Intraocular lens choices for patients with glaucoma

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Purpose of review
To discuss the unique functional and structural changes in glaucoma and the impact on intraocular lens (IOL) selection.

Recent findings
Glaucoma is a common ocular disease. Functional and structural changes associated with glaucoma require special consideration in the patient who is undergoing cataract/IOL surgery. Decreased contrast sensitivity found in glaucoma may be enhanced by the use of aspheric IOLs. Small pupils and weakened zonules necessitate meticulous surgical technique and increase the risk of IOL dislocation, as does anterior capsular contraction. Posterior capsular opacification is a common postoperative complication and may be related to IOL material and design. Both anterior chamber depth and axial length may change in patients who have had trabeculectomy and should be considered in the preoperative plan. Multifocal IOLs may afford spectacle independence for patients; however, there is a paucity of data for their use in concurrent ocular disease.

Summary
Although there are challenges in performing cataract surgery in patients with glaucoma, excellent outcomes may be obtained with proper preoperative planning, meticulous intraoperative technique, and appropriate selection of IOL design.

Keywords
cataract surgery, glaucoma, intraocular lens

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Introduction

Just as the mantra in pediatric medicine states that children are not merely small adults, the mantra in ophthalmology should state that glaucoma patients are not merely cataract patients with optic disc changes or visual field defects. Glaucoma patients have unique functional and structural differences that affect the preoperative, intraoperative, and postoperative periods when undergoing cataract/intraocular lens (IOL) surgery. As well, there is the confounder of combined procedures and cataract surgery after primary glaucoma surgery. In this review, we will examine IOLs in the setting of glaucoma.

Functional changes in glaucoma

The visual field defects acquired in glaucoma are well established. There has been substantial research investigating the effect of cataract extraction on visual fields in patients with glaucoma. The majority of studies show an increase in mean deviation and a decrease in pattern standard deviation (PSD) [1–7], whereas others have shown no change in these measures [8], and still others reveal an increase in mean deviation and no change in PSD [9].

Patients with glaucoma often complain of decreased vision; however, when tested by Snellen or ETDRS, these patients may have excellent visual acuity, often as good as 20/20. Studies have elucidated that, although these patients may have good visual acuity, their complaints are not without merit, as they often will have decreased contrast sensitivity – an important visual function for day-to-day activities [10,11]. Contrast sensitivity is the visual function that allows one to differentiate the luminance between two appositional areas. Decreased contrast sensitivity is correlated with visual field loss in patients with glaucoma, and the evidence reveals that the disease affects contrast sensitivity preferentially as compared with visual acuity [10].

Great advancements have taken place in the field of cataract surgery in the past few decades. We have entered a time when mimicking the youthful eye is the goal for which many of our patients strive. The decrease in visual acuity and contrast sensitivity that occurs with age is partially caused by changes in the lens related to increased wavefront aberration. In most patients, the cornea has positive spherical aberration. In youth, the lens balances for this by inducing negative spherical aberration; however, as the lens ages, this decreases until the point when the lens itself also produces positive spherical aberration. It was hypothesized that an IOL that would correct for corneal spherical aberration would increase contrast sensitivity in the pseudophakic eye

[12]. The first available aspheric IOL was the Tecnis (Abbott Medical Optics, Santa Ana, California, USA), which has a modified prolate anterior surface and adds −0.27 μm of spheric aberration into the eye. Most companies now have an aspheric model. The advent of aspheric IOLs has given patients undergoing cataract extraction and IOL implantation a new option in treatment. These lenses reduce spherical aberrations, and thus, decrease the glare, halos, and other optical phenomena that give rise to patients' complaints. Moreover, these IOLs have been shown to increase contrast sensitivity in patients in which they were implanted. This situation may be of special importance in patients with glaucoma, as they are already suffering from decreased contrast sensitivity. A number of studies have shown that aspheric IOLs improve both mesopic and scotopic contrast sensitivity [13–26], whereas some have shown only improvement in contrast sensitivity under mesopic conditions [27–29], and still others have shown no improvement in contrast sensitivity [30–33], although some only evaluated patients under scotopic conditions [34,35]. Although none of these studies specifically investigates these effects in patients with glaucoma, it stands to reason that in a disease process that decreases contrast sensitivity, an attempt to increase contrast sensitivity would be beneficial to the patient. The one caveat that should be mentioned is that glaucoma patients often have weak zonules, as discussed later, and decentration of wavefront-corrected IOLs has the potential to distort vision with the induction of further higher-order aberrations more so than decentration of spherical lenses [36,37]. Lastly, the issue of spherical aberration is more relevant in the patients with larger pupils, as it is the more peripheral rays that are refracted more powerfully in spherical lenses that cause the problem.

