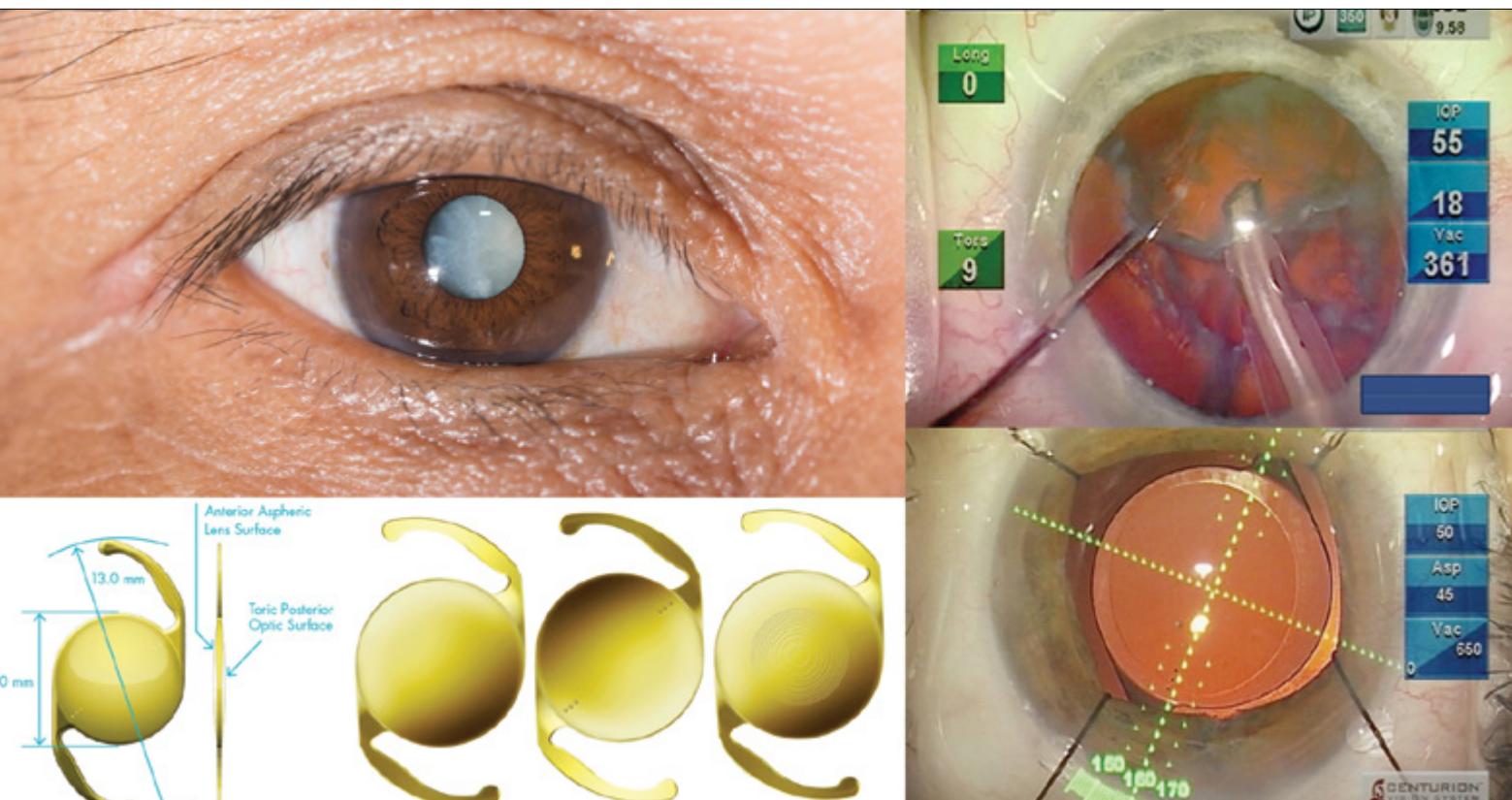


CJO RCO

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Cataracts in Canada

Preparing, and caring for, your patient

Modern cataract surgery

Advanced technology intraocular lens options

Medico-legal considerations: patient choice



CANADIAN ASSOCIATION OF OPTOMETRISTS
ASSOCIATION CANADIENNE DES OPTOMÉTRISTES

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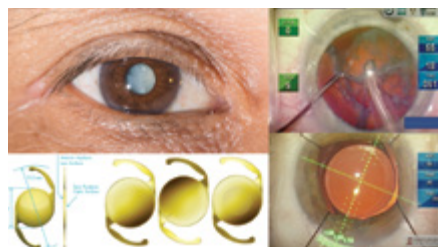
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On the Cover

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A mature cataract. Ultrasound phacoemulsification for cataract extraction. A virtual heads-up display on a surgical microscope to assist with toric intraocular lens alignment. Single-vision, toric and multifocal design elements in the AcrySof® family of intraocular lenses.

INTRODUCTION

Raise your hand if you are getting older. Admittedly, a trick question. Your patients would answer the same way, of course. The Canadian population as a whole is also aging, a function perhaps of the availability of improved health care and generally healthier lifestyles. In 1991, 11.5% of the Canadian population was estimated to be 65 years of age or older. In 2011 the figure was 14.4%, and it is estimated that by 2031 one in five Canadians will be over the age of 65.¹

Not surprisingly, with this aging demographic, the number of cataract surgeries performed in Canada is predicted to rise significantly. Using population data for Ontario, Hatch and colleagues predicted that the annual volume of cataract surgery would rise from a 2014 level of 175,000 cases to 250,000 cases by 2026 in that province, a 43% increase.² It is likely these numbers from Ontario reflect a national trend.

Cataract surgery is one of the most common surgeries in North America. Thirty years ago it might have involved a hospital stay, a large corneal incision, and a long recovery time. Today a patient can expect to complete the entire procedure as an outpatient, returning to their daily routine the same day; the cataract surgery itself will likely take 15 minutes or less.

The goals of cataract surgery have also changed. Before the 1980s the usual treatment after surgery was a pair of heavy aphakic spectacles, worn for life. It was 1981 before the US Food and Drug Administration approved the first intraocular lens (IOL).³ In a study around that time, 85% of patients were reported to have a best-corrected acuity of 20/40 (logMAR 0.3) or better after surgery,⁴ but high-powered aphakic spectacles were no longer required. Intraocular lenses were available in 2D steps, and there was debate regarding whether IOL power calculations were necessary to achieve acceptable results.⁵ These days the most common intraocular lenses are available in 0.5D steps, and numerous formulas are available to calculate the appropriate power for the eye. The EUREQUO database, containing outcomes data for over half a million cataract surgeries in Europe, suggests the current standard of care is to achieve corrected distance visual acuity of 20/40 (logMAR 0.3) or better in 97% of patients with no ocular comorbidity and a refractive error within ± 1.0 D of the intended correction in 87% of eyes.⁶

With the exception of uncorrected refractive error, cataracts are the leading cause of vision loss, accounting for about one-third of all cases of visual impairment worldwide and half the cases of global blindness.¹¹ Untreated, cataracts are known to decrease personal safety, lower a patient's independence in performing daily activities, and are associated with increased mortality.^{12,13} Living with cataracts has been shown to have a negative effect on mobility and more than doubles the likelihood of an at-fault car accident.¹³

Fortunately, the cause is reversible. Cataract surgery results are generally safe and predictable, with complication rates from modern surgery low and continuing to drop.¹⁴ Cataract surgery is a highly successful and cost-effective procedure that improves vision-related quality of life.^{12,13,15} Surgical outcomes include improved contrast sensitivity and visual acuity at near and distance, which makes tasks such as reading, watching TV, driving, and face recognition easier.¹⁵⁻¹⁷ Surgery has been shown to improve mental health, emotional health, adaptation and social interactions while reducing psychological distress; social activities increase and are reportedly easier after surgery.^{15,17} Fall rates and fractures have been reported to decrease after cataract surgery and the probability of having a car accident appears significantly lower.¹³

Patients often initially present to an optometrist's office with complaints related to a diagnosis of cataracts but may be unaware of the cause of symptoms or treatment options. They may report trouble with driving at night, distance vision, reading small print, doing fine handiwork, and watching TV.^{15,18} Symptoms related to vision deterioration from cataracts have been found to be highly correlated to vision-related quality of life.¹⁹ ***It is the optometrist's role to raise awareness of the effect of cataracts on daily life, to accurately diagnose the cause of symptoms, determine the patient's visual objectives, and educate the patient about their treatment options.***

Given the effect of cataracts on quality of vision and quality of life, the optometrist must ensure the patient is diagnosed appropriately so that treatment is timely. In the past, visual acuity and lens opacity have been used to diagnose cataracts, but they are no longer considered sufficient indicators of visually significant cataracts.^{12,19} Contrast sensitivity may be more important than visual acuity in influencing quality of life.^{20,21} This is not surprising, as the real world contains more low- than high-contrast visual stimuli; low-contrast stimuli are not appropriately represented with a high contrast visual acuity chart. Glare also has a great impact on patients with cataracts, as the scatter of light in the crystalline lens is increased.²² Given these factors, the current paradigm is that cataract surgery is indicated if the visual impairment from cataracts is interfering with the patient's performance of routine activities.²³

Age-related cataracts generally develop slowly, so the appropriate time to have cataract surgery is a topic of continuing debate. There is generally considerable time between the first diagnosis of cataract and any cataract surgery. Appropriate counselling in this period can help relieve anxiety related to the surgery. Fear of cataract surgery is a common emotion,²² and has been linked to anxiety-induced hypertension and reduced satisfaction with results.^{23,24} The optometrist typically has the opportunity to educate patients about the surgery and the expected effects of treatment options.

The optometrist may influence both the timing and the nature of the cataract surgery for their patients, so up-to-date information on cataract surgery and intraocular IOL options is important. Advances in cataract surgical technology, such as femtosecond laser systems as well as improved biometry and intraocular lens calculations, have made cataract surgery more of a refractive procedure, with a high percentage of patients achieving near-emmetropia after surgery.⁶ Advanced technology IOLs such as multifocal, toric, and accommodative lenses, have significantly improved a patient's chance of achieving their desired visual outcome. With up-to-date information, the optometrist can play a key role in setting appropriate patient expectations for cataract surgery. ***They can also help the patient choose the IOL that will best meet their visual goals.*** This is important, as previous research suggests decisions made prior to seeing the cataract surgeon remain largely unchanged.²⁵

This supplement contains four articles that provide essential information regarding modern cataract surgery. Drs. Blaylock and Petrick provide an overview of the new technology your patient might be exposed to in a modern cataract surgery procedure. Drs. Braga-Mele and Makari outline current features of the IOLs available in Canada, and I provide a patient-centric overview of the procedure. Finally, lawyer Gilbert Sharpe provides some important legal and regulatory considerations, such as informed consent, when you are dealing with cataract surgery patients. A supplement like this cannot be all-inclusive, but hopefully it provides the background for you to look forward to assisting your patients with this important ophthalmic procedure.

As a final comment, I would like to share my “tale of two mothers,” both of whom have granted me permission to tell their stories. As a researcher in the field of cataract surgery and technology, it is not surprising that both my mother and my mother-in-law consulted me for advice on their IOL choices. My mother was moderately myopic with low corneal astigmatism and had been wearing glasses since the age of 10. She doesn't mind wearing glasses but looked forward to the chance to be spectacle-free for distance, so that walking in the rain or in cold weather would be less of a hassle. We discussed multifocal options, but they had little appeal as she was “used to” wearing glasses. My mother-in-law was moderately hyperopic and didn't need reading glasses until about age 40. She never liked them and was kidded a great deal about the need for “granny glasses.” She was very excited to hear about the possibility of no longer needing glasses with a multifocal IOL; she understood the potential for glare and halos might increase with such an IOL.

