Cataract Surgery in Short and Long Eyes

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Hyperopes

Preoperative Discussion, Examination, and Planning

Hyperopic eyes present a unique challenge to cataract surgeons, and require distinct preoperative and intraoperative considerations. Axial lengths are usually shorter in hyperopic eyes, and may be less than 22 mm. Inaccurate measurements of the axial length will result in larger refractive errors compared to eyes with more common dimensions. An axial length that is 0.5 mm off may result in missing the target by 1.0 to 1.5 diopters in a normal eye; in a hyperopic eye, this could result in an error of 2.0 to 3.0 diopters. Optical means of assessing the axial length are preferred.

There are several ways to mitigate the risk of refractive surprise in hyperopic cataract surgery. Many surgeons prefer to operate on the non dominant eye first. Many also use multiple formulas and compare predicted and postoperative refractions to determine the most accurate formula, using this information to guide the lens selection for the dominant eye. Lens calculations in the axial hyperope are affected primarily by the estimated effective lens position (ELP). Because a high-power lens will commonly be implanted in a hyperope, changes in ELP will have greater refractive consequences. A variety of approaches are used to predict the ELP. Of the third generation formulas, the Hoffer Q is accepted as being more accurate in eyes with axial lengths less than 22 mm [1, 2]. Fourth and fifth generation formulas, such as the Ladas Super Formula, Haigis, Barrett II, Hill-RBF,

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Kane, and Holladay 2, are considered accurate in hyperopes because they use additional variables to predict the ELP; these include anterior chamber depth, age, horizontal white-to-white, lens thickness, and preoperative refraction [1].

Lens selection is important when operating on hyperopic eyes. Flexible haptics are preferable in a small capsular bag, and can be found in single-piece acrylic lenses, or 3 piece acrylic or silicone lenses. Hyperopic eyes require higher power lenses, and every effort should be made to use a single lens with the appropriate power. The surgeon may need to special order a lens outside of their regular consignment; one such example is the single-piece acrylic AcrySof SA60AT, which has powers available up to +40D in the United States. If the required power is greater than +40D, it may be necessary to "piggyback" using two separate intraocular lenses (IOLs.) This is best accomplished by implanting the higher power IOL in the capsular bag, letting the eye heal, selecting the second IOL based on the postoperative refractive results, and implanting the corresponding second IOL in the sulcus space. Using two acrylic lenses is thought to increase the risk of interlenticular opacification, so the surgeon should consider using two silicone lenses or mixing materials [3]. Care should also be taken when considering a piggyback technique to ensure that there is sufficient space in the posterior chamber to avoid uveitis-glaucoma-hyphema (UGH) syndrome.

Shorter eyes tend to have narrow anterior chambers, with a depth of 2 mm or less. The growth of a cataract can further shallow the anterior chamber, putting the corneal endothelial cells at increased risk during cataract surgery. Therefore, a thorough preoperative examination of the cornea, with attention to the endothelium, is warranted. Specular microscopy can be employed to quantify endothelial cell density in suspicious cases; this may help in preoperative counseling if it reveals an increased risk of pseudophakic corneal edema.

Intraoperative Considerations

It can be more difficult to maneuver inside a narrow anterior chamber, leading to a higher risk of trauma to the iris or corneal endothelium during hyperopic cataract surgery. A dispersive viscoelastic may be used to coat the corneal endothelium, followed by a cohesive viscoelastic to deepen the anterior chamber. The surgeon can also consider increasing the intraocular pressure infusion settings, as well as lowering the aspiration rate, to maintain a larger working space in the eye. If an anterior chamber is extremely narrow, preoperative mannitol may be administered to dehydrate the vitreous; care should be taken that the patient does not have any contraindications to mannitol, and the patient should be monitored closely with the help of anesthesiology. If these interventions fail to deepen the chamber adequately, a limited pars plana vitrectomy may be performed, removing 0.2–0.3 cm^3 of retro-lental vitreous with a 25-gauge cutter [4].

Care should be taken throughout the cataract surgery to keep the chamber as deep as possible. This may require refilling the eye with viscoelastic to prevent run out of the capsulorrhexis. Extra dispersive viscoelastic may be injected prior to phacoemulsification to further protect corneal endothelial cells.

