Karickhoff, J.R.: "Instruments and techniques for anterior chamber implants." Archives of Ophthalmology. 98:1265-1267, 1980

5. Karickhoff, J.R.: "Flying corpuscle macular test performed with the slit lamp." Ophthalmology. Vol. 88, #95, pg. 91, 1981

6. Karickhoff, J.R.: "Flexibility and weight of anterior chamber implants." Contact and Intraocular Lens Medical Journal. 7:348-350, 1981

7. Karickhoff, J.R.: "Elimination of distance glasses in implant patients." Contact and Intraocular Lens Medical Journal. 8:114-117, 1982

8. Karickhoff, J.R.: "Techniques for sizing anterior chamber implants." Amer. Intra-ocular Implant Society Journal. pg. 206-208, Spring 1983

9. Karickhoff, J.R.: "Wound closure technique in cataract surgery." Amer. Intra-ocular Implant Society Journal. pg. 213, Spring 1983

10. Karickhoff, J.R.: "Demonstrating the cataract to the patient." Amer. Intra-ocular Implant Society Journal. Winter issue, pg. 51-52, 1983

11. Karickhoff, J.R.: "Twelve steps to prevent macular edema." Amer. Intra-ocular Implant Society Journal. pg. 191-192, March 1985

12. Karickhoff, J.R.: "Office suture cutting." Amer. Intraocular Implant Society Journal. pg. 609-610, Nov. 1985

13. Karickhoff, J.R.: "Techniques with high vitreous pressure." Journal of Cataract and Refractive Surgery. pg. 427, 428, July 1986

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Appendix R) **About the Author**

Doctor Karickhoff was born in Spencer, West Virginia. He graduated Magna Cum Laude from **Marshall University** in Huntington, West Virginia. He was the #1 graduating pre-medical student out of 110 beginning freshmen, and the #1 graduating science student out of 705 in the class. He was presented the "Outstanding Physics Student Award". He was President of his Freshman, Sophomore, Junior classes, and was President of the Student Body his senior year; was President of the Student Christian Association; and was on the university Debating Team. In 1989 he was chosen Marshall's Distinguished Alumnus.

He received his M.D. degree from **Duke University**, graduating in the top fifth of his class while holding a job in Duke Hospital all four years. His internship in Internal Medicine and residency in Ophthalmology are also from Duke.

He then joined the **U.S. Army Medical Corps** for two years as an eye surgeon (rank of Major and receiving the Bronze Star). While in Vietnam, he started a large charity eye surgery clinic. Upon returning to the United States he began private practice of ophthalmology in Falls Church, Virginia. For 25 years he also lectured, consulted in the clinic, and taught eye surgery at **Georgetown University Medical Center** where he was Clinical Associate Professor of Ophthalmology. He donated his time and all surgical fees to the university. Georgetown University Medical Center presented him with their Vicennial Teaching Award in 1995. He is Board Certified by the American Board of Ophthalmology and served several years on the Medical Advisory Board of the **Duke University Eye**

Center. He is the **sponsor** of the annual Duke University and Georgetown University / Washington Hospital Center **Ocular Innovation Awards**.

Doctor Karickhoff is **recognized nationally** as a surgical innovator, researcher, lecturer, writer of published medical papers (41), as the author of the first and only book on Laser Treatment of Eye Floaters, designer of medical devices (7), designer of surgical instruments (6), originator of ophthalmology concepts (11), inventor (two U.S. Patents), and for clinical firsts (12). He introduced many surgical techniques to the Washington area such as no-stitch cataract surgery and laser disruption of vitreous floaters. He developed the first internet practice of ophthalmology in this area with patients coming from all U. S. states and 42 foreign countries.

Dr. Karickhoff is perhaps the only ophthalmologist in the world who has completed a 30 year goal of producing **through clinical research *an innovation or significant contribution of each of the 14 anatomical structures of the human eye***. (Each is documented with literature references, designs or patents in his book. Appendix J)

Dr. Karickhoff solved the two problems (accidental encroachment on the central clear optical zone and shallow incisions) of **radial keratotomy** surgery by developing a two direction incision. His incision was adopted by nearly all surgeons.

Dr. Karickhoff was responsible for most if not all of the major advances to laser treatment of eye floaters since its inception in 1983. This surgical procedure is based on plasma physics and is at the cutting edge of medicine.

In recent years **floater patients made up 90 percent of his medical practice**. He is also involved professionally in research, designing and inventing, and as a **medical book publisher**.