My mother opted for a monofocal IOL and was corrected bilaterally for distance vision. My mother-in-law chose a multifocal option, bilateral ReSTOR +3.0. Both mothers had successful surgery with very good uncorrected distance vision, thanks to their respective surgeons.

My mother wears a pair of progressive add spectacles with a plano distance component and doesn't need glasses for distance work. My mother-in-law does not require spectacles for near, intermediate, or distance vision. The point of the story is they both had cataracts, they had different goals for their respective cataract surgeries and *both ended up happy with their outcome*. My hope is that ***the information in this supplement, and your attention to the goals of each of your patients at the time of cataract surgery, will provide the means to maximize their post-surgical satisfaction.***

Richard Potvin, Guest Editor

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Laser Assisted, Image-guided Cataract Surgery: The Operating Room of the Future is Here

John F. Blaylock, MD, FRCSC

Michael S. Petrik, OD

INTRODUCTION

Cataract surgery has seen tremendous development in the past few years, such that we like to think the “Operating Room of the Future” is beginning to emerge. Pre-operative imaging systems tied to femtosecond lasers, coupled with high-resolution anterior segment ultrasound and Star Wars generation tracking capability provide an unprecedented level of precision to the surgery. The cataract surgical systems that remove the crystalline lens also continue to evolve, and new instruments allow intraoperative measurements of the eye. The hope of refractive/cataract surgeons is that these futuristic systems will be safer and provide more predictable refractive outcomes when performing cataract surgery.

Our high-volume practice strives to stay at the forefront of technology, provided we see potential benefits to the patient. We converted to all-laser LASIK in 2006. Our use of a femtosecond laser system for cataract surgery dates back to 2013, and we have incorporated the Verion™ Image-Guided System since 2014. As such, we believe we are in a unique position to comment on many of the questions around these emerging technologies. Despite the obvious promise and enthusiasm, controversy surrounds the technology. Is it safer? Are the outcomes better? Is there a positive cost-benefit ratio for patients? What follows is a brief overview of the various technologies mentioned above, along with our comments on the implementation of each and how they have affected our surgical procedures and clinical outcomes.

Imaging Systems

Infrared cameras and sophisticated tracking algorithms have led to the ability to reliably track an eye, based on features such as the iris and/or limbal vasculature. Incorporating these technologies into an imaging system has introduced a new level of precision to our measurements of the eye. For instance, our clinic has implemented the Verion™ Image Guided System (Alcon). When we capture an image and subsequent keratometry for the purpose of calculating intraocular lens power, that information is linked. Subsequent keratometry measures on the same instrument would be “registered” to the same eye image, improving inter-test reliability. The same image and eye data can be imported into the femtosecond laser system (described below). This allows us to correct for eye position, including cyclotorsion (the rotation of the eye when a patient moves from sitting up to lying down), which is typically several degrees.¹ The image can also be imported into a heads-up display on the surgical microscope (Luxor™, Alcon). This improves the accuracy of our surgical planning and improves the placement of our toric intraocular lens (IOL). Figure 1 shows the alignment marks and heads-up display in the surgical microscope when a toric IOL is being aligned in the eye after cataract extraction.

The Laser-Assisted Cataract Surgery Procedure

It is helpful to be reminded of the original femtosecond laser systems for ocular use; they were applied to traditional LASIK. All-laser LASIK has become the premier LASIK refractive procedure available today.

We initially learned the art of interfacing femtosecond lasers with patients in 2006 for all-laser LASIK. The process of coupling or docking the patient to the interface platforms required a new skill set and a broadening of focus by the surgeon on very large data sets of information to

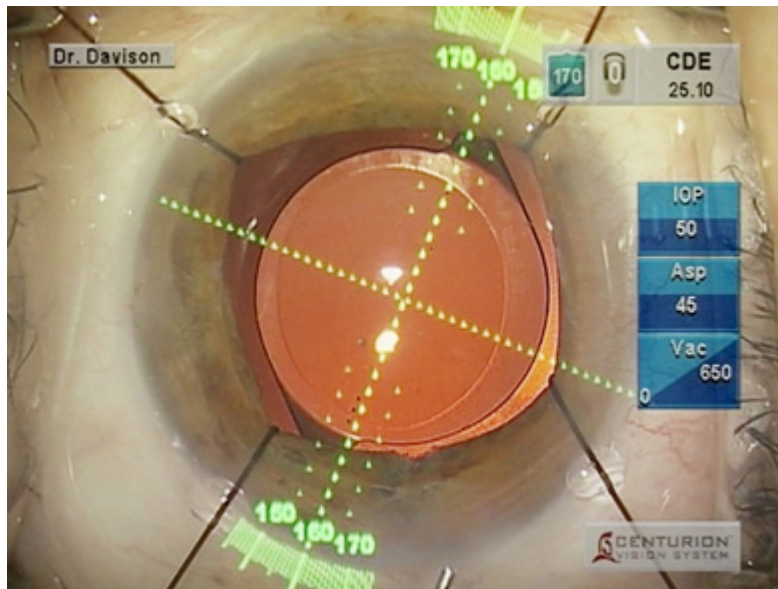


Figure 1. Heads-up display of the Verion™ Image Guided System for Toric IOL Alignment. Image courtesy of James Davison, MD. Used with permission

achieve safe, predictable, and eventually superior outcomes. There certainly are manual skills to be learned, but you need also learn to “operate with your mind.” What we mean is, there are a multitude of clinical options presenting in real time that require a fluency of choice and reaction in programming, above and beyond the usual manual responses that surgeons are adept at. This experience helped us to adapt to our femtosecond cataract system (the LenSx® Laser System, Alcon) quickly and safely. We were also well aware of the amazing potential these systems possess, perhaps more so than surgeons without a refractive background. This experience also helped us to become a surgical team of technologists, optometrists, and ophthalmologists, working together and responding to inputs from each member of the team during the surgical procedure. We think this is key to excellence and success.

We have personally performed over 1100 LenSx® procedures for cataract surgery and refractive lens exchange, with no significant surgical complication (we have observed five small anterior capsule tears). Understanding that the laser has to “see” what it is cutting, and developing the ability to interpret the imaging in real time, becomes the initial challenge for the surgical team. During our initial procedures, we felt intimidated by the technology as the laser was trying to guide us. But as we learned more and gained experience, we began to harness the technology and now feel we are using it as a versatile tool under our control. Our recollection is that it took between 100 and 150 cases before we were comfortable with the technology. This is similar to experiences reported from other practices.² From that point on we have found that we use the laser as a highly precise surgical cutting device and have become increasingly adept at the subtleties of placement of incisions, incision architecture, ideal location of capsulotomies, and relative energy levels.

The LenSx® Laser System we use is one of the most studied laser-assisted cataract surgery platforms. It uses optical coherence tomography (OCT) to provide clear anterior segment images³ to perform three cataract surgery steps. First is the creation of a circular opening at the anterior capsule (capsulotomy), followed by the cutting/softening of the nuclear cortical complex (fragmentation). Last is the creation of corneal incisions to gain access to the anterior chamber.⁴

We will review the essential steps involved in the laser-assisted cataract surgery procedure and discuss the current understanding, our clinical pearls, and controversies that apply to each part of the process.

Programming

The procedure begins with an initial plan developed for the location and dimensions of the incisions, both primary and secondary (tertiary if required), location and diameter of the capsulotomy, nuclear and cortical incision patterns to assist in lens disassembly, as well as arcuate corneal incision location and size. The optometrist enters the plan while the surgeon is marking the primary incision using the pilot digital marking device (Verion™, Alcon). The uploaded data are programmed into the laser, based on prior surgical planning; the technician completes this well in advance before entering the operating room. The optometrist also loads the patient interface kit that allows coupling of the patient eye to the femtosecond laser system. In the near future, the marking step will be eliminated.

Docking

Before performing the laser steps, the system must be docked onto the eye in such a way as to provide excellent stability and centration without applying too much pressure to the eye. Increased pressure or intraocular pressure (IOP) may result in corneal folds that impact visualization of the ocular structures.⁵ The recent update to the LenSx® docking device decreases the likelihood of corneal folds.⁶ Generally, the increase in IOP induced by the docking device is considered safe,⁷ with no reported macular changes, compared with conventional cataract surgery.⁸ The less time the eye remains docked, the lower the likelihood of ocular complications;⁹ the LenSx® device has been noted to be especially efficient in this regard.⁷ In our practice, the patient is rolled under the interface kit, lying supine on a specialized operating table that is able to roll in any direction.

The most difficult manual aspect of the surgery is learning to dock or interface the patient with the laser technology. We have developed our own technique that we call “power dock.” The docking system is designed to be universal, but some of our patients were undockable (less than one percent). Ironically, patient compliance was not a significant impediment, as even Parkinson’s and moderately noncompliant Alzheimer’s patients do well. In our experience, unsuccessful docking was seldom due to the type of speculum and was more associated with unusual corneal curvature or severe dry eye. In these few cases, we reverted to bladed manual technique.

Upgrades to the patient interface design have significantly increased docking success and patient comfort. We have performed LenSx® cataract procedures on patients with mild to moderate nystagmus with success, converting a difficult procedure into a relatively easy one.

Once docking is accomplished, we further refine the surgical plan and orient the treatment on the alignment from the digital marker (Verion™, Alcon). This amounts to a conversation among the technician, optometrist, and ophthalmologist regarding all steps of the surgery and some good-natured debate of what the best alignment is.

Primary, Secondary, or Tertiary Incisions

Laser-created incisions have been demonstrated to improve accuracy, safety, and predictability over incisions created manually with a blade, presumably by improving incision architecture and inducing less corneal edema.¹⁰

The most challenging part of femtosecond laser-assisted surgery for us was mastering the primary and secondary incisions. At first, they always seemed to be slightly misplaced and failed to seal easily at the end of surgery. By learning to place the incision as peripherally as possible and experimenting with corneal wound architecture, we obtained well-sealing incisions with highly predictable surgically induced astigmatism (important for toric IOL planning). We are able to adjust internal and external wound dimensions, the number of planes, and the slope and length of the incisions. We continue to modify our incisions for different lenses and techniques. Learning how to efficiently open the incisions was a fairly steep learning curve in the early cases, as was managing incomplete incisions.

Arcuate Incisions

The wonderful improvement in creating near perfect arcuate incisions easily and predictably using digital markers (Verion™, Alcon) can lead to improved refractive outcomes for patients. Using digital markers, messy and inaccurate manual marking techniques are replaced with real-time placement of incisions to within a degree of predicted axis (personal observation). The planning is performed at the initial measurements prior to surgery and networked to the operating room for the surgery. They can be fine-tuned in the operating room easily. The digital markers incorporate physician optimization so patients can be rescanned after surgery to determine outcomes, giving better predictability of subsequent results. We are still in the early phase of harnessing the full potential of these systems.