Due to the proximity of the corneal endothelial cells in narrow chambers, phacoemulsification performed in the capsular bag is preferred to supracapsular techniques in order to prevent excessive corneal edema. A more anterior corneal incision may be beneficial in preventing iris prolapse. It is also important to note that standard corneal incisions on smaller eyes have a larger relative area and arc length, which can increase the astigmatic effect of the incisions, and may also prevent sufficient sealing of the wounds. Nanophthalmic eyes (AL < 20.5) have an increased risk of intraoperative and postoperative uveal effusions, and the surgeon may need to use scleral windows as a preventative measure [5]. While rare, choroidal hemorrhages are more common in smaller eyes.

Postoperative Follow Up

Hyperopic eyes are at greater risk for aqueous misdirection, which may not manifest immediately. The cataract surgeon should advise patients to call if they develop pain, or if their vision becomes progressively more blurry, as increasing myopia may be a sign of insidious aqueous misdirection. Hyperopic patients are at higher risk of corneal decompensation, and postoperative corneal edema should be monitored closely. If a piggyback technique is used, the surgeon should watch for the development of interlenticular fibrosis. Due to the higher risk of refractive surprises, a careful postoperative refraction should be performed with appropriate counseling on corrective procedures if desired. If a patient is to undergo cataract surgery in their second eye, the refractive outcome from the first surgery should help guide the selection of the lens for the second eye.

Myopes

Preoperative Discussion, Examination, and Planning

High myopia has profound effects on ocular health, and on outcomes after cataract surgery. It is therefore important for the surgeon to have a frank discussion with the patient about the general and individual risks of surgery. Of particular importance is the risk of rhegmatogenous retinal detachment (RRD.) At the initial evaluation, the patient should be counseled about the association of high axial length and retinal detachment [6, 7] Younger age, male sex, and vitreous loss during surgery are also reported risk factors for RRD after cataract extraction [6], and the confluence of these variables can make RRD significantly more likely in certain axial myopes. The patient should be taught the symptoms of retinal tear or detachment, including new floaters, flashing lights, and curtain-like visual field deficit. The patient should seek immediate care if any of these symptoms develop.

Long eyes with cataract are at high risk for comorbidities of the retina and optic nerve. Conditions associated with myopia include amblyopia, RRD, open angle glaucoma, and myopic macular degeneration with or without choroidal neovascularization [8, 9]. The cataract surgeon should perform a complete preoperative examination with attention to the macula, optic nerve, and retinal periphery. If significant myopic morphology is apparent, such as peripapillary atrophy, oval-shaped tilted disc, or degenerative changes of the macula, further testing is warranted. This testing should be based on the individual characteristics of the eye being evaluated. Testing may include optical coherence tomography (OCT) of the macula and nerve, visual field testing, and fluorescein angiography if choroidal neovascularization is suspected. If posterior staphylomatous changes are present B-scan ocular ultrasound should be obtained to assess the shape of the eye, which may affect foveation and the optically measured axial length. The cataract surgeon should not hesitate to refer to a retina specialist colleague for a scleral depressed examination of the periphery. Prophylactic laser retinopexy may be necessary if any symptomatic holes, tufts, or tears are present.

Lens calculations in the axial myope are affected primarily by corneal contour and the axial length. Because a low-power lens will be implanted, changes in effective lens position (ELP) have less refractive consequence. In a simple example, a lens with zero diopters of power has no vergence, and will not change with ELP. Similarly, low power positive or negative lenses are minimally affected by changes in ELP; however, very deep anterior chambers greater than 4 mm may impact the IOL calculation. It is important to have accurate measurements of the corneal curvature (K values,) but the greatest challenge in high axial myopia is often to obtain an accurate axial length (AL.) Again, optical means of measuring AL are preferred. Here the patient is instructed to fixate on a target, which aligns the biometer measurement beam with the fovea. Care should be taken with directly applying the AL value produced by an optical biometer, as biometers generally assume a constant refractive index of the eye. This assumption does not remain accurate in extremely long eyes, in which the vitreous cavity may represent a higher proportion of the measurement beam path. With older generation two-variable formulas, it was advisable for the surgeon to adjust AL measurements greater than 25 mm using the formula proposed by Wang and Koch [10]. Newer generation formulas such as the Ladas, Barrett Universal II, and Hill-RBF automatically account for measurement characteristics in long eyes.

Highly myopic eyes will need a low-power or even negative-power lens. The geometry of the lens implant changes at very low or negative powers. The most popular U.S. lens platforms begin at +5 to +6 diopters. Lenses below this power, or negative power lenses, are likely to employ a meniscus design. These lenses are commonly produced in one-diopter increments. Meniscus geometry shifts the optical principal plane relative to standard biconvex design, and thereby alters the effective lens position. Meniscus lens geometry is compared to biconvex designs in Fig. 1.