Doctor Karickhoff is involved in **community service** through the projects and fund raisers of the Rotary Club of Falls Church, Virginia. The Rotary Clubs of Northern Virginia selected him for their "Service Above Self" award. He is an active member of his church as a greeter and performing music; raises money annually for an organization for the homeless; works each year in the local homeless shelter; and he is the founder of a band that gave free concerts in retirement homes and for charity events. Dr. Karickhoff was the sole recipient of the 2014 Fairfax County Human Rights Award for Humanitarian Service to the county.

His **hobbies** are being in a music performance group (guitar, ukulele, keyboard, harmonica, and voice), amateur radio (extra class), video production, multi-track audio recording, attending cultural and musical events, public speaking, reading, being a member of the National Press Club, golf and billiards.

Dr. Karickhoff's wife, Madge, of 42 years (deceased 2014) was a former high school English teacher and had a Master's Degree in Guidance and Counseling from the University of Virginia. They have two **daughters**. Julie is a graduate of Duke University, has an MBA degree from Georgetown University, and lives in Alexandria, VA. Maggie is a graduate of Duke University, has a Master's Degree in speech-language pathology from the University of Redlands, California and lives in Van

INDEX

Aiming beam 89
- defocused 93, 154
- missing one 116
- none seen 116
- not aligned 116

Aiming system 46
Aron-Rosa, Dr. Daniele 44
Asteroid hyalosis 20, 65, 115
Astigmatism, excessive 86
Benefits 71
Capsule
- Contracted anterior 86

Capsulotomy
- inadequate 85, 87
- posterior 85

Cataract formation 135
Cataract plus floater 27, 74, 86
Cavitation 92
Combination floater 113
Complications (possible)
- avoiding 122-136
- avoiding glaucoma 128
- cataract formation 135
- corneal 123
- contact lenses, from 124-125
- elevated pressure 125-129
- gonio fluid, from 123
- macular damage, preventing 134
- pain, avoiding 123
- staphylococcal keratitis 125
- superficial punctate keratopathy 123, 159

Contact lens, diagnostic 149
- Fundus Laser Lens 39, 150
- Karickhoff 4 Mirror lens 149
- putting on 92

Contact lens, treatment
- Abraham iridotomy 156
- Abraham posterior capsulotomy 155
- designing a 157
- general concepts 150
- Karickhoff Off-Axis 116, 151, 152
- Karickhoff 21 mm Vitreous 151
- Lasag CGV 154
- Peyman lenses 153
- Peyman 25mm 154

Contact lenses 149-158
Contraindications 74
- relative 76

Corneal dystrophy, geographic 85
Delaney 62
Elbow support 166
Elschnig's pearls 86
Fankhauser, Dr. Franz 45, 154
FDA, see Food and Drug Administration
Femtosecond 57
Flashing stopped 135
Floater
- after vitrectomy 115
- asteroid hyalosis, 20, 115
- bean-shaped 114
- broad, thin 11
- duet 21, 112

cigar shaped 115
course, 22
demonstration 42
depth of 38
dilemma 108
drawing 40
examination 36
fan-shaped 108
FDA application 118
fibrous 96
Finder 37
finding, Patient Assisted
Method 79
formation, 18
from argon laser 115
from cryopexy 115
from inflammation 22
from LASIK 85
hairy rope-like 97
high myopia, in 114
history 34
incorrect assumptions 33
"invisible" 77
locating elusive 40
lost 116
location, patient
assisted 40
move faster after
treatment 113,
170
moving it forward 105,
171
milk pod 110
multiple 80
near retina 89, 105
non-fibrous 95
obliteration 50
peripheral 109
plus cataract 27
snow globe 112
stringy, fibrous 96
suspended 111
symptoms 31
symptoms formula 32
syneresis 110-114
cigar shaped 115
hidden below 112
non-suspended
110
suspended 111
thin, cobweb 96
transparent 33
treatable, 21
types 91, 95
unseen by doctor 77
vaporization 48, 57
very small 108
wafer-like 114
Weiss rings 97
Posterior move-
ment 104
Sixteen tech-
niques 104
Weiss ring + syneresis
cloud 113
Flying Corpuscle Viewer 41
Follow up 137
day after treatment 137
examinations 138
immediately after 137
Food and Drug Administration
118
early ruling 118
final ruling 118
Invest. Device Exemption
Application 118
Foot rest 167
Fundamental mode 53
Gas bubbles 81, 92
Gaasterland, Dr. Douglas 133

