Cataracts and the Amateur Astronomer
by Kathy and Jerry Oltion

Imagine smearing Vaseline all over your primary mirror, then smashing it into several pieces. The view through your eyepiece would not be pretty: fuzzy and broken up into multiple images.

That's what a cataract will do to your vision. *Everything* will look like that. The brighter the object, the worse it will look.

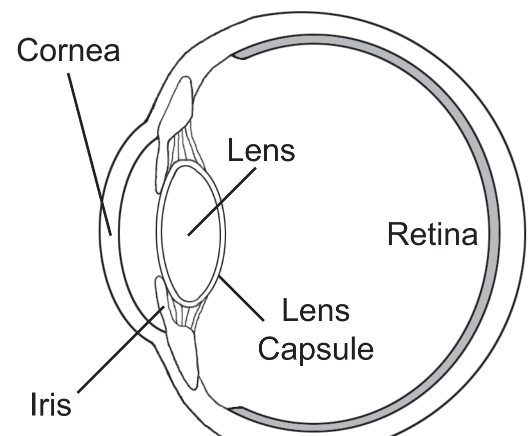
Fortunately, cataract surgery has become so routine that you can simply have the cloudy lens removed from your eye and a new one implanted, then go on as if nothing had ever happened, right?

Wrong. That myth applies only if you don't pay much attention to your vision. If you don't know what a diffraction spike is, you may not notice the new ones in your field of view, but amateur astronomers pay close attention to what they're seeing and we most definitely do notice the effects of cataract surgery. We even hear horror stories of people who have given up astronomy because of the degradation of their vision after cataract surgery.

The good news is, if you go into it with your eyes open, so to speak, you will have a much better chance of coming out of it with eyes that you can still use for astronomy.

If you live to 80, you're nearly certain to develop cataracts sometime along the way. They may not become bad enough to require surgery, but you'll have them. And cataracts aren't just an old-people's problem: they can develop at any age. Newborn babies sometimes have cataracts. Kathy's developed in her early fifties, just a few years after we became amateur astronomers. She started seeing multiple images of planets and bright stars, surrounded by fuzzy halos. Her eyeglass prescription began to change, skewing radically toward nearsightedness. By the time she decided she had to do something about it, she had gone from -6 to -10 diopters of correction just to bring the most useful portion of her natural lens to a focus.

Kathy didn't have much choice but to have the cloudy lenses replaced. Her surgeon reassured us there would be no detrimental effects, even after we'd related the stories we'd heard from other amateur astronomers. Unfortunately, he was used to dealing with patients who paid little attention to the quality of their vision as long as they could read or drive. His assurances that all would go well hardly applied to Kathy.



The Anatomy of the Eye

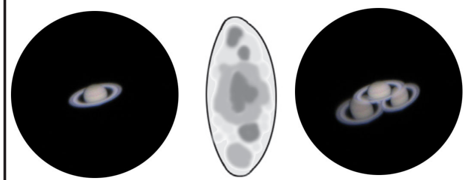
The eye is composed of a clear membrane in front called the cornea, then behind that the iris, which regulates how much light passes through, then the lens behind that, which resides inside a clear membrane called the lens capsule. Behind the lens capsule lies the main cavity of the eyeball, filled with a clear jelly-like fluid called the vitreous humour. Along the sides and rear of the eye is the retina, upon which the lens focuses an image.

We did at least convince him to use the largest-diameter lens he could implant so that Kathy's dilated pupil wouldn't leave the lens edge in the light path when she went out observing. That lens was 6mm in diameter; a dicey proposition for a relatively young person whose pupils might still open to 7mm, but that's as large as the surgeon would go.

What we didn't understand at the time is that the diameter of the lens is only one consideration. The lens is surrounded by a paper-thin clear sack of tissue called the lens capsule. When the surgeon removes the natural lens and implants the artificial one, he removes the front of the lens capsule in a process called the capsulorhexis. That opening is typically smaller than the lens, and for good reason: it helps hold the lens in place and helps prevent migration of loose lens cells that can later cause cloudiness in the rear part of the lens capsule. But the smaller diameter capsulorhexis means that Kathy didn't get a 6mm clear aperture when she chose a 6mm lens; she got more like a 5mm aperture. That was better than having cataracts, so Kathy went ahead with the surgery.

Cataract surgery is done one eye at a time. After the first operation, Kathy noticed two positive benefits immediately: She could see clearly again, and everything looked bluer in that eye. The cataract had been acting like a yellow filter. For the first few hours, she was very pleased with the outcome.