Capsulotomy

Laser-created capsulotomies have improved centration, regularity, and circularity over manually created capsulotomies; this allows the intraocular lens to have a more stable position.¹¹ A stable IOL position may mean less IOL tilt, coma aberrations,¹² and improvement in the predictability of refractive outcomes.¹³ This is an important consideration when implanting patients with aspheric, multifocal, and/or toric IOLs. One study demonstrated that more patients implanted with a multifocal IOL had 20/25 or better uncorrected distance visual acuity if they received laser-assisted cataract surgery, as opposed to conventional manual cataract surgery.¹⁴

The most dramatic part of the procedure to the observer is the capsulotomy. You can choose the diameter to within a tenth of a millimeter and centre the opening to your preference, line of sight, or pupil centre. In agreement with results in the literature, our capsulotomies are virtually perfect and far superior in predictable dimension than manual techniques. None of our minor anterior capsule tears occurred during the LenSx® treatment, but were caused by the surgeon (JFB) during quadrant removal with phacoemulsification.

Lens Fragmentation

Femtosecond laser systems have incorporated many patterns of lens fragmentation, including quadrant chopping and cylinder dissection. Figure 2 shows a matrix pattern that efficiently disassembles the nuclear cortical complex. The key to all these patterns is to fragment the lens as much and as efficiently as possible, while ensuring the anterior and posterior capsules remain intact. This requires sophisticated imaging and adjustment for the grade of cataract. Efficient laser fragmentation significantly reduces the amount of time and energy spent on cataract extraction once the eye is opened.

With the acquisition of our femtosecond laser system, our plan was to operate on every patient who came into the operating room, regardless of how difficult the anatomy appeared or how difficult the cataract appeared. We have been able to use the laser successfully in almost all cases.

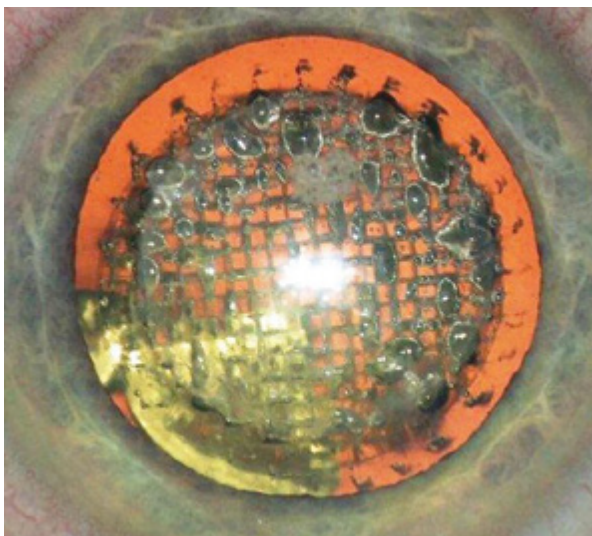


Figure 2. A femtosecond laser fragmentation pattern.

The Cataract Removal System

Phacoemulsification is the term used for the ultrasonic breakup of the crystalline lens, which introduces energy into the eye and causes turbulence in the anterior chamber. The harder the cataract, the more phaco energy is generally required; minimal energy is the goal. Femtosecond laser fragmentation has led to a 50% reduction in phacoemulsification time in our clinical experience and an additional 50% reduction when we obtained the latest generation phacoemulsification unit (Centurion®, Alcon).

We expect phaco times to reach near zero with the new matrix patterns. These results agree with the literature reporting reduced phacoemulsification time and endothelial cell loss with the laser-assisted cataract surgery, over manual cataract surgery.¹⁵ This may be especially advantageous in eyes with a compromised corneal endothelium.¹⁶ We have significantly reduced the amount of manipulation required to remove the nuclear and cortical material and believe the technology is far safer for pseudo-exfoliation patients as well. We have learned to treat even hyper-mature cataracts with fewer complications than expected. Even white cataracts are successfully treated. We are still obligated to remove the nuclear and cortical material manually after laser disassembly, but it is less injurious to the eye and therefore safer. Our experience agrees with literature suggesting this laser technology can be applied in complex cases where ocular spaces may be small, less stable, and harder to maneuver.¹⁶

Intraoperative Aberrometry Systems

The provision of a precise emmetropic correction to each patient is the goal of every surgery. Modern biometry provides measurements that bring us close to this goal, but some patients have anatomical features that are outside the norm, on which intraocular lenses power calculations are based. This is particularly true, of course, with patients who have had previous kerato-refractive surgery, such as LASIK. There are significant challenges to calculating the correct IOL power for such eyes.¹⁷ It is also more difficult to calculate toric IOL power in patients with significant posterior corneal astigmatism.

One of the recent innovations to try to address this issue is the introduction of intra-operative aberrometers. One example, the Wavetec ORA system, attaches directly to the surgical microscope and allows surgeons to measure the wavefront of the eye once the crystalline lens has been removed. Clinically significant improvements in the results of cataract surgery for post-LASIK patients have been demonstrated.¹⁸ This technology may have the potential to reduce the percentage of patients with “refractive surprises” after cataract surgery. The technology continues to evolve and we are following it closely.

CONCLUSION

The “Operating Room of the Future” is really a mythical notion that surgeons pursue as medical technology evolves. What was science fiction yesterday is applied science in our operating rooms today.

This modern approach begins in the examining room, prior to surgery, and starts with a discussion about surgical options for patients. There is an intuitive feeling by patients that lasers are better, safer, and the newest technology available. That leads to high patient interest and a lessening of patient anxiety about their surgery. Patients find the procedure simple and painless and perceive it as less invasive than bladed surgery.¹⁹ The “Operating Room of the Future” consists of a fully networked operating room where preoperative diagnostics and planning devices are networked with intra-operative tracking devices. These are then integrated through the microscope, phacoemulsification, and femtosecond laser systems.

Perhaps the most interesting perspective is how these systems allow the integration of optometry and ophthalmology. In our operating room, the optometrist (MSP) programs the laser during the first part of the surgery. This gives us the ability to have a conversation about every patient and what is the best location, the best angle, and how to maximize the efficiency of the surgery or alter planning “on the fly” if required. Optometrists have an in-depth knowledge

and appreciation for refractive dynamics and optical theory and understand the “operating with the mind” aspect of the procedure intuitively. The laser is an amazing tool, but it is dependent on the team to be used efficiently and effectively. This makes an optometrist a favourable assistant, under the medical guidance of the ophthalmologist, when running lasers in future operating suites.

Currently, most surgeons are primarily interested in the femtosecond laser; however, this is only a part of the process of the evolution of surgery in modern operating rooms. The femtosecond laser is just one of several new tools among a sophisticated orchestra of complex technologies used in the cutting-edge operating theatre. Several supplementary devices perform data collection, image acquisition, surgical planning, live eye tracking, and surgical optimization. As we learn to harness the orchestration of these devices, we expect to see even better outcomes.

To answer our original questions: Are they safer? We believe so. Are the refractive outcomes better? Certainly. Is there a positive cost-to-benefit ratio? It depends.

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Intraocular Lenses in Canada

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I. INTRODUCTION

Modern-day cataract surgery, depending on the patient's desired visual outcomes, can be considered a refractive surgery. The surgeon aims to provide a correction that meets the patient's desire for spectacle independence. Choosing the best intraocular lens (IOL) to meet each patient's specific visual needs is a critical step during cataract surgery consultation. Unfortunately, choices are often not apparent to patients; a recent survey suggests that 45% of cataract surgery patients did not recall discussing their IOL options with their doctor.¹ Presenting to patients their lens options will help them make a more informed decision on what would work best for their lifestyle; this can have a positive impact on postoperative satisfaction and in building the physician-patient relationship.

Currently, there are four main IOL options for your patients to consider. The first is a standard spherical intraocular lens that corrects the patient's eye at one focal point, either distance, intermediate, or near; this option is available at no cost to patients in Canada. The second is a single-focus aspheric IOL, which has been demonstrated to improve visual quality, specifically at dusk or night, when compared to the standard spherical option.² Third is a toric IOL option (usually also aspheric), which has been shown to be safe and effective at reducing corneal astigmatism of 0.75D or higher.^{3,4} The fourth option is a presbyopia-correcting IOL, which includes accommodative and multifocal designs, as well as accommodative and multifocal toric options. The majority of presbyopia-correcting IOLs are also aspheric. The following is a review of the basics of IOL material and design, with a description of the most commonly implanted IOLs in Canada used routinely in uncomplicated refractive cataract surgery.

II. IOL MATERIALS AND DESIGNS

Lens material and design play an important role in IOL performance. Together they affect IOL stability and are the most significant determinant of posterior capsular opacification (PCO), the "secondary cataract" that can occur when lens epithelial cells proliferate between the lens and the posterior capsule.⁵ Lens material also affects spectral transmission, an important consideration because of the potential negative effects of ultraviolet and short-wavelength blue light on the retina.⁶

A. IOL Material

Some of the most common IOL materials in use today are polymethylmethacrylate (PMMA), silicone, hydrophilic acrylic, and hydrophobic acrylic. The PMMA material is not usually used in routine cases, primarily because IOLs made of PMMA are not foldable and therefore require a larger incision. Smaller incisions are generally preferred for cataract surgery, as they decrease recovery time and reduce the variability and magnitude of surgically induced astigmatism.⁷

At present, hydrophobic acrylic IOLs are the most commonly implanted. When compared to hydrophilic acrylic IOLs, hydrophobic acrylic IOLs have been shown to have a lower rate of neodymium-doped yttrium aluminum garnet (Nd:YAG) capsulotomy (the creation of an opening in the posterior capsule to resolve the effects of PCO).⁸ This is attributed to its greater bioadhesion to the capsule, relative to other materials.⁹ By virtue of their chemical makeup, hydrophobic acrylic lenses attract fibronectin to bind to their surface; this allows a strong bond

between the fibronectin on the IOL and the collagen of the posterior capsule.⁹ The resulting lower capsulotomy rates noted above contribute significantly to health economic evaluations that suggest hydrophobic acrylic IOLs are more cost-effective than PMMA, hydrophilic acrylic, and silicone IOLs.^{8,10}

Even inside the hydrophobic acrylic category of IOL there are measurable differences in performance, attributed to differences in the specific material composition.¹¹ When compared with other hydrophobic acrylic IOLs, the AcrySof® IOL (Alcon, Inc.) has been demonstrated to result in lower Nd:YAG rates,¹² better bioadhesion,¹³ and better capsular biocompatibility.¹⁴

Greater bioadhesive force not only decreases the likelihood of needing a Nd:YAG⁹ capsulotomy; it also contributes to lens stability. This is particularly important when implanting aspheric,¹⁵ toric, and multifocal IOLs, because significant rotation or decentration of these IOLs can compromise visual outcomes. Most important in this regard is the rotational stability of a toric IOL, as there is a 3% reduction in effectiveness with each degree of misalignment of these lenses. Mean rotation for the AcrySof® spherical lens has been reported at less than two degrees.¹⁶ The Tecnis® Toric IOL (Abbott Medical Optics, Inc.) exhibits similar rotational stability.¹⁷

B. IOL Design

Posterior chamber IOLs have two main features. The first is the central optic, the size and shape of which dictates the refractive properties of the lens. The second feature is the “arms,” or haptics, that serve to centre the optic in the bag. Most modern IOLs are a one-piece design, though three-piece designs (with two haptics made of different materials, attached to a central optic) are used in some situations.