Geller 62
Geographic corneal dystrophy
    124
Glaucoma, complication 125
Gonioscopic fluid 159
    diluting 159
    ethylcellulose 160
        advantages 161
    making 162
    methylcellulose 159
    substitutes 162
Hemorrhage, vitreous
    treatment 74, 172
HeNe beam 89
Herbal medicines 24
Hruby lens 39
Illumination beam
    central 92
    diameter 93
    power 93
    to side 92
Indications 73
Inflammation 22, 65
Intraocular contact lens 88-89
Intraocular lens 87
    accommodative 88
    multifocal 76, 87
    piggyback 87
Invest. Device Exemption
    Application 118
Keratoplasty
    conductive 85
    penetrating 85
Laser
    aiming system 46
    components 50
    continuous 53
    femtosecond 57
    fundamental mode 53
    history 44
    light characteristics 51
    shock wave 121
    testing your 61, 139
LASIK 84, 124, 153
Lens, pseudoexfoliation of 87
Light of room 167
Light flashing stopped 135
Loosing the floater 116
Low brow 117
Machemer, Dr. Robert 25
Macular damage, preventing 134
Macular examination 41
Measuring distances inside
    the eye 130
Memorable cases 168
Mode-locked 45, 54
Moses Maneuver 106, 171
Multi-burst mode 92, 126
Multimode 53, 92
Multiple sclerosis 74
Nanosecond 54
Ninety diopter lens 39
Off-label procedure 16, 119
One-eyed patients 76
Ophthalmoscope, direct 37
Optical breakdown 45, 48, 51,
    94, 121
    loss of 94
    not achieving 49, 52, 181
Optical coherence tomography
    77, 79
Optics needed 60
Optic neuritis 74
Photographing floaters 164
    digital camera 165
    Docustar camera 164
    stereo camera 165
Picosecond 45, 54
Physics, laser 50
Pigment dispersion syndrome

127
Pigmentary glaucoma 127
treating 128
Plasma
formation 48
shield 52, 121
Posterior vitreous detachment, 21, 36
none produced 136
Power setting 52, 62, 70, 104
Procedure 66, 82
off-label 16, 119
Pseudoexfoliation 85
Pulsed 53
Q-switched 45, 54
Radial keratotomy 84
Retinal anterior limiting membrane 115
Retinal damage
lack of 129
preventing 129
Retinal detachment
lack of 86, 120, 134
treatment causes floaters 21
with posterior capsulotomies 134
Retinal hemorrhage,
compared to PRP lesions 132
intentional 131
pre-retinal 133
when treating Weiss rings 132
why they occur 133
Retinal protection 120
Retinal safety, indicator 130
Re-treatments 138
Retinoschisis 73
Risks 71
Sarcoidosis 74
Satisfaction 168
Scanning laser ophthalmoscope 42, 78
Shock wave 121, 131
monitored 121
Stool height 91
Studies
formal
Karickhoff's 64
informal
Geller's 62
Karickhoff's 62
Tsai's 62
Success
criteria for 67
rate 71
two ways to obtain 71
Superficial punctate keratopathy 123, 159
Technical problems 116-117
low brow 117
Technique 91-115
concentration 91
fixation light 91
multi-burst mode 92
stool height 91
three basic 95
work on one end 97
Tonography 129, 194
Karickhoff simplified 129
Toxoplasmosis floaters 22, 74, 168
Treatment 91-115
advantages 28
after retinal detachment 73, 89
after retinal tears 89
after vitrectomy 115
three basic techniques 95

do nothing, 23
herbal medicines 24
improvement in vision 34
justification for 35
laser 28
plan 81
post op. instructions 83
procedure 66, 82
sub-hyloid hemorrhage 172
sunglasses 23
vitrectomy 25-28
vitreous hemorrhage 74, 172
which eye do first? 81
why unknown 28
work front to back of eye 122
work top to bottom of eye 122
YAG 44, 51
Treatment beam
coning 150
converging 120
divergence behind floater 151
invisible 121
off-set 94
reflection 95
Tsai 62

US Food and Drug Administration (see Food and Drug Administration)
Vaporization 48, 57
Visual acuity improvement with treatment 138
Vitrectomy 25-28
laser treatment after 115
Vitreous
haze, generalized 109
in high myopia 90
normal, 18
liquefaction, 18
Vitreous face 80,
prominent 109,
no connection to 115
Vitreous traction
reduction of 121, 130, 135, 172
light flashing stopped 135

Weiss rings, 97
move posterior 93
moving forward 93
Young patients 77