That night, however, was a different story. The moment



Lens

How does a cataract happen?

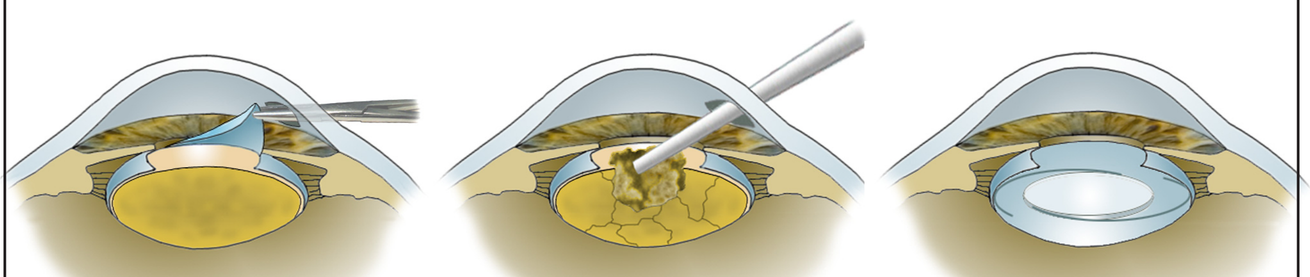
The eye's natural lens is made of cells called lens fibers, which are nearly transparent when new. When a cataract develops, the lens fibers become cloudy and change their index of refraction. The cloudiness imparts a general fuzziness to the image, while the change in index of refraction affects the lens's focus. The change in index of refraction is often not uniform throughout the lens, which means that different parts of the lens will focus light to different points, creating multiple distorted images.

How is cataract surgery done?

In the early days, cataract surgery meant opening up the cornea and working through an opening as large as the lens implant, or larger. Nowadays everything can be done through a 2-3mm incision in the side of the cornea. The incision is small enough to heal without stitches in most cases.

The first step is the capsulorhexis, the opening in the front of the lens capsule. The surgeon pulls loose a flap of tissue with a bent needle, then grips the flap with forceps and tears a circular hole much as you might tear a circle out of the center of a piece of paper.

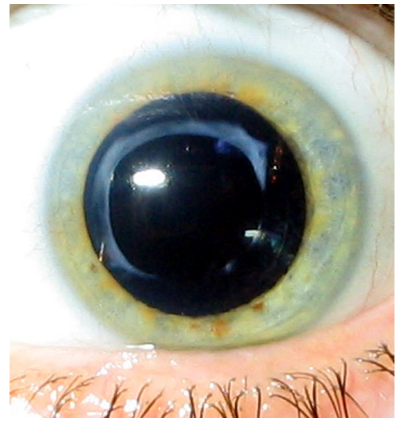
Then the surgeon uses an ultrasound probe to break up the natural lens (this is called phacoemulsification). The pieces are suctioned out and the replacement intraocular lens, or IOL, is inserted. The IOL is folded to fit through the tiny incision in the cornea; then it unfolds inside the eye and the surgeon places the support wires, or haptics, into place in the remaining lens capsule.

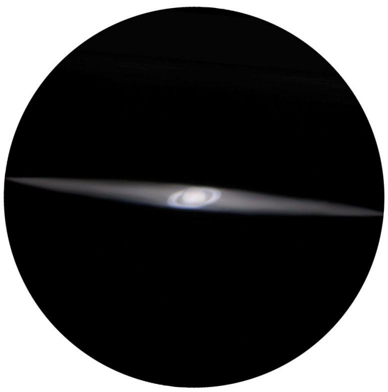


Capsulorhexis Phacoemulsification IOL in place she looked at a bright light, she knew something was wrong. She had a huge diffraction spike in the eye with the new lens. It was a not-quite-horizontal bar that stretched from edge to edge of her field of vision. Every street light, porch light, and even bright stars produced a spike. The flare off oncoming headlights extended across the entire road, even sidewalks and cross-streets. When she looked through a telescope, planets were bright bands stretching all the way across the field of view, and any first- or second-magnitude star did the same.

Capsulorhexis

This is Kathy's left eye after surgery. The edge of the capsulorhexis (the opening in the front of the lens capsule) is clearly evident in the upper left side of the image, just inside the dilated pupil.