1. Optic Edge

There is a large body of literature suggesting that a square or less rounded posterior optic edge design reduces PCO and the associated need for laser capsulotomy, relative to a round-edge design.¹¹ It is hypothesized that the more square the edge is, the stronger the contact between the posterior lens optic and the posterior capsule; a strong contact between these two surfaces is thought to inhibit lens epithelial cell migration and subsequent PCO formation.¹⁸ Most hydrophobic acrylic IOLs have a square-edge design.^{11,18}

2. Haptics

As noted above, there are two main IOL types, categorized by their haptics. A three-piece IOL generally has two relatively rigid PMMA haptics and a central optic made from the base IOL material. A one-piece IOL is continuous, with a smooth transition from the central optic to the haptics. The most commonly used lens in routine cataract procedures is a one-piece IOL. One piece IOLs appear to be more stable in the capsular bag;¹⁹ it has been suggested that when the three-piece lens is placed in the capsular bag, the angle of the haptics may change, causing the lens to move more anteriorly. This anterior displacement may result in slightly less stable effective lens position and, therefore, slightly more variable postoperative refractions, when compared with the one-piece lens.²⁰ Complementing material bioadhesion, the haptics of a one-piece IOL provide additional stability and support; this has been demonstrated in bench and clinical studies related to the one-piece AcrySof® lens.^{21,22} However, three-piece IOLs are very useful in the case of an anterior or posterior capsular tear and the need of a sulcus fixated IOL. A single-piece IOL should not be placed in the sulcus, as it can cause complications.

C. UV and Blue Light-Filtration

Almost all IOL manufacturers have a UV cut-off filter to block the potentially negative effects of UVA and UVB light on the retina. In addition, some IOL manufacturers include a blue-filtering chromophore to reduce the amount of blue light entering the eye; the Alcon Natural chromophore, for instance, has a spectral transmission curve similar to that of an adult crystalline lens.²³ Figure 1 illustrates the effect of this filter on a series of patients, comparing their contrast sensitivity to age-matched phakic patients with clear lenses and pseudophakic patients with a similar lens that did not have the blue light-filtering chromophore; there was no

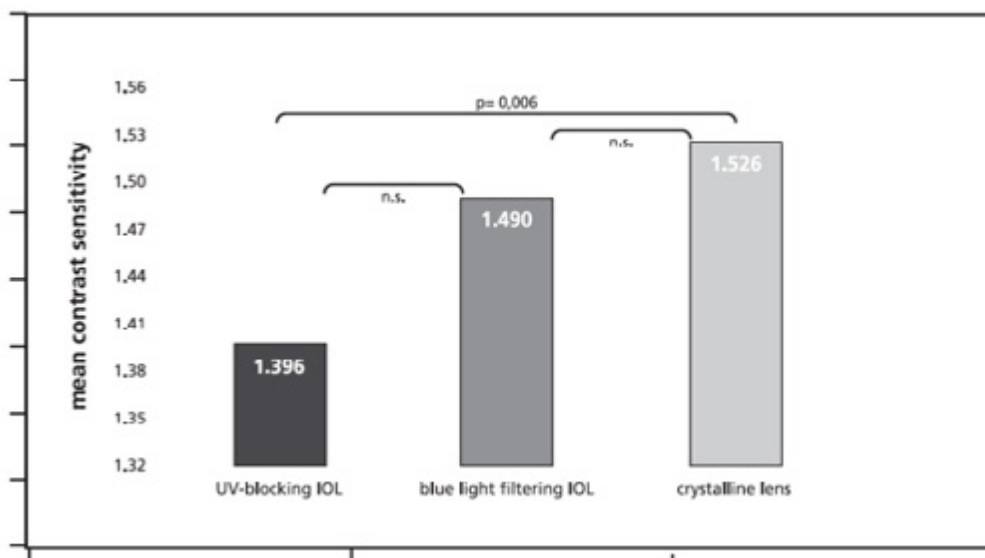


Figure 1. The clear crystalline lens has a mean contrast sensitivity closer to a blue light- filtering lens than to the UV-blocking lens.²³

statistically significant difference between the blue light filtering IOL and the natural crystalline lens.²³

Some studies have suggested there may be a decrease in contrast from a blue-filtering chromophore;²⁴ while mesopic contrast sensitivity is marginally lower with BLF IOLs, the amount is not visually significant.²⁵ Visual acuity, contrast sensitivity, and colour vision under photopic light conditions did not differ between blue light-filtering and clear IOLs.²⁶ Other studies have shown that the chromophore does not impact the quality of vision;²⁷ visual acuity, colour perception,²⁸ and contrast sensitivity are largely unaffected.^{29,30} In one study, implanting the BLF IOL resulted in better low-contrast acuity when compared to age-matched patients with clear phakic lenses.³¹ Lenses that filter blue light might actually decrease glare and improve photo-stress recovery time, relative to clear IOLs.³² In one driving simulation study, patients implanted with a blue light-filtering IOL noted less glare and had fewer (simulated) vehicle collisions than those implanted with clear lenses.^{33,34} The lack of any visual compromise is not surprising, as the estimated 14% of scotopic light filtered by the natural chromophore is noted by one author as “visually inconsequential,” given the four-log unit range of human scotopic sensitivity; the same author suggests it would be “improbable” that any difference in scotopic vision could be reliably detected.²⁵ On balance, blue light filtration similar to that of the adult crystalline lens appears warranted; it has a potential protective effect with no significant visual impact.

III. IOL TYPES

The material and IOL design considerations above provide a platform on which the optic design element of the lens can be built. As noted in the introduction, there are four common types of IOLs available in Canada: spherical, aspheric, toric, and presbyopia-correcting, although some lenses may contain one or more of these elements (e.g. an aspheric multi-focal toric IOL).

A. Aspheric IOL

The human cornea has positive spherical aberration (SA), while the crystalline lens has negative SA that compensates.³⁵ A spherical IOL design has positive spherical aberration, increasing the net SA in a pseudophakic eye.³⁵ Aspheric lenses are designed to address this, reducing net SA in the eye and thereby improving visual quality.³⁵ The effect of SA in a lens increases with greater distance from the optical centre, so the benefits of correcting SA are more evident when the pupil is larger; eyes with pupil diameters ≥ 4 mm in dim light are more likely

to benefit from aspheric IOLs.³⁵ The measured SA of the eye is lower with aspheric lenses,^{36,2} lowering higher-order aberrations overall when compared to the spherical option.² An aspheric IOL is also likely to improve contrast sensitivity² under low illumination.^{37,38}

Different IOL models have differing levels of asphericity, from a level designed only to correct the spherical aberration in the IOL to a level that compensates entirely for the IOL and corneal asphericity in the average eye.³⁹ Clinical studies suggest that eliminating all aberrations may not be ideal and that some residual spherical aberration may be beneficial in increasing depth of focus⁴⁰ and improving contrast sensitivity.⁴¹

B. Toric IOL:

A patient may be considered a candidate for toric IOL implantation if their corneal astigmatism is greater than or equal to 0.75D.³ Generally, the threshold for treating against-the-rule corneal astigmatism is lower than that for with-the-rule astigmatism.⁴² This is due to the fact that most technology currently available does not measure posterior corneal astigmatism, which is typically against-the-rule and should be considered when evaluating total corneal astigmatism. Only the corneal astigmatism is considered here because the preoperative refractive astigmatism is a function of total astigmatism, including the contribution from the crystalline lens, which is (of course) removed at the time of surgery. When selecting patients for toric IOL implantation, few ocular comorbidities are likely to impact successful outcomes.⁴³ For instance, the surgeon may elect to implant a non-toric IOL in cases of irregular corneal astigmatism or unstable corneal astigmatism.

The AcrySof[®] toric IOL is one of the most commonly used toric lenses; it demonstrates excellent stability as a result of its strong adhesion to the capsule and the support of its haptics.⁴⁴ AcrySof[®] toric IOLs can correct up to 4.0D of corneal astigmatism. Toric IOLs are generally very stable. Rotation can occur, most frequently within the first two weeks postoperative.⁴⁵ Patients with long/large eyes appear more at risk for IOL rotation.⁴⁵ A study demonstrated that 91% of the AcrySof[®] toric IOLs rotated by five degrees or less.⁴⁶ Similar results have been reported for the Tecnis[®] toric IOL.¹⁷ Rotational stability is important because one degree of rotational misalignment results in approximately a 3% loss in astigmatism correction.⁴⁶ Generally speaking, less than 10 degrees of IOL misalignment is unlikely to significantly impact patient satisfaction.⁴⁷

Toric IOLs have been shown to significantly reduce postoperative astigmatism relative to preoperative corneal astigmatism, from a mean of 1.7D to 0.4D six months after surgery, in one Canadian study.⁴⁶ Patients with high and low levels of preoperative corneal astigmatism can benefit from toric IOLs.^{3,4} Figure 2 shows the difference in postoperative astigmatism reduction between the toric and monofocal IOL.³ In patients with low preoperative astigmatism, no

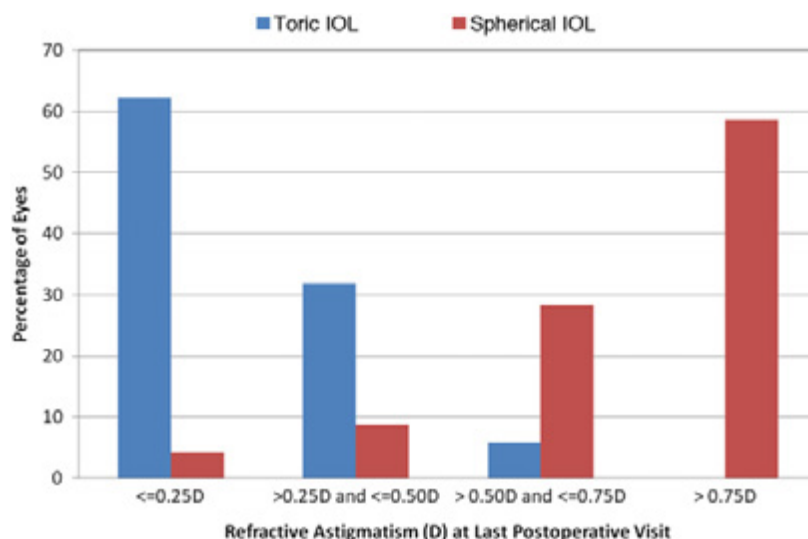


Figure 2. Toric intraocular lenses reduce astigmatism significantly more than monofocal IOLs in patients with low levels of preoperative astigmatism.³

reduction in postoperative astigmatism could be demonstrated with monofocal IOLs.³ Patients with corneal astigmatism $\geq 0.75\text{D}$ are likely to benefit from a discussion about toric IOLs.

Multiple large clinical studies have demonstrated that more astigmatic patients receiving toric IOLs achieved 20/25 or better uncorrected vision, with correspondingly higher spectacle independence for distance vision, when compared to those receiving a spherical IOL.^{46,48} Spectacle independence after bilateral toric IOL implantation has been associated with reduced lifetime costs for the patient, when compared with monofocal IOLs.⁴⁹ Aberrations, visual quality, and quality of life were improved in those patients receiving toric IOL correction, compared with those who received a spherical correction.⁵⁰

Although there are other means of correcting low amounts of corneal astigmatism, such as corneal relaxing incisions, the use of toric IOLs appears to reduce higher amounts of astigmatism with less variability.^{51,52,53} Spectacle independence and contrast sensitivity under low illumination have been reported to be better with toric IOLs, compared with relaxing incisions.⁵⁴ Visual outcomes have been reported to be better with toric IOLs, but studies have been comparing incisions made with a blade.⁵⁴

C. Presbyopia-Correcting IOLs:

1. Monovision:

Monovision IOL options generally correct the dominant eye for distance and the non-dominant eye for near. The success with monovision may largely depend on the level of ocular dominance: the greater the patient favours one eye for distance or near, the less likely they are to be a good candidate for monovision.⁵⁵ The degree to which a patient can tolerate monovision, and how much they can tolerate, can be easily tested with contact lenses. In order to preserve binocular function, low amounts of correction for near is targeted for the non-dominant eye.⁵⁶ One study suggests that leaving the non-dominant eye with 0.25 to 1.25D of residual myopia will minimize binocular function difficulties,⁵⁷ but this level of near correction is likely to leave the patient with higher spectacle dependence than multifocal IOLs.⁵⁸ To improve the rate of spectacle independence, one study suggested implanting a monofocal IOL in the dominant eye and a multifocal IOL in the non-dominant eye.⁵⁹

2. Accommodative Lenses:

Only one accommodative IOL is currently approved for use in Canada: the single-optic Crystalens® accommodative IOL. This IOL is designed with a flexible optic-haptic junction, allowing for potential movement of the lens anteriorly for near viewing and posteriorly for distance viewing.^{60,61} One study demonstrated posterior, instead of the expected anterior, motion during an accommodative attempt,⁶⁰ and another reported variable movement distances.⁶² The single optic design means all light is focused at one point, which has the potential benefit of avoiding the visual disturbances associated with multifocal IOL designs.