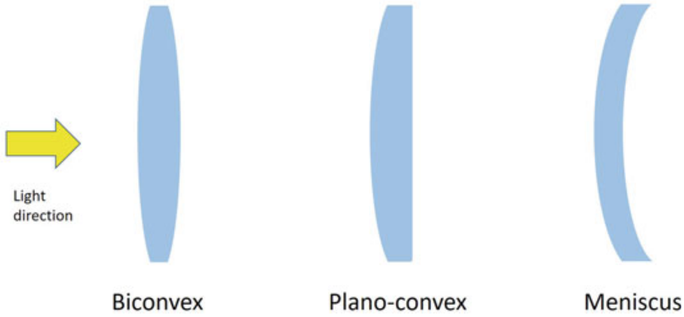


Fig. 1 Lens geometry of common IOL designs

Various means of adjusting lens calculation equations for high axial myopia have been employed. One strategy is to adjust the lens A-constant with each step in dioptric power of a meniscus lens platform [11, 12]. These optimized A-constants can be accessed at the User Group for Laser Interference Biometry (ULIB) online, and can be applied to standard formulae. A second proposed strategy is to adjust the axial length, using a formula that accounts for the effect of a longer biometry measurement beam path through the vitreous cavity [10, 13] Studies of axial myopes note that two variable formulae with axial length adjustment have lens power calculation accuracy comparable to fourth generation formulae [14, 15]. One study noted that the incidence of small hyperopic outcomes was reduced by using the Wang-Koch AL adjustment when compared to fourth-generation formulae [16]. Fourth-generation formulae use additional variables, such as anterior chamber depth or lens thickness, to increase accuracy in all eyes. The accuracy of these modern formulae have been analyzed repeatedly in the setting of high axial myopia. Excellent results have been achieved using the Barrett Universal II [15–19]. Hill-RBF [16, 19] and Olsen [17] formulae among others. One study of Chinese patients with extreme axial myopia found the Haigis less accurate in the subgroup with AL >30 mm [17]. For practical purposes, the authors recommend the surgeon become familiar with one or two modern formulas and apply it as intended by its creator(s), as not all formulae require measurement data adjustment of any kind. High quality outcomes can be achieved with several formulae, but all the above-referenced studies indicate high performance of the Barrett Universal II in high myopia.

Consider targeting residual myopia in patients with high axial length. Despite the advancement of biometry and lens calculation, it is still possible to end up with an unintentional hyperopic outcome if measurement error is introduced to any variables. The patient is habituated to myopia, and may appreciate the finer near vision afforded by low degrees of myopia. The surgeon should freely discuss the option of targeting near vision. In the past, it has been common practice to target one to two diopters of residual myopia. Given the advancement of lens calculation and formulas which use anterior chamber depth as a variable, the authors recommend targeting only 0.5 to one diopter of residual myopia if an emmetropic result is desired.

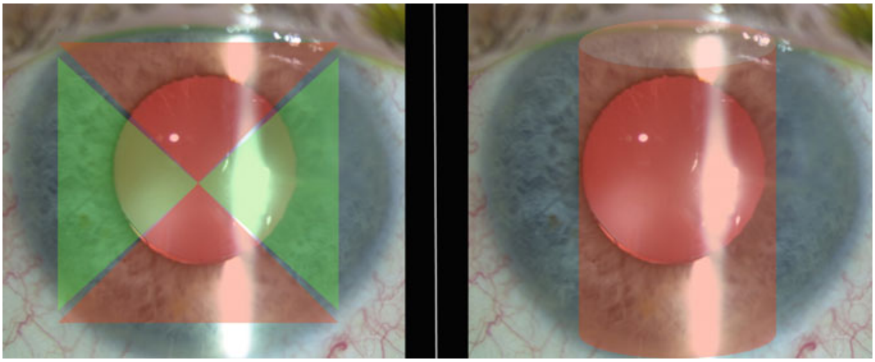


Fig. 2 The left image depicts an eye with postoperative refraction +1.00 −2.00×090. The excimer laser would steepen the horizontal axis, and flatten the vertical axis. The surgeon should avoid this situation, or consider postoperative limbal relaxing incisions. The right image depicts an eye with postoperative refraction plano −2.00 × 090, simplifying the ablation pattern