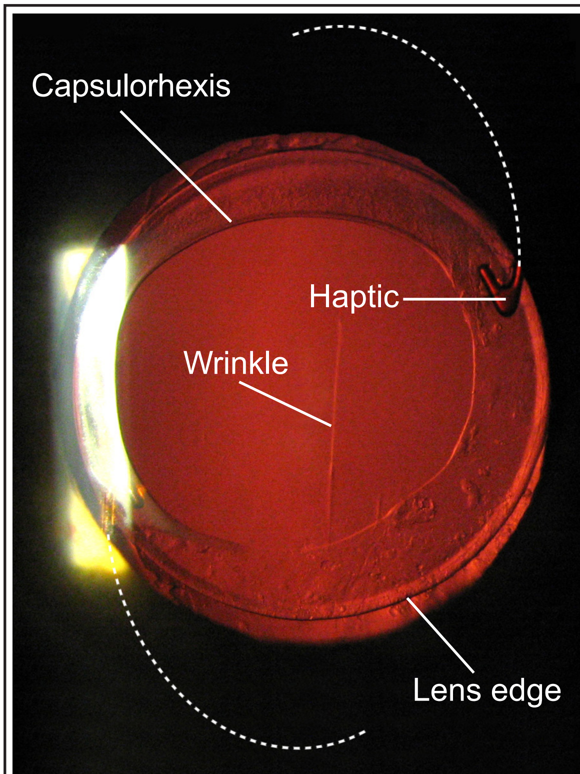




And so began a long, arduous process of figuring out what went wrong and how to fix it. Her regular optometrist saw a wrinkle in the lens capsule behind the newly implanted lens, caused by the two whiskers (called "haptics") that hold the lens in place. They were stretching the back of the lens capsule, and much like cling wrap that's not evenly stretched over a bowl, it wrinkled. The wrinkle was not quite vertical, but exactly 90 degrees away from Kathy's diffraction spike. Any experienced amateur astronomer knows that a linear obstruction generates a diffraction spike perpendicular to it, so we immediately suspected that the wrinkle was the problem.

Our optometrist didn't want to jump to conclusions. While he agreed that the wrinkle was a possible candidate, in his experience the diffraction from a wrinkle is lost in the white noise of the visual world and seldom if ever bothers people. He felt it was proper to remove the more likely possibilities first. In his words, "When you hear hoofbeats think horses, not zebras." He thought that the severity of Kathy's flare might be from astigmatism, which the surgery hadn't corrected. Kathy wound up trying a series of toric contact lenses to see if they could correct the problem, but none did.

The surgeon flatly refused to believe that the



The wrinkle in Kathy's eye

This is a retroilluminated image made by shining a bright light from a slit lamp through the edge of the cornea. It reflects off the retina and illuminates the lens capsule, lens, and capsulorhexis (front opening in the lens capsule) from behind. Note the diffraction-causing wrinkle in the rear part of the lens capsule.

Also note the edge of the lens and the ends of the haptics that hold the lens in place. (The one on the lower left is partially obscured by the glare of the slit lamp.)

wrinkle could be causing the diffraction spike. Many implantees got that wrinkle, he said, yet few of his other patients complained. We learned later that the wrinkle is so common it's called the "in the bag sign," an indicator that the lens is resting properly within the lens capsule. We also learned that patients often do report diffraction spikes, but they generally don't know what to call them and seldom insist that they be corrected. Many patients simply stop driving at night, or doing much of anything in low-light situations. (What's scarier: some continue to drive at night, despite having diffraction effects that could partially obscure a pedestrian, for instance, next to an oncoming car.)

Needless to say, Kathy sought out another surgeon for the other eye. When she described the problem to him, he looked into her eye, saw the wrinkle perpendicular to the direction of her diffraction spike, and said, "Case closed."

He had good news: when he did her other eye, he could insert a ring inside the lens capsule that would hold it tight so the lens haptics wouldn't stretch it enough to wrinkle. He gave that a good chance of success, but couldn't promise that it would work. That's how pervasive the wrinkle is: even efforts to mitigate it during surgery aren't always successful.

And sure enough, it wasn't successful in Kathy's case. Her second eye wound up with a wrinkle, too. Like the first one, it was mostly horizontal, but cocked at a jaunty angle from the other so she had two wide bands coming off every bright light.

With two wrinkles and two spikes at exactly 90 degrees away from the wrinkles, everyone had to admit that the wrinkles were causing the problem. So the question became what to do about it.

Phase Two: the Capsulotomy

Sometimes the wrinkle will go away over time as the lens capsule shrinks. Unfortunately, Kathy's showed no sign of doing so.