Structural changes in glaucoma

The most commonly identified cause of primary open angle glaucoma is pseudoexfoliation syndrome (PXF) [38]. PXF is a condition of extracellular material deposition in the anterior chamber and other tissues of the body [39–44]. PXF is related to glaucoma [45] as well as cataract [38]. Patients with pseudoexfoliation have a tendency to have a poor response to pharmacologic dilation and may have weakened zonules, which may manifest as iridodonesis, phacodonesis, or lens subluxation/dislocation. These factors increase the risk of intraoperative zonular dialysis and postoperatively these patients have an increased risk of posterior capsular opacification, capsular phimosis, inflammation, and IOL dislocation [46–50].

Early studies have found a 5–10-fold increase in the rate of complications in cataract surgery in patients with PXF; however, more recent studies show these numbers to be less [51••]. Patients with PXF may have higher pressures in the postoperative phase [52]. Intraoperatively, many complications arise due to poor pupillary dilation and the subsequent small capsulorhexis. Zonular weakness in PXF should be evaluated preoperatively. Despite the zonulopathy, the anterior and posterior capsules appear to be equal in strength to those of patients without PXF, which affords the opportunity for the use of intraoperative capsular devices [51••]. As is the case with routine cataract surgery, appropriate use of ophthalmic viscosurgical devices (OVDs), a well centered and adequately sized continuous curvilinear capsulorhexis, hydrodissection, hydrodelineation, viscodissection, centered positioning during phacoemulsification and careful cortical clean-up are essential.

Studies have revealed that preoperative nonsteroidal anti-inflammatory medications (NSAIDs) in combination with mydriatics may improve intraoperative dilation [53,54]. As well, OVDs can be used to increase pupil size. Iris hooks can be inserted through small accessory incisions or a pupil expander ring can be inserted through the main incision. The decision of whether to expand the pupil as well as the method by which to do so should be a decision made by the individual surgeon based on comfort and experience.

There are a number of methods one can use to manage zonular weakness. A capsular tension ring (CTR), a circular polymethyl methacrylate (PMMA) device, can be inserted into the capsular bag to manage mild cases of zonular instability defined as less than or equal to four clock hours of dialysis [55–57]. CTRs have been shown to reduce intraoperative complications [58] and IOL decentration and tilt [59]. In cases of more severe zonular weakness, a modified capsular tension ring (mCTR) can be sutured to the sclera [60,61]. Moreover, a capsular tension segment (CTS) can be utilized as a surgical assistive device or a postoperative sutured fixation device in eyes with compromised capsules [62]. These devices may also be used in conjunction with a CTR. Lastly, iris hooks may be used to gently retract the anterior capsule during surgery.

Rigid PMMA IOLs have the advantage of added capsular support; however, as zonular weakness is often managed with a capsular support device, the need for a rigid IOL and their subsequent disadvantages, are outweighed by the advantages of newer foldable IOLs.

In the setting of zonular instability, sulcus placement of an IOL is not advised, as the loss of integrity may allow the IOL to decenter or dislocate. There are a number of options for IOL placement in the setting of capsular instability and zonular weakness and they will be discussed below with IOL dislocations.

As the newer acrylic IOLs unfold slower when inserted, there may be less trauma to the capsule and zonules and the reduced trauma of unfolding of one-piece IOLs may be an advantage over three-piece lenses [51••].