The approach to astigmatism management in extreme axial myopes differs from the general population. Toric intraocular lenses are only available down to +5 or +6 diopters depending on the manufacturer. Astigmatism management patients may therefore require cornea-based treatment. The surgeon can perform intra- or post-operative astigmatic keratotomy or limbal relaxing incisions. Another option is to plan postoperative laser vision correction, termed bioptics by the refractive surgery community. If bioptics are planned, it is beneficial to leave the astigmatic patient with pure myopic astigmatism, and not with mixed astigmatism. Outcomes from excimer laser ablation are more predictable and durable for myopic treatment, so a spherical equivalent in excess of one half the corneal astigmatism should be targeted. This gives the laser a simple ablation pattern, as outlined in Fig. 2. If a spherical equivalent of plano is targeted, resulting in mixed astigmatism, the laser would attempt to steepen one axis while flattening the other; this situation should be avoided if possible. A final consideration is the Light Adjustable Lens (LAL,) which has been reported to be efficacious in astigmatism management in axial myopes [20]. This platform is currently limited by its dioptric range, which extends from +10.0 to +30.0 diopters, and may therefore not be suitable for extreme axial myopes. The LAL is able to correct up to two diopters of cylinder.

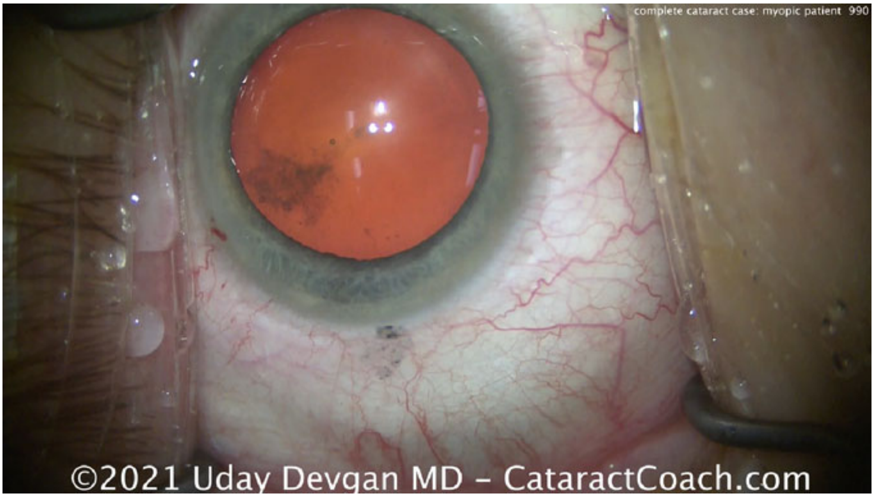
Intraoperative Considerations

Elongated eyes are likely to be larger in several dimensions, and may have a white-to-white corneal measurement of 13 mm or more. Myopic eyes may also dilate excessively. If the surgeon proceeds to create a continuous curvilinear capsulorhexis (CCC) gauged by the pupil size, it may become larger than the IOL optic. The authors recommend one of two means of ensuring a consistent capsulorhexis size. One common method is to use a ring guide to indent and thereby lightly mark the cornea; the ring guide takes into account the twenty percent magnification of the anterior lens capsule that is produced by the cornea itself. The rhexis can then simply trace the mark. Another method is to mark the 2.5 and 5 mm distances from the tip of the capsulorhexis forceps, to visualize the intended rhexis size prior to its creation. Before CCC, the surgeon should be aware that a larger amount of ophthalmic viscosurgical device (OVD) may be needed to adequately form the chamber and flatten the anterior lens capsule. Further alternatives include the use of a nanopulse vacuum capsulotomy device or femtosecond laser-assisted capsulorhexis.

The lens capsule in highly myopic eyes is prone to large anteroposterior movements, which may heighten the risk of capsular rupture. Supracapsular lens disassembly can mitigate this risk. Some surgeons favor prolapsing the lens nucleus into the anterior chamber (AC). Due to typically larger AC, safe distance can be maintained from the corneal endothelium while the nucleus is then chopped and emulsified in the AC. In addition to capsular movement, many surgeons have noted qualitatively that zonular laxity is common in extreme axial myopia. Decades of research into the genetics of myopia have indeed found polymorphisms in proteoglycan synthesis and cell signaling pathways, which would be expected to interact with zonular strength; some of these include PAX6, WNT, and Decorin mutations [21]. It is therefore wise to avoid stressing the zonules. Some surgeons prefer chop techniques for nucleus disassembly. Most agree that thorough hydrodissection can reduce zonular trauma. It is also wise to have assistive devices such as capsular tension rings, capsular tension segments, and capsular hooks readily available in the operating room.