Many cataract patients develop what's often called a "secondary cataract" after surgery. The secondary cataract is a completely different phenomenon caused by the growth of leftover lens cells on the back of the lens capsule. The cure for it is to laser away the back of the lens capsule — a "capsulotomy." An infrared YAG (yttrium aluminum garnet) laser is shone through the front of the eye, and where it comes to a focus, the intense beam disrupts the tissue. A hole is cut in the cloudy lens capsule so light can pass unimpeded to the retina.

And here's the second opportunity for amateur astronomers to practice expressive new words in French. More diffraction!

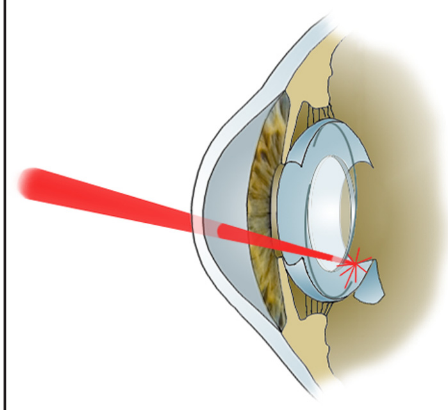
Surgeons don't like to make big holes in people's eyes. That's generally a good thing. Small incisions when implanting the new lens mean faster healing times and fewer complications. Big capsulotomies leave more debris floating around in the eye afterward, and increase the risk of "vitreous prolapse," where the vitreous humor in the main cavity of the eye leaks forward around the implanted lens. But small capsulotomies mean leaving a ragged and/or cloudy edge in the light path of a dilated eye. Imagine smearing Vaseline on the outer two inches of your 8" mirror. Nobody in their right mind would do that. Yet that's just what a small capsulotomy will to do to your eyes.

Some capsulotomies are cruciate, essentially a big X cut in the tissue. Others are polygonal, with straight edges. Yet others are jagged like a Norwegian coastline. Can you say "diffraction spikes going every which way?"

One of the remedies commonly offered is to prescribe eyedrops to constrict the patient's pupils while observing, so the edge of the capsulotomy is hidden behind the iris. Our response was the same as yours: "You've got to be kidding." We don't drive an hour out of town to find dark sky just so we can constrict our pupils as if we were still in town.

After the wrinkle experience (squared), we were skeptical of any claim about the performance of any procedure. Yet Kathy's eyes were developing "secondary cataracts," so there really wasn't much choice: she was going to have to have capsulotomies. The only question was how big we could convince the surgeon to make them.

Our optometrist recommended a relatively new surgeon who was current with the most recent technology and methods. During the pre-operative interview, *we* interviewed *him*, assessing his knowledge of diffraction effects and his understanding of our concerns. He impressed us with not only his existing knowledge but his willingness to listen and learn. Kathy was his first amateur astronomer, and she taught him plenty about what's important to us, and why. He agreed to make the biggest capsulotomy that he could make without endangering her eye or the intraocular lens. And he promised to make it as round as he could.



Capsulotomy

Sometimes after cataract surgery, leftover lens cells will grow on the back of the lens capsule, turning it cloudy. When this happens, surgeons use a laser to cut away a circular portion of the lens capsule, letting light pass unimpeded. The size and smoothness of the capsulotomy is important to amateur astronomers. One that's too small and/or with ragged edges will cause diffraction in low light conditions.

The procedure itself was simple and painless. Kathy was in and out of the office in an hour. She didn't even see any bright lights during the procedure, since the laser is well into the infrared region of the spectrum. The only effect she could see was that the cloudy haze that had been building up around everything had gone away.

And so had the diffraction spike. Any lingering doubt that the wrinkle in the lens capsule had caused the diffraction spike was erased in that moment.