Results with the Crystalens® IOL have been mixed. Some studies have reported the Crystalens® IOL improved near and intermediate vision without compromising distance vision, compared to a monofocal IOL.⁶⁰ In another study, the Crystalens® IOL was demonstrated to have similar near VA, better intermediate vision, as well as less starbursts and halos when compared with multifocal IOLs; however, the authors of this study claim the placement of the lens and targeting -0.5D in one of the eyes could be part of the reason for these results.⁶³ Several other studies failed to show any real accommodation or motion taking place with the Crystalens® IOL,^{60,64} while others report near VA similar to that for patients receiving monovision corrections of -0.25D and -0.75D .^{62,65} These findings raised a concern over the unpredictability of outcomes with this accommodative IOL.⁶²

Studies of accommodative lenses have yet to demonstrate a stable, predictable, accommodative effect. Capsular fibrosis after surgery is likely to limit movement of an IOL in the long term. The material and design of accommodative IOLs also makes them more prone to posterior capsule opacification, necessitating a higher rate of laser capsulotomy.⁶¹ Laser capsulotomy will alter the forces affecting the lens capsule and can affect lens position for any accommodative IOL.

designed to move with capsular force.^{61,65} For these reasons, despite their single-focus design, current accommodative IOLs are not as popular among cataract surgeons as multifocal IOLs.

3. Multifocal Lenses:

Multifocal IOLs provide near vision to patients through separating light into a near and distance focus; this can be achieved with a refractive or diffractive design. Refractive designs have specific concentric or asymmetric zones for near vision, which makes them pupil-dependent and sensitive to centration.^{66,67} Transition zones are also required to avoid discontinuities on the optical surface. Asymmetric designs increase ocular aberrations that are not radially symmetric, such as coma.⁶⁸

A diffractive multifocal IOL works by using a diffractive element to split the incoming light into a distance focus and near focus.⁶⁹ There are no specific distance or near zones, so there is less sensitivity to centration.

There are two common diffractive lens technologies available in Canada, one is a full-optic diffractive and the other an apodized diffractive. The Tecnis® multifocal is a full-optic diffractive that splits the light evenly between distance and near foci for every pupil size. The AcrySof® ReSTOR® lens is an apodized diffractive lens with a peripheral distance-only annulus and a diffractive design that reduces the amount of near light as the pupil gets larger.^{66,70} Figure 3 illustrates the light distribution pattern for two different versions of the ReSTOR® IOL; the 2.5D version is designed to provide more distance-dominant vision.⁷¹ This design allows better distance vision in dim light (larger pupil) and better near vision in bright light (smaller pupil).⁷⁰ A full-optic diffractive lens will be pupil independent, providing more light for near vision with a larger pupil, but increasing the potential for visual disturbances, such as glare and halos.⁶⁹

There is a large body of literature available related to the performance of multifocal IOLs. A meta-analysis of 16 trials looking at 1608 patients concluded that multifocal IOLs significantly improve near vision without compromising distance vision, when compared to monofocal IOLs.⁷² Compared to monofocal IOLs, multifocal IOLs have been shown to increase spectacle independence and⁷² provide better pseudo-accommodation and higher patient satisfaction.⁷³ Multifocal IOLs do not appear to impact stereoacuity⁷⁴ but may compromise the optical quality⁷¹

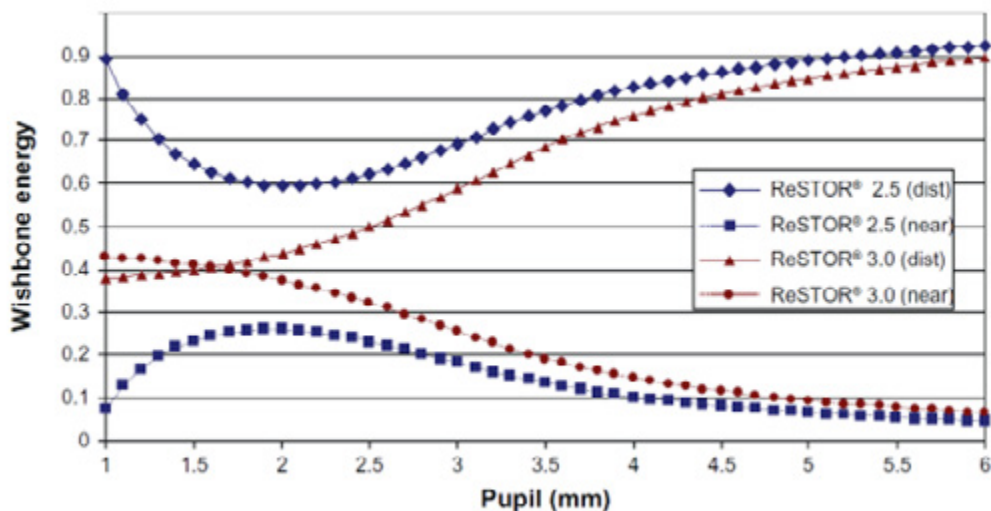


Figure 3. Apodized diffractive multifocal intraocular design showing the difference in light distribution between the +3.0D and +2.5D adds⁷¹

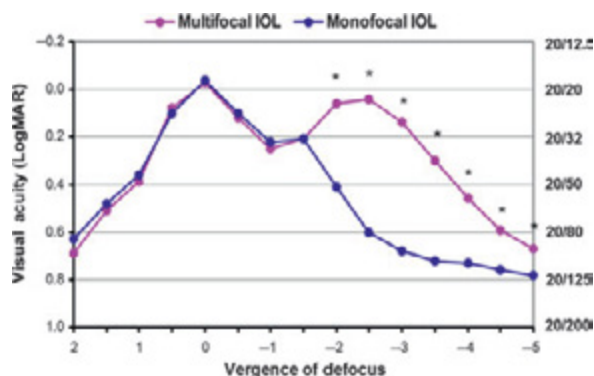


Figure 4. A defocus curve: visual acuity at a range of defocus using an aspheric apodized diffractive multifocal intraocular lens (IOL) with +3.0D add and an aspheric monofocal IOL⁷⁶ (predictive of visual acuity at the equivalent distance: e.g., -2.0D = 50 cm).

with more spherical aberration,⁷⁵ halos,⁷² straylight,⁷⁶ and reduced contrast sensitivity,^{72,73,75} this is a function of the defocused second image. In most cases, the perception of visual disturbances decreases with time, presumably as a result of neural adaptation.⁷⁷

The range of clear vision with multifocal IOLs is an important topic that has been addressed in multiple studies. One of the larger studies examining this found that multifocal IOLs improved binocular intermediate and near vision, ranging from 50–20 cm, significantly more than monofocal IOLs. Figure 4 shows that, unlike the monofocal IOL, which demonstrates 20/20 VA only at distance, the multifocal IOL provides 20/20 VA at distance and similar VA at 50–40 cm for near tasks. Patients implanted with multifocal IOLs experience 20/40 or better VA over a greater range of distances than patients implanted with monofocal IOLs.⁷⁶

4. Accommodative and Multifocal Toric Lenses:

Residual astigmatism after multifocal IOL implantation is known to reduce the effectiveness of multifocal IOLs.⁷⁸ Before the advent of presbyopia-correcting toric IOLs, the surgeon required a non-lens related method to correct astigmatism, such as refractive surgery or corneal relaxing incisions. An accommodative toric IOL is now available; the first available data on its clinical performance suggest it effectively reduces astigmatism and improves distance and intermediate vision, but near vision correction remains problematic.⁷⁹

Diffractive multifocal toric IOLs are also available for presbyopic patients with ≥ 0.75 D of corneal astigmatism who are motivated to be spectacle-free.⁸⁰ The ReSTOR® Toric multifocal IOL combines the ReSTOR® and AcrySof® IQ Toric IOL designs to provide multifocal and astigmatism correction.⁸¹ Performance is similar to spherical multifocals; in one study all eyes implanted with a multifocal toric IOL had uncorrected distance VA of 20/30 or better and uncorrected near VA of 20/40 or better. The mean astigmatism was reduced from 1.04D preoperatively to 0.21D postoperatively and IOL rotation was less than five degrees in all cases.⁸¹ Three quarters of patients in another study had less than 0.5D of refractive astigmatism postoperatively, 20/32 or better average VA across distances from far to 33 cm.⁸² Patients receiving multifocal toric IOLs report being more satisfied and with greater spectacle independence, when compared to patients receiving monofocal toric IOLs.⁸⁰ The Tecnis® multifocal also has a toric IOL variation available.

IV. CONCLUSION

IOL selection should be discussed with and tailored to your patient's lifestyle to optimize their personal visual outcomes. Advancements in IOL design and materials provide modern lenses with excellent stability and low complication rates. The addition of asphericity and light filtration improves visual quality and safety. Astigmatism and presbyopia can safely and effectively be corrected, separately or together, to increase the potential for your patient's freedom from spectacles postoperatively. A strong understanding of available lens choices

will allow for a helpful discussion of these options with your patients, empowering them to choose the best lens to meet their visual needs and potentially contributing to their postoperative quality of life.

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Patient Factors Affecting the Success of Cataract Surgery

Richard Potvin, MASc, OD

Other articles in this supplement discuss new technology in cataract surgery and new intraocular lens (IOL) options. While of considerable interest, it is important to remember these are both just contributing factors to the ultimate objective of the surgery—addressing the visual needs of your patient. As their primary care provider, you have the privilege and responsibility to ensure that each patient has their best outcome.

As you know, with exceptions such as trauma, the development of a cataract is generally a slow and continuous process, not an overnight event. Your patients will have a lot of time between when you identify lenticular changes in a slit lamp examination and when their cataract may be removed. This provides you with the time to prepare your patients for surgery, including discussing their operative and IOL options.

Your opinions and recommendations matter to your patients. A recent telephone survey of 1,000 respondents over age 50 years, classified by self-reported cataract status, demonstrated this. Respondents were screened to include 500 who reported never being diagnosed with cataracts, 250 who reported they had been diagnosed with cataracts but had not had surgery and 250 who reported they had cataract surgery in both eyes in the past five years. In the last two groups, 41% of those who had not yet had surgery and 81% of those who had surgery indicated that their doctor's recommendation significantly influenced their decision.¹

Outlined below are some of the factors that can aid you in helping your patients to understand the surgery, their options, and how they (and you) can ensure their most successful result. Comments are related to the “typical” cataract surgery case and do not reflect the additional issues associated with special cases, such as pediatric cataracts or traumatic cataracts.