Complications in the setting of glaucoma

Concern has been raised regarding capsular and uveal biocompatibility of IOLs in glaucoma and PXF. Studies have shown that all of the current types of IOLs have excellent biocompatibility [63,64].

Early postoperative intraocular pressure spikes are more common in glaucoma patients than other patients undergoing cataract extraction and in eyes with PXF [65]. As well, glaucoma increases the risk of macular thickening postoperatively [66] and this can be treated with NSAIDs [67].

Posterior capsular opacification (PCO) is the most common visually significant complication after cataract surgery [68–77]. The cause is known to be a migration of lens epithelial cells into the visual axis and subsequent opacification [78–80]. The incidence has been reported to be between 15 and 50%. Many factors play a role in this wide range, including length of time of follow-up, variation in surgical technique, IOL material and IOL design. It was 10 years ago that Nishi *et al.* [81,82] discovered that a sharp bend in the capsule retarded cell migration and PCO formation and subsequently listed the factors involved in PCO formation, including IOL design, IOL material, and surgical technique. Some studies observed that IOL material is an important factor in PCO formation, with hydrophobic acrylic IOLs producing fewer cases of PCO than hydrophilic acrylic, silicone and PMMA, whereas others reveal the importance of a square edge in the prevention of PCO [83–100]. A recent Cochrane review revealed that sharp edges are an important factor in PCO incidence, regardless of IOL material [101] as well as a recent study from China [102]. Another recent study has elucidated that the 'sharpness' of the various IOLs is not equal, and this fact may play a role in the differing incidences of PCO [103]. Moreover, whereas some studies have exposed no difference in PCO rate between one-piece and three-piece IOLs [104,105], others have shown an increased incidence of PCO in one-piece IOLs compared with three-piece IOLs [106]. Studies have also investigated haptic angulation, and found that there is little difference in the rate of PCO formation [107].

Studies have been performed to investigate the rates of PCO during routine phacoemulsification and phacotrabeculectomy showing no difference, although the use of mitomycin-C (MMC) may be protective [108,109]. In a study specific to phacotrabeculectomy, there were higher incidences of PCO in groups implanted with silicone and PMMA lenses as compared to acrylic lenses [110], whereas another study showed no difference in PCO between silicone and acrylic lenses [111].

Anterior capsular opacification (ACO) may occur more frequently in the setting of silicone IOLs and this situation may increase the incidence of anterior capsular phimosis [112,113]. Anterior capsular contraction is related to age, blood-aqueous compromise and chronic inflammation, retained cortex, IOL material and design and compromised zonules [51••,114]. Anterior capsular contraction is more common in eyes that have been implanted with silicone lenses [115–118]. Decrease in the size of the capsulorhexis is also greater in eyes implanted with silicone IOLs [119,120]. Anterior capsular contraction has been observed more frequently in IOLs with round edges [116,121]; however, in other studies, it has been observed in lenses with square edges [122]. When opacification, contraction, or phimosis is detected, it should be treated either with laser or surgically, as soon as possible, to reduce the risk of IOL decentration or dislocation, which these have been associated with.

The precise incidence of IOL decentration and dislocation in glaucoma is not known. IOL dislocation may be higher with plate haptics than open haptics after laser capsulotomy [123]. There are a number of options for IOL implantation in patients with capsular or zonular instability, including anterior chamber IOLs (ACIOLs), iris-sutured posterior chamber IOLs (PCIOLs) scleral-sutured posterior chamber IOLs, and iris-claw IOLs. Open-loop anterior chamber IOLs are significantly better than the previous closed-loop design that has been associated with a high complication rate and worse best-corrected visual acuity (BCVA) [124]. Insertion of an anterior chamber IOL is the simplest surgical procedure for correction of aphakia. Disadvantages of anterior chamber IOLs include the need for appropriate sizing, large surgical incision of at least 6 mm, risk of corneal decompensation, worsening of glaucoma and chronic inflammation [125–127]. Iris-sutured posterior chamber IOLs using the McCannel-type technique have gained popularity recently [128]. Iris-suturing retains the benefits of a posterior chamber IOL and avoids the risks of trans-scleral suturing. This technique requires suturing to the fragile iris, which can lead to iris erosion, neovascularization, chaffing, iridodialysis, pigment dispersion syndrome, peripheral anterior synechiae, glaucoma and suture migration [129,130]. Scleral-sutured posterior chamber IOLs avoid some of the angle-related complications of anterior chamber IOLs as well as the difficulties with sizing and produce good visual outcomes with good anatomic and functional results. However, it is a technically more demanding procedure that requires scleral needle passes that risk intraocular hemorrhage,