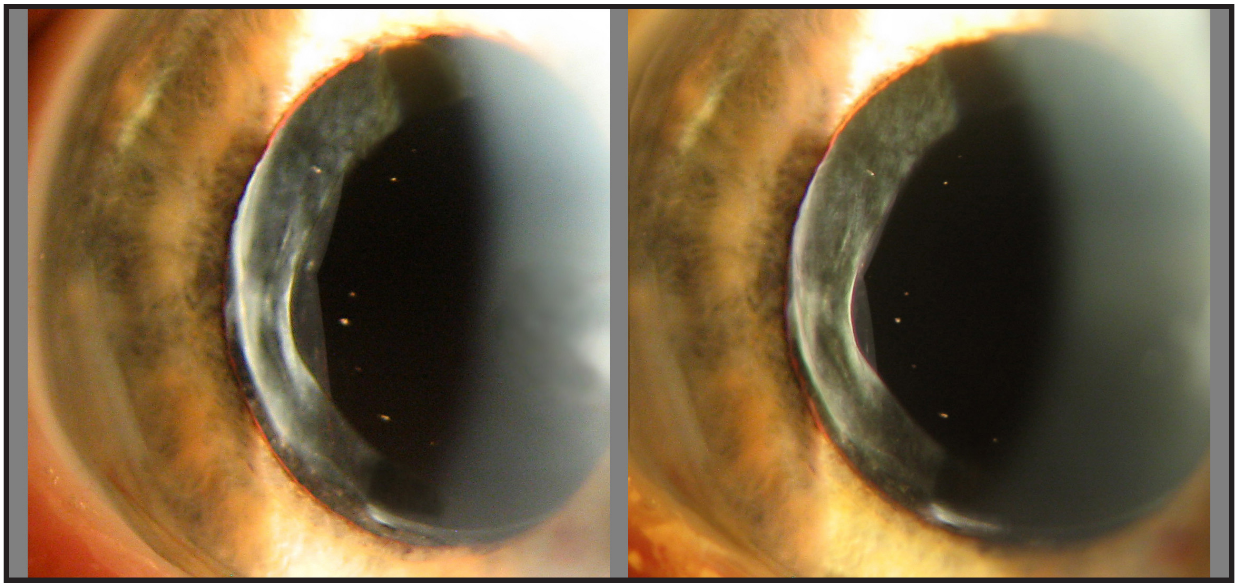
When we went out with a telescope, we were even more pleased. Kathy's eye performed as well as it had before the whole cataract nightmare began. Even Venus produced no glare or diffraction spikes. She was back in business.

She had the other eye done a month later and the results were the same. No diffraction spike anymore. She doesn't even detect much diffraction from the edge of the capsulorhexis, probably because that's nice and round, too. Her eyes behave as they did before her cataracts developed. She looks forward to many more years of astronomy.

What did we learn from this experience? Wrinkle-caused diffraction may be considered normal in cataract patients, but you don't have to put up with it. Likewise the effects of small capsulorhexes and capsulotomies. As with the rest of our optical train, amateur astronomers want the largest clear aperture we can get, emphasis on "clear."

Your Mileage May Vary

As always when discussing medical concerns, your situation will differ from ours. Your needs and your risk of complications may differ. Don't take this article as a prescription for what everyone should do; rather use it as a guide for discussing frankly with your surgeon what you need in your particular case. There are medical constraints to what's possible and safe, but there are also optical constraints to what's acceptable for amateur astronomy. Make sure both you and your surgeon understand what you want, why you want it, and how to achieve as much of it as medically possible. If you go into cataract surgery informed, you stand a much better chance of coming out of it happy.



Stereo Image of Kathy's Right Eye

This is a stereo image of Kathy's right eye after the entire procedure was over. It's a cross-eyed pair, which means you should look at the left image with your right eye and the right image with your left eye. When the two images overlap, you'll get a 3-D view of her eye showing the iris in front, the capsulorhexis (opening in the front of the lens capsule) next, the clear lens with a few specks on it behind that, and the edge of the capsulotomy (the opening in the back of the lens capsule) just peeking out from the left side.

In this photo her pupil is dilated way more (7.5mm) than natural. In normal conditions, even at night, the capsulorhexis and capsulotomy are very nearly covered by the iris.

Accommodating lenses

One downside of the typical artificial lens is that it doesn't adjust for far and near vision the way a natural lens does. (Although by the time you develop cataracts, your natural lens probably doesn't adjust very well anymore, either.) Newer technology addresses that problem in various ways. Some "multifocal" lenses are made like Fresnel lenses, with different focal lengths in concentric rings. Other multifocal lenses use diffraction effects to achieve the same result through constructive and destructive interference. Other "true accommodating lenses" have hinged haptics that pull the lens forward and back to focus it. Unfortunately the multifocal types can cause unwanted diffraction from their concentric rings and the accommodating type currently has a small (4.5-5mm) lens diameter, leading to diffraction from the lens edge when the pupil dilates. At the current time, neither type is recommended for amateur astronomers.

Technology keeps improving, though. Stay abreast of new possibilities and discuss them with your eye doctor(s). Accommodating lenses will almost certainly become serious contenders in the near future.

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