Patient Awareness and Preoperative Considerations

At some point during their examination, a patient may comment to you that they notice halos around lights while driving at night, or they might state that things appear blurry and their glasses don't seem to help the situation. Alternatively, they may not notice any change in their vision, but you may detect early nuclear sclerosis or other cataractous changes in their lens. Or, you may notice a decrease in their best-corrected spectacle acuity. At this point, discussion of their “emerging cataract” would be in order.

There is a current question as to whether cataracts are being diagnosed early enough. For instance, in the telephone survey noted above, one-quarter of the 500 respondents who reported not having been diagnosed with cataracts reported difficulty with glare and halos in another part of the survey.¹ It may be that the criteria the eye care professional was using for diagnosing their cataracts did not include such consideration. This would not be unusual, as a loss of several lines of high-contrast acuity has often been considered an appropriate indicator of significant cataract. Even where questionnaires or other objective measures additional to visual acuity are included in the preoperative evaluation, some patient's disability is not adequately quantified.⁹ A discussion with the patient regarding their visual quality is always appropriate. One of the challenges here is that the change with cataracts can be gradual, so the loss of visual quality is sometimes not apparent to the patient.

A more recent diagnostic paradigm for evaluating the need for cataract surgery is the loss of visual function that interferes with normal activities, such as driving at night. More appropriate diagnostic tests include contrast-sensitivity testing, glare testing, or questioning the patient regarding the effects of vision on their lifestyle, since even objective tests may fail to determine the extent of a patient's visual disability. There have been a number of recent efforts to design new objective tests to improve the ability to detect the effects of cataract before changes in high-contrast acuity are noted.^{10,11}

A clinical recommendation from the Canadian Ophthalmological Society Cataract Surgery Clinical Practice Guideline Expert Committee reflects the need to consider all aspects of vision: Cataract surgery is indicated primarily for the correction of *visual impairment* that cannot be adequately improved non-surgically and that is directly attributable to the presence of a lens opacity.¹²

Visual impairment is defined to include considerations such as loss of resolution of fine detail, an increase in observed glare, and halos or binocular vision issues; these effects may be situational, only occurring at night, for instance. This reinforces the notion that a loss of high-contrast visual acuity is not the standard by which referral for cataract surgery should be made. However, it must be noted that when visual acuity drops below a given specified standard for an activity (e.g., driving or piloting an aircraft), surgery is indicated even if the patient reports no visual impairment, if the reduction in acuity is attributable to the crystalline lens.

Earlier diagnosis and referral of cataracts can positively impact patients' well-being. Earlier treatment of cataracts has shown significant benefits in terms of both patient safety and quality of life.^{13,14} In particular, cataract surgery has been determined to significantly reduce the incidence of motor vehicle accidents, all other things being equal.^{15,16} Earlier referral based on recognizing that waiting times can be long is also a factor. A systematic review of the literature, conducted to evaluate the effects of waiting time for cataract surgery in Canada, showed that significant visual deterioration can be observed during the waiting period, even when it is as short as six months.¹⁷ Visual acuity changes can be as high as 3 logMAR lines of acuity per year in patients diagnosed with cataract.¹⁸ A separate Canadian study documented significant visual acuity changes and associated depression in patients waiting for surgery.¹⁹

The suggestion that earlier diagnosis and referral can be beneficial is supported by comments from respondents to the telephone survey mentioned above. In the group that had surgery, 68% of respondents (170/250) "strongly agreed" they were surprised at how much their vision improved, while 62% (155/250) "strongly agreed" that they were happy they had cataract surgery and wished they had done it sooner.¹

At the point where a cataract (even if early) has been mentioned to your patient, you have an opportunity to educate them with regard to modern cataract surgery, including the surgery itself and the IOL options they can consider.

Discussing the typical surgical experience with them well before they are scheduled to see a surgeon can be helpful. Respondents to the survey referenced above¹ noted fear as an emotion associated with eye surgery; familiarizing your patient with the nature of modern cataract surgery can significantly allay this fear. By raising the possibility of surgery well in advance, it also gives interested patients the chance to research the topic on their own. The Internet is a common source for more information; a recent survey indicates that 59% of US adults looked online for health information within the past year.²⁰ Usage rates are likely similar in Canada.

One survey evaluated the preoperative information shared with cataract patients²¹ and found the five questions that patients appeared most interested in were as follows:

- What are the chances my vision will improve?
- When will my vision improve?
- What is the overall risk of me losing vision after the operation?
- What is the effect if I choose not to have the surgery?

- What are the most serious complications that might occur?

The results above were reported in 2004, when options for IOLs were more limited, and refractive outcomes were more variable. It is interesting to compare these concerns with the topics of interest in the telephone survey mentioned early, which was conducted in 2013.¹ The top five issues discussed by the respondents who had talked to a doctor about cataract surgery were the following:

- The benefits of having surgery and how it can improve my vision
- A description of the surgery procedure
- The recovery from the cataract surgery
- That I may be able to wear glasses less often
- The different types of lenses that can be implanted during cataract surgery

For optometrists educating patients regarding cataract surgery, both of these lists are helpful in understanding the most important patient concerns.

The differences in the survey responses noted above illustrates a shift in the cataract surgery paradigm; cataract surgery is increasingly being considered a refractive surgery, where the post-operative refraction of the patient is of greater interest than it was in the past. This is a function of more accurate IOL power calculations and more accurate biometry, measuring the variables that contribute to IOL power, primarily axial length. It is also a function of the increase in IOL options for your patient. As recently as 15 years ago the discussion regarding the intraocular lens to be used might only have been about the IOL material, as every lens had only spherical power. Today there are aspheric IOLs to improve image quality, toric IOLs to reduce the effects of astigmatism, presbyopia-correcting IOLs to provide better near vision while preserving distance vision, and presbyopia-correcting toric IOLs. These IOL options are discussed in detail in an article by Braga-Mele and Makari in this supplement. Here the focus is how to help your patients choose their best option.

Discussing the correction of astigmatism at the time of cataract surgery is more straightforward in many respects than discussing the correction of presbyopia. Reviewing keratometry data, you might inquire of a patient who has more than 1.0D of corneal astigmatism whether they would be interested in depending less on their glasses for distance vision. In a recent Canadian toric IOL study, 120 patients were implanted with the AcrySof Toric IOL; postoperatively, 7 of 10 patients reported not requiring spectacles for distance vision, and 63% of patients had uncorrected binocular distance vision of 20/20 (0.0 logMAR) or better.²²

There is one case where discussing options for the correction of astigmatism may be more challenging. This occurs when your patient has significant corneal astigmatism but little to no refractive cylinder, usually due to compensating astigmatism from the crystalline lens. It is important to explain to the patient that after cataract surgery the crystalline lens will be removed, so the corneal astigmatism would no longer be compensated for. In order to maintain their low refractive cylinder, an intraocular lens with the same level of astigmatism as the lens being removed (i.e., a toric IOL) would be required.

There are no specific contraindications with toric IOLs that are not similar to those for a spherical IOL. However, toric IOL calculations are generally based on anterior corneal astigmatism. When your patient has significant posterior corneal astigmatism, the cylinder correction of the toric IOL may be lower. Research is underway to better understand this phenomenon, and some surgeons have advocated an adjustment factor to compensate for this effect.²³ As will be noted in the postoperative section of this article, there are methods to adjust toric IOL outcomes to improve astigmatism correction when postoperative residual cylinder is present.

As an alternative to toric IOLs, surgeons may attempt to correct low levels of corneal astigmatism, using limbal relaxing incisions, arcuate incisions of a predetermined length and depth (typically between 50% and 80% of corneal thickness). Previously performed by hand

with a blade, results have shown early variability (up to 10 weeks post-surgery) but long-term stability (10 weeks to 3 years).²⁴ Today, if a surgeon is using limbal relaxing incisions to correct astigmatism, they are more likely to be made with a femtosecond laser system, improving incision location, depth, and consistency.²⁵

The choice of patients for a presbyopia correcting option at the time of cataract surgery is perhaps more complex than choosing a lens to correct astigmatism, as there is no IOL at present that can accurately mimic a young crystalline lens; all options involve some compromise. Your role is to help your patient by pointing out the relative strengths and weaknesses of the many options they have available for addressing presbyopia.

The first question for your patient is whether they have any interest in reducing or eliminating their dependence on spectacles for both near and distance, or intermediate and distance. If there is no perceived benefit for your patient, then there can be no advantage to recommending a presbyopia correction. The greater your patient's interest in spectacle independence, the more likely they will tolerate any potential visual compromise. The discussion is best directed to the patient's activities and their lifestyle, rather than specific distances. For instance, "Would it interest you to know there is a lens that might let you drive and read in bed, without the use of spectacles?" sounds more patient-friendly than "Would you be interested in a diffractive multifocal IOL that provides 80% of patients with visual acuity of 20/32 at 6 m, 60 cm, and 40 cm?"

The simplest choice for presbyopia correction involves use of monofocal IOLs to provide a permanent monovision solution to patients. This can be particularly effective with patients who are using monovision in a contact lens modality. If this is the case, they have demonstrated their ability to adjust to the anisometropia. If they are interested in monovision as a cataract surgery option, then it would be helpful to fit them in contact lenses with monovision. In this manner, they can experience the effect in a temporary fashion and determine if it is right for them. Patients who can tolerate monovision have best visual function when the non-dominant eye has an add of 1.5D or less.²⁶ As a function of this, the monovision option is not ideal for patients who are interested in a higher likelihood of not needing spectacles for near vision; monovision with a high add increases visual symptoms, reduces contrast acuity, and can increase binocular vision issues.²⁷

Accommodating IOLs are also available in Canada, including a toric-accommodating IOL; these lenses are discussed in detail in the IOL article. Accommodating IOLs do not "split light," so the potential for visual disturbances is not as high as with multifocal IOLs. However, as with the monovision approach, caution must be exercised with these lenses if your patient has a strong desire to read without spectacles; accommodating IOLs appear best suited to individuals interested in distance and intermediate vision.

If patients are interested in spectacle independence for near and distance vision, multifocal IOLs provide them the highest likelihood of achieving this goal. Multifocal IOLs are those IOLs that focus light at one or more focal points, to provide clear vision at near and distance, for instance. Diffractive multifocal IOLs are most common. They provide demonstrably better near vision than monofocal IOLs and accommodating IOLs. In particular, a meta-analysis of diffractive IOLs suggested that visual disturbances such as halos were similar across various platforms, but that the ReSTOR apodized diffractive design showed "better uncorrected near visual acuity, uncorrected distance visual acuity, and higher spectacle independence rates, compared with other multifocal IOLs."²⁸ The tradeoff for better near acuity is an increased potential for visual disturbances such as glare and halos. More details regarding multifocal IOL performance are found in the IOL article in this supplement.

When discussing advanced technology intraocular lens options, whether toric, presbyopia correcting, or both, it is important to appropriately qualify the expected outcomes. These advanced technology IOLs increase the likelihood of spectacle independence at distance (for toric IOLs) or at distance, intermediate and/or near (for presbyopia-correcting IOLs). Every

eye is different, and there are no guarantees. Clinical research demonstrates these increased likelihoods in study populations, but there will be outliers. This is important for your patient to understand and appreciate before surgery.