suture breakage, externalized sutures, IOL tilt and endophthalmitis [131]. Currently, there is no definitive evidence to suggest that one technique is superior [132–134].

Combined procedures and cataract surgery after trabeculectomy

Performing cataract surgery in glaucoma patients often necessitates that the surgeon performs surgery in an already operated eye or perform a combined procedure. A study that compared PMMA lenses to silicone for phacotrabeculectomy showed increased inflammation in the silicone IOL group [135]. Another study revealed an early nonsustained increase in intraocular pressure (IOP) with acrylic lenses compared with silicone lenses after phacotrabeculectomy [136], whereas another study found no difference in postoperative IOP when comparing acrylic to PMMA lenses in phacotrabeculectomy [137].

A number of studies have exposed a decrease in axial length after glaucoma surgery from 0.1 to 0.9 mm [138–141], as well as an increase in with-the-rule astigmatism [142–146]. Studies have investigated refractive outcome after cataract surgery in eyes that had previously had trabeculectomy and found that the final refraction was reasonably predictable with no statistical difference between these patients and those individuals who had not had previous glaucoma surgery [147•,148]. Other studies have shown that although there is no statistically significant difference in the mean refraction between patients undergoing phacotrabeculectomy versus standard phacoemulsification, there were statistically more patients in the phacotrabeculectomy group with postoperative refractions greater than 1.00D predicted or a myopic shift of greater than 0.50D. Caution must be taken in higher myopic eyes, in younger patients due to scleral elasticity and in eyes with higher preoperative intraocular pressures as they are at risk for a hyperopic surprise. The surgeon should aim for slight myopia, −1.00D is the authors' preference. Surgeons should consider the use of noncontact biometry in these patients, as contact methods may deform the softer eyes.

Newer technologies

Studies have investigated the use of blue-light-filtering IOLs and their effect on contrast sensitivity. Whereas a number have shown no difference in contrast sensitivity [149–156], others have had differing results. One study showed that although there was no objective improvement in contrast sensitivity, some patients subjectively described an increase in contrast perception [157]. Another study revealed an increase in contrast sensitivity with blue-light-filtering IOLs in patients with diabetes [158]. Further studies have shown improvement at the lower spatial frequencies [159] and at the middle spatial frequencies [160].

The advent of multifocal intraocular lenses has provided patients undergoing cataract extraction and IOL implantation a new option in treatment. For those who would like to achieve spectacle independence, these lenses have this potential. Multifocal IOLs have multiple focal distances, usually one for reading, and one for distance. After multifocal IOL implantation, as few as 20% of patients require glasses, and of this 20%, the prescription is much less than would be required had a monofocal IOL been implanted [161]. Since their introduction in the 1980s, multifocal lenses have also improved greatly.

Multifocal IOLs are not without their downside, however. A recent Cochrane review concluded that, although patients who received multifocal IOLs achieved better near and overall vision, as well as spectacle independence, they also experience unwanted photic phenomenon, including haloes and glare [162]. Souza *et al.* [163] reported patients implanted with the AcrySof ReSTOR (Alcon Laboratories, Fort Worth, Texas, USA) versus the AcrySof SA60AT (Alcon Laboratories) had statistically lower monocular photopic contrast sensitivity. Ravalico revealed that the ReSTOR, ReZoom (Abbott Medical Optics, Santa Ana, California, USA) and Tecnis lenses all slightly decreased contrast sensitivity [164]. In their study of 466 patients, Steinert *et al.* [165] found that there was some loss of low contrast visual acuity. The Array multifocal IOL (Abbott Medical Optics) has been associated with reduced contrast sensitivity at low contrast levels [166,167]. A study that compared the AcrySof ReSTOR versus the AcrySof SA60AT also exposed that contrast sensitivity was lower with the multifocal IOL [168]. The above studies were performed with the previous spherical multifocal IOLs and with the advent of aspheric multifocal IOLs; some of the loss of contrast sensitivity may be ameliorated.