Lens-iris diaphragm retropulsion syndrome (LIDRS) refers to posterior movement of the iris and lens capsule complex. This typically occurs in myopic eyes during cataract surgery. It is caused by a reverse pupillary block, when fluid can no longer travel out of the posterior chamber. In addition to being painful for the patient, it may stress the zonules. The reverse pupillary block can be broken either by gently lifting the underside of the iris or by depressing the anterior capsule to re-establish fluid flow into the retro-irideal space. For persistent reverse pupillary block, an alternative that is rarely necessary is to place a single nasal iris hook.

Care should be taken throughout lens removal, and especially between steps which require removal of the handpiece, to prevent collapse of the anterior chamber. The first important step is to create an adequately long corneal incision, the architecture of which limits fluid egress. The surgeon should next lower the infusion pressure; high infusion pressure can deepen the anterior chamber excessively in myopic eyes, which causes more anteroposterior movement upon depressurization. The surgeon can also use his or her second hand to inject viscoelastic while the handpiece is still in the eye on position one, prior to removal of the handpiece at the end of cortical cleanup. Likewise, after implantation of the intraocular lens and removal of the viscoelastic, balanced saline can be injected in the paracentesis during removal of the handpiece. These extra steps aimed at preventing chamber collapse can reduce anterior movement of the vitreous base, which may theoretically reduce the risk of vitreous traction and subsequent retinal tears.



Video 1 Cataract surgery in a highly myopic eye. Cataract Coach original video #990 (▶ https://doi.org/10.1007/000-8dc)

Postoperative Follow Up

In the postoperative period the cataract surgeon should again carefully counsel the patient regarding the symptoms of retinal tears, and of retinal detachment (RD.)The patient should resume care with their habitual retina specialist, ideally one who examined their eyes prior to surgery. Retrospective studies have found variable rates of retinal detachment in myopic eyes after cataract surgery. A large retrospective review of eyes with axial length greater than 27 mm found no increased risk of RD after cataract surgery through two years, when compared to reported idiopathic incidence [22]. A smaller retrospective study sorted their study population into subgroups, and found a high rate of retinal detachment in eyes with lattice degeneration who first developed posterior vitreous detachment (PVD) in the postoperative period; among this smaller group, the rate of RD was reported to be 21% at five years [23]. This same study noted a low rate of RD (0.70%) in patients who had neither lattice nor preoperative PVD. Though the exact incidence of retinal tear or detachment is unclear, and certainly varies depending on what group is selected, evidence distinctly recommends close follow up.

Myopic patients may require prompt sequential surgery, within two weeks, due to intolerable degrees of aniseikonia. Patients should be alerted preoperatively, so they may plan on sequential surgery. The visual disturbance of aniseikonia is likely to be mitigated by the high residual myopia in the partner eye. An alternative to prompt sequential surgery, if the patient can tolerate their degree of aniseikonia, is contact lens use.

Author's recommendations

Hyperopes

1. Preoperative examination and counseling should focus on anterior chamber depth, axial length, and the health of the corneal endothelium.
2. Lens calculations are greatly affected by effective lens position (ELP). We recommend using Hoffer Q in conjunction with fourth and fifth generation formulae, including Barrett II, Kane, Holladay II, and Ladas Super Formula.
3. High powered lenses are not often on consignment and may need to be specially ordered. Piggy-backing lenses may be required.
4. Actions to deepen the anterior chamber include preoperative mannitol, increasing the intraocular pressure on the phaco machine, using a liberal amount of dispersive viscoelastic throughout the case, and performing a limited vitrectomy.
5. Intracapsular nucleus disassembly and frequent use of dispersive viscoelastic can prevent excessive corneal endothelial cell loss.
6. Postoperative counseling and examination should include monitoring for aqueous misdirection, corneal decompensation, and refractive error.

Myopes

1. Preoperative examination and counseling should focus on common retinal and optic nerve comorbidities.
2. Lens calculations are affected mainly by keratometry. We recommend becoming acquainted with fourth generation formulae; the Barret Universal II performs well in high myopes. Consider targeting residual myopia of −0.5 to −1.0 diopters.
3. Intraoperative steps to reduce fluctuation in the anterior chamber include making longer incisions, lowering bottle height, supracapsular nucleus disassembly, and replacing fluids before withdrawing infusion.
4. Postoperative counseling and examination should highlight the risk of retinal detachment.

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