There is one more important thing to remember when discussing IOLs with a patient. These are not contact lenses. The biggest advantage in this regard is that the intraocular lens sits in a stable position near the nodal point of the eye. As a result, the decentration that can be common with bifocal or multifocal contact lenses, and the rotation that can often occur with toric contact lenses, will not be issues. There will be no visual fluctuation with blinking, unless the patient has dry eye, which has been discussed previously.

As a final comment about lens selection, numerous resources can help identify those patients most likely to be successful with these advanced technology IOLs. Companies are generally happy to share their clinical data from their approval studies, or from post-market studies. They are as interested in having successful outcomes as you are. The peer-reviewed literature is another good source, of course. For instance, the American Society of Cataract and Refractive Surgery (ASCRS) Cataract Clinical Committee published an article on relative indications and contraindications for the implantation of multifocal IOLs.²⁹

Whatever the IOL chosen, calculation of the appropriate IOL power for each eye is critical to a successful refractive outcome. This is important in all surgeries but perhaps more so when advanced technology IOLs are implanted, because the patient has paid a premium for a higher likelihood of not depending on spectacles as much after surgery. A large number of factors can influence the calculation of the appropriate IOL power for an eye. The two most important preoperative measures are keratometry and axial length. One of the most significant recent discoveries is the degree to which dry eye can affect keratometry measurement. A study of variability in keratometry readings in patients with normal or hyper-osmolar tears showed a significant difference between the two groups (Figure 1); results of the study are soon to be published in the *Journal of Cataract and Refractive Surgery*.³⁰ The differences are sufficiently high to affect IOL power calculation. Calculated IOL sphere power from the two keratometry readings differed by > 0.5D in 10% of hyper-osmolar eyes. The measurement of corneal astigmatism, important in calculating a toric IOL, was also affected: 17% of hyper-osmolar eyes had > 1D (diopter) of difference in keratometry cylinder values between two visits.

The results above raise the question of how prevalent dry eye is in the cataract surgery population. In a recent study, Trattler suggested that 4 of 5 cataract patients may have moderate to severe dry eye (Figure 2).³¹ Perhaps more importantly, he indicates that only 22% of the patients in this group had a diagnosis of dry eye before their surgical consult. This would suggest that optometrists are under-diagnosing dry eye, which, as noted above, can significantly affect their surgical outcome. This also suggests that one of the most significant impacts you might have on your patient's cataract surgery is preoperative management of their dry eye; having dry eye under control before their surgical referral is likely to improve the quality of the biometry at that referral visit. As noted earlier, this is particularly important with the use of advanced technology IOLs, such as toric or multifocal, where the patient is paying a premium for a higher likelihood of spectacle independence with these lenses.³²

A detailed discussion of the diagnosis and management of dry eye is beyond the scope of this article. It is helpful to note, though, that many patients in this age group may be asymptomatic, but exhibit signs of dry eye. Meibomian gland dysfunction (MGD) is a major contributor to dry eye in this age group;³³ using a dry eye therapy that includes consideration of the lipid layer is likely to be beneficial. Figure 3 shows how management of dry eye can positively impact the measurement of the cornea preoperatively.

There is an adage that if something is discussed preoperatively, it is a recognized risk and/or expectation. If something is discussed postoperatively it is a complication. In this context, through appropriate preoperative patient counseling, you can help reduce surgical complications. Appropriate preoperative education can also help set appropriate expectations.

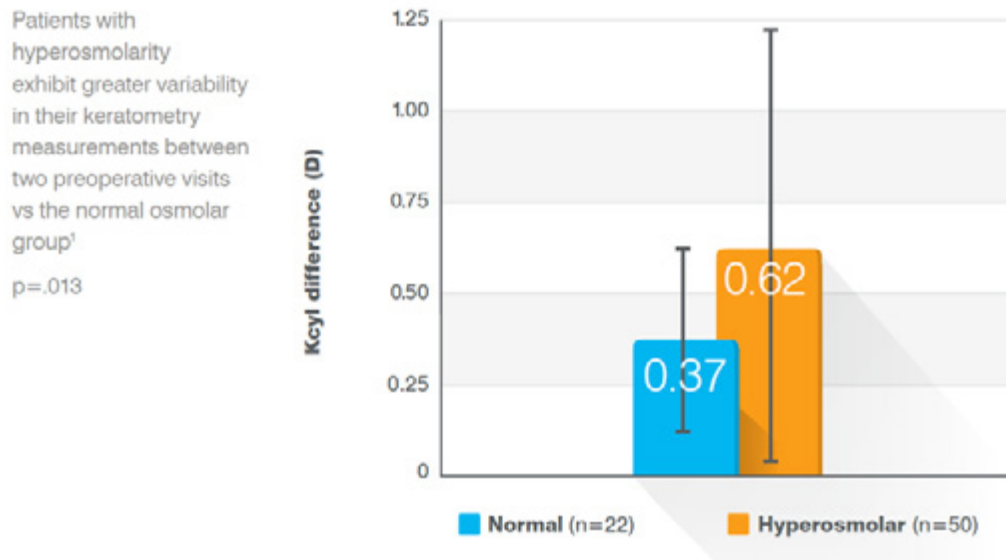


Figure 1. Effect of tear hyper-osmolarity on variability of K readings

Courtesy TearLab Corp. Used with permission. From: Epitropoulos AT, Matossian C, Berdy GJ, et al. The effect of tear osmolarity on repeatability of keratometry for cataract surgery planning. J Cataract Refract Surg. In Press.

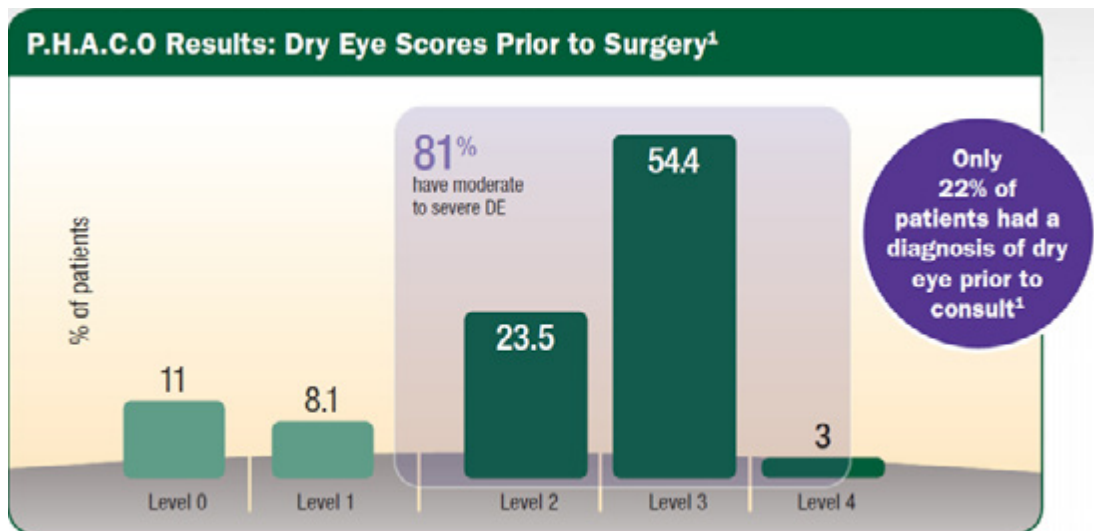


Figure 2. The prevalence of dry eye disease in the cataract surgery population

Adapted from: Trattler WB. Prevalence of dry eye in surgical populations; ASCRS Eye world CME Supplement; October 2013.

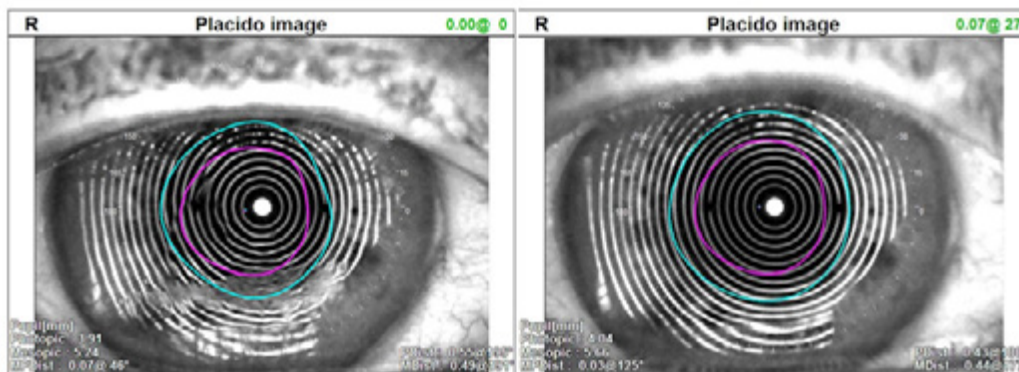


Figure 3. Pre- (left) and 1-month post-treatment (right) topography from a cataract patient with dry eyes (note the improvement in the quality of the ring reflections, particularly inferiorly).

Courtesy Cynthia Matossian, MD. Used with permission.

This is important because research has shown that the difference between what the patient expects and the eventual outcome (the “expectation–outcome gap”) is a primary driver of satisfaction with surgical procedures;^{34,35} a patient’s satisfaction with the surgical outcome of cataract surgery appears not only associated with the objective results, but also with preoperative education about options and expected results.³⁶

Surgical Referral

Once you and your patient have agreed cataract surgery is appropriate, a surgical referral is necessary. It can be helpful to have a relationship with the surgeon or surgeons in your area who perform cataract surgery. If you’ve never visited them, nor watched their surgery, it can be instructive to make some time for this, if the practice is amenable. It is also useful for you to know whether the surgical practice uses advanced technology IOLs. This can prevent confusion on the part of your patient if you discuss options such as a multifocal IOL and then refer them (inadvertently) to a practice that only implants traditional spherical monofocal lenses.

Outside of discussing the general surgery, it is also helpful if you can advise your patient of some likely surgical options, such as arcuate or limbal relaxing incisions for astigmatism management (if appropriate for the particular patient), the use of a femtosecond laser system during surgery, or the use of intra-operative diagnostic equipment to try to maximize the likelihood of an emmetropic result. You should be familiar with the advantages and disadvantages of these options and be able to provide some input for your patient. In their article “Laser Assisted, Image-guided Cataract Surgery: The Operating Room of the Future is Here” Blaylock and Petrik provide a useful overview of modern cataract surgery.

Your patient will be seen by the surgical practice preoperatively, and a series of diagnostic tests and biometry measurements will be made. This will include keratometry and axial length measurement at a minimum, as these values are required for calculation of the appropriate IOL power. Latest-generation formulas also benefit from anterior chamber depth measurement and crystalline lens thickness, as well as the patient’s manifest refraction.

As you will generally have seen your patient several times in the past few years, your practice can provide a number of helpful things to the surgery centre. One is the keratometry measurements for the patient. As noted in the preoperative considerations, dry eye can produce significant variability in keratometry. Showing consistency in the keratometry for the patient in the recent past is helpful; conversely, identifying variability may also be helpful. Note that any time keratometry measurements are provided, the instrument used should be recorded. Different keratometry and topography instruments measure at different radii from the corneal

apex, so there will be some inter-instrument variability.³⁷

Differences are most evident between keratometry systems (automated or manual) and simulated keratometry from topography systems. The average K reading for the eye will affect the calculation of the spherical power of the IOL to be implanted, while the corneal astigmatism measured will affect any calculations for the cylinder power in a toric IOL.