As both glaucoma and multifocal IOLs decrease contrast sensitivity, there has been much debate over whether multifocal IOL implantation into a glaucomatous eye is a reasonable practice [169,170]. To make matters more difficult, there is a paucity of data on the subject [171]. In what is currently the only study to assess multifocal IOLs in patients with eye disease, Kameth *et al.* [172] study 133 eyes in 111 patients, 29 of them had either glaucoma or ocular hypertension. Eleven eyes with glaucoma and six with ocular hypertension were stratified into the study group, receiving Array multifocal IOLs compared with the 12 who were implanted with monofocal IOLs (AMO SI 40 NB; Abbott Medical Optics). The only difference in the outcome of the two groups was that the patients who received the multifocal IOL had better near-visual acuity. The sample size in this study was small; however, it

demonstrates that people with previous eye disease can benefit from multifocal IOL implantation, and that aforementioned potential disturbances, in practice, were not as disruptive as previously thought.

Another consideration is the effect of these lenses on the monitoring of patients. A recent study revealed that multifocal intraocular lenses cause wavy artifacts on optical coherence tomography images [173•].

Currently, eye disease is a relative contraindication for multifocal IOL implantation and the benefits remain uncertain. Both glaucoma and multifocal IOLs affect contrast sensitivity; however, the impact of this situation on a patient's life is unknown and may be quite limited, as evidenced by a few small studies.

Patient selection will be crucial to implantation of multifocal IOLs and we suggest the following groups as potential candidates: glaucoma suspects and ocular hypertensive patients with no disc or visual field damage who have been stable; glaucoma patients with early or mild visual field damage that has been controlled and stable; and in patients with a level of glaucoma in the fellow eye that is similar, and not severe, advanced or progressive [170].

Lastly, the newer accommodative IOLs may be better for patients with concurrent ocular disease; however, at this time, this hypothesis remains to be proven as one must consider the risk of capsular contraction in these patients and that these IOLs require an intact accommodative system, whereas many of these patients may have weakened zonules. Furthermore, capsular contraction, which is more often found in PXF eyes, is a relative contraindication for accommodating IOLs.

Another premium IOL consideration is the astigmatism correcting lenses. The same issue of zonular instability must be considered as decentration of these lenses may induce significant refractive error.

Conclusion

Patients with glaucoma have unique functional and structural characteristics that should be considered prior to cataract surgery. Decreased contrast sensitivity may be improved with aspheric IOLs; however, if these lenses decenter, they may induce more aberration than spherical IOLs. Patients with glaucoma may have smaller pupils and zonular weakness that may be managed intraoperatively by meticulous surgical technique as well as adjunctive devices including capsular tension rings and segments. In the setting of zonular/capsular instability, there are a number of surgical options to place an IOL in good position including anterior chamber IOLs, iris-sutured posterior chamber IOLs, scleral-sutured posterior chamber IOLs, and iris-claw IOLs, although some may exacerbate glaucoma and should be tailored to the individual patient. PCO is a common postoperative problem and as it stands, surgical technique, IOL design and potentially IOL material may play a role in decreased incidence. Anterior chamber depth and axial length have been shown to change after glaucoma surgery and should be considered when calculating IOL power. Lastly, multifocal IOLs provide patients with the opportunity for spectacle independence. There is currently a paucity of data in patients with concurrent ocular disease and newer accommodative IOLs have yet to be studied in patients with glaucoma. Although cataract surgery in patients with glaucoma may have challenges, it affords us the opportunity to greatly improve the quality of life of our patients.

References and recommended reading

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Additional references related to this topic can also be found in the Current World Literature section in this issue (p. 156).

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