One of the other factors that can cause variability in keratometry readings preoperatively is the use of contact lenses. While rigid gas permeable lenses are generally deemed to have more of an effect on the anterior corneal curvature, there are measurable effects from soft contact lenses as well. Recent research suggests that a two-week period of non-contact lens wear is sufficient to resolve wear-related changes in corneal curvature in both cases.^{38,39} However, there is no substitute for demonstrated stability through a repeat keratometry measurement. Patients who might find this period of non-wear difficult should be reminded that variability in the measurement of corneal curvature would affect their IOL power calculation and therefore have a permanent impact on their postoperative refraction.

Another useful variable to provide to the surgical practice is the most-plus manifest refraction. The manifest refraction is included as a variable in several latest-generation IOL power calculation formulas. However, cataracts can cause a myopic shift.⁴⁰ The formulas benefit from the most-plus manifest refraction recorded in the past, unless pathology, trauma, or other considerations are likely to have influenced the refraction in the intervening time period.

As noted earlier, dry eye treatment prior to surgical referral is beneficial. Meibomian gland dysfunction has been addressed, but there is also the possibility of blepharitis. You should ensure that any blepharitis has been adequately treated before referral, as it has been reported as a primary reason for cancellation of surgery, due to the increased risk of endophthalmitis.⁴¹

Finally, it is helpful to the surgical practice if you can provide some indication of whether the patient has had the opportunity to discuss the available advanced technology intraocular lenses. The surgical practice is likely to have their own procedure for discussing lens options, based on such things as a patient questionnaire or particular diagnostic measurements (for instance, high corneal astigmatism). However, knowing that the patient has already been advised of the different IOL options now available in Canada, and having some sense of their interest in these technologies, has the potential to improve the patient–surgeon dialog.

The Surgery

Once your patient has completed their cataract referral visit, it is likely their surgery will be scheduled. The time for this will vary by surgeon. Blaylock and Petrik provided details of a modern cataract surgery in a separate article in this supplement.

Post-Surgery

In the immediate postoperative period, the surgeon will be managing the patient, to ensure the surgery was successful, or to deal with any complications. A same-day or one-day postoperative visit is general practice, as well as a follow-up visit at 1 to 2 weeks postoperative. Specific postoperative schedules will vary by surgeon or practice. Most surgeons will refer the patient back to the optometrist if the vision of the patient at this second postoperative visit is in the expected range and the patient is generally happy. At this time the patient will return to your care, though if you or the patient have any concerns related to the surgery, a referral back to the operating surgeon is appropriate.

In this early timeframe there can be refractive changes as the eye returns to its new physiological state. Corneal swelling, which can affect keratometry measures, generally resolves. If the IOL is placed in the lens capsule, the capsule will fibrose around the IOL, which is what provides positional stability to the lens; there can be refractive changes if the lens moves forward or backward in the eye while this takes place. Typically by one week, a stable spherical equivalent refraction will be achieved.⁴² In most patients with a toric IOL implanted,

the refractive cylinder will also be stable by this point, though in a small percentage of patients, the lens may exhibit some rotation, reducing the effectiveness of the astigmatism correction.

For your patients who elected a non-toric, non-presbyopia-correcting IOL and who had uncomplicated cataract surgery, their only need in the near term, relative to their cataract, is likely to be a new refraction and appropriate spectacles, if required. If they had a significant preoperative refraction, results from modern uncomplicated cataract surgery suggest their new refractive state will be much closer to emmetropia, or whatever refractive target was chosen preoperatively.⁴³ A high percentage of patients are likely to have good distance vision without correction. Complications after the immediate postoperative period are uncommon.^{43,44}

For your patients with a toric intraocular lens, their residual refractive astigmatism is going to be of greatest interest to them, followed by their manifest spherical equivalent refraction. Their refraction is likely to have stabilized in the first month after surgery. In the rare event that residual astigmatism remains an issue for them and you have ruled out other causes of visual compromise (e.g., dry eye, discussed below), then a referral back to the surgeon may be in order to discuss potential solutions.

For patients with a multifocal IOL, some patients will adapt very quickly to their new vision, but for others there will be an adaption period, which can be from six months to a year, in some cases.⁴⁷ It is important for your patients to appreciate this. Some patients will notice significant visual disturbances, while others will not, and the degree to which they bother the patient is also likely to vary.⁴⁸ While patients who are not satisfied with their vision in a multifocal will understandably discuss their problems with you, it can be helpful to remind them of the vision they've obtained as a result of the multifocal implant. If they can read at 40 cm, for instance, placing a -2.50D lens over both eyes will demonstrate what their near vision would be like without the multifocal.

In those patients dissatisfied with a multifocal IOL, the single greatest source of dissatisfaction appears to be residual refractive error. In a study that reviewed only dissatisfied patients, 64% were found to have significant residual ametropia or astigmatism.⁴⁹ In the same study, remediations such as post-cataract PRK and capsulotomy for posterior capsular opacification, resolved vision issues for 84% of dissatisfied patients; an IOL exchange was required in only 4% of eyes of these dissatisfied patients. In an unrelated study of 50 patients who had a multifocal IOL explanted, two common reasons were inability to adapt to the visual disturbances (e.g. glare/halos) and unrealistic expectations preoperatively.⁵⁰ As noted earlier, some of these can be avoided through appropriate preoperative counselling. A recent comprehensive review of the performance of multifocal versus monofocal IOLs concluded that motivation to achieve spectacle independence was an important success factor in multifocal IOL acceptance.⁵¹

A final comment related to your patient's satisfaction with their vision after cataract surgery is that dry eye can have a significant impact.³² Dry eye can be increased by the cataract surgery, though this effect appears to be temporary.⁵² It is relatively easy to isolate this issue because dry eye is likely to cause vision to fluctuate throughout the day, where such fluctuation would be highly unlikely to be a function of the IOL. If it is likely that dry eye is a contributing factor, it is prudent to manage that dry eye before any referral back to the surgeon.

Whatever IOL is implanted, you may be asked by the surgical practice to provide a brief follow-up report on your patient's postoperative status. This might include a refraction and summary of other findings that might have affected that refraction. This information can be used to "fine tune" the surgeon's IOL power calculations. Because you are more likely to see the patient at a time when their refraction has stabilized, which may take up to a month after surgery, the data you can provide the surgical practice will be very helpful.

In the longer term, typically a year or more post-surgery, a small percentage of patients may experience posterior capsular opacification (PCO), or what is often termed a *secondary cataract*. Treatment for PCO involves using a laser to create an opening in the posterior capsule. It is

typically a short outpatient procedure with immediate results. Patients may experience floaters for days or weeks as the posterior capsule material settles. Less common complications include cystoid macular edema and (very rarely) retinal detachment. High PCO rates are considered undesirable because PCO requires an additional procedure and adds to the overall economic burden of cataract surgery.⁵⁶ Referral for a laser capsulotomy is appropriate when slit lamp examination demonstrates an opacity behind the intraocular lens and the patient reports visual compromise, such as blurred vision, not correctable with spectacles. Other pathology should, of course, be ruled out.

In summary, while the information above is by no means comprehensive, it should provide you with an understanding of how you, as your patient's optometrist, can have a significant impact on the success (actual and perceived) of their cataract surgery.

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Patient Choice

Gilbert Sharpe, B.A.L.L.B, LL.M.

A patient's right to self-determination with respect to their health care underlies the doctrine of informed consent. Health practitioners support this right through education and open communication with their patients. This article reflects on the role of optometrists in educating a patient who is considering cataract surgery.

More generally, informed consent requires that a patient receive the information that a reasonable person in the circumstances would need in order to make a fully informed decision. A patient must receive an adequate explanation about the nature of the proposed treatment and its anticipated outcome, as well as the risks involved and alternatives available.¹ The patient must also receive responses to his or her requests for additional information.

While optometrists themselves do not perform cataract surgery in Canada, they play a key role in educating patients about the surgical and non-surgical options to manage and treat cataracts. Optometrists are increasingly the first regulated health professional to diagnose a cataract and may recommend referral to a cataract surgeon where surgery is indicated. Before making a referral for cataract surgery, the optometrist has an important role in discussing with patients what to expect from surgery and what their surgical options are.

Best practice guidelines issued by the College of Optometrists of Ontario indicate that cataract patients should be provided with the following:

- General information, including a description of the procedure, expected outcomes, normal healing course, and expected postoperative care schedule and procedures
- Benefits, including potential improvement in visual acuity
- Potential risks, including possible surgical and healing complications, changes in optical quality, and potential adaptation problems associated with postsurgical status
- Provider options, such as available surgical facilities and surgeons, as well as those qualified to provide preoperative and/or postoperative care
- Practitioner responsibilities so patients are informed of who will provide each aspect of their care
- Details of any referral to a cataract surgeon

The guidelines indicate that “[counselling] may also include additional information such as A-scan technologies, intraocular lens (IOL) options and associated refractive surgical procedures.” I believe education provided to patients should encompass information about the range of insured and non-insured IOL options that are available and indicated. The provision of such information helps to support a patient's informed decision-making regarding cataract surgery in light of their individual goals and values. Having a discussion about these options early on might also aid optometrists in making the most appropriate referral, by matching the needs expressed by the patient and services offered by a particular ophthalmologist.

In providing information about upgraded lens options, optometrists should ensure patients are similarly informed about the insured options. In Canada, the provincial insurance plans generally cover a basic type of intraocular lens. By contrast, upgraded lens options generally

require the patient to pay additional costs out-of-pocket. After having been presented with all of the options, many patients will still opt for the basic insured lens. The objective is not to “up-sell” patients but rather to ensure each patient is armed with all the information they need to make an informed decision based on the range of available options—both insured and non-insured.

To support these discussions, it is important that optometrists maintain knowledge of current practices relating to cataract surgery and IOLs.

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EDITOR'S NOTE: PATIENT CHOICE

The article above provides important information regarding the professional care of your patients at the time of cataract surgery. This is a more complex issue today because patients diagnosed with cataracts in Canada have far more options to consider at the time of surgery than they did in the past; some of these options are covered by their health insurance, some may not be.

Standards of practice require us to provide appropriate vision care to each patient, from prescribing refractive correction to maximize vision, managing any ocular health issues with appropriate referral when necessary, and referring when signs of systemic disease or other observations warrant. We are expected to ensure patients have appropriate care in our facilities and to collaborate and communicate with other health care providers as the patient's condition requires. Importantly, we are also required to encourage patient decision-making, providing patients with the information they need to make their personal choices about treatment options (insured and non-insured), and ongoing care. These are important considerations, particularly with regard to cataract surgery – it's one of the more common referrals we may make in our practices. Increasing numbers of patients receive their initial diagnosis of cataract in our optometry offices during a routine ocular assessment.

In the context of patient care, it is our responsibility to know patients are likely to be presented with numerous surgical alternatives at the time of cataract surgery. This might include such things as the choice of including femtosecond laser technology in the procedure, or the choice of an advanced technology intraocular lens. Patients should have some sense of the advantages and disadvantages, potential benefits, and associated costs of such alternatives. Cost is an important discussion point, because some alternatives will have a non-insured component to them.

The ongoing working relationships between optometrists and ophthalmologists are unique arrangements, dictated by the needs of each patient. Working together with cataract surgeons to share patient history and patient expectations and ensuring patients are aware of the range of options that are available to them will help the patient receive the best overall care.

With Canada's aging population, you are likely to be referring a large number of patients for cataract surgery, so referral does not need to be considered an isolated event. Proactively reaching out to your local ophthalmologists to understand their expectations will help establish lines of communication that can contribute to successful surgical outcomes for all your patients. This has the potential to enhance each patient's overall experience with cataract surgery.

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