Chapter 15
Multifocal and Accommodating Intraocular Lenses

Basak Can Ermerak, William Johnson, and Erin Stahl

Loss of accommodation is one of the main challenges faced by pediatric cataract surgeons during postoperative management and visual rehabilitation of their patients. Without accommodation, dependence on corrective aids to provide image clarity over multiple distances becomes necessary. With continued innovation in surgical techniques and intraocular lens (IOL) design, enhanced visual and refractive outcomes have become possible for the adult population. Multifocal, extended depth of focus (EDOF), and accommodating IOLs, sometimes termed "premium IOLs," have allowed modern cataract surgery to provide spectacle-free, clear vision at nearly all distances for select patients. These options have extensively reduced patients' overall postoperative spectacle dependence and improved their quality of life, though evidence demonstrates careful patient selection remains a key component when considering presbyopia-managing IOLs.

For pediatric patients, loss of accommodation after cataract surgery is a well-published contributor to amblyopia, with subsequent disruption of binocular vision. Thus, early rehabilitation of near vision after lens extraction has utmost importance in this at-risk group [1–3]. The ability to have a range of functional vision has become an exciting topic for pediatric cataract surgeons given presbyopia-managing IOL technology has been steadily evolving since its introduction in the 1990s [4]. As these novel applications are being investigated and widely adopted in adults, the same question arises for many pediatric ophthalmologists: Would premium IOLs be an adequate and safe alternative to conventional monofocal options without sacrificing image quality, degrading contrast sensitivity, or introducing dysphotopsias?

In practice, pediatric cataract surgeons likely experience preoperative questions influenced by the senile cataract experience, such as, "Will my child need to wear glasses/contact lenses after her/his cataract surgery?" From the lay perspective, the

B. C. Ermerak · W. Johnson · E. Stahl (✉)
Children's Mercy Hospital, Kansas City, MO, USA
e-mail: edstahl@cmh.edu

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opportunity or expectation of spectacle independence is commonplace, due to awareness of adult cataract surgery from direct to consumer advertising, interaction with family and friends who have experienced lens-based procedures, or confusion with other ophthalmic surgery, such as laser-based keratorefractive procedures. Of course, all of these assumptions are false. Nonetheless, they remain prevalent, likely to be an enduring feature of the collective outlook of patients' parents and grandparents due to the success of adult cataract surgery. Furthermore, if a patient's family is aware of "premium" options from advertising or personal experience, they may be confused or suspicious if they do not hear at least a discussion of the technology. It would be natural for a family to want to make every effort to optimize the child's long-term spectacle independence, though the durability of such an expectation remains tenuous given the myriad of variables including age of the patient, visual potential of the eye, etiology of lens abnormality, possible surgical complications, and amount of remaining axial growth.

Varying degrees of near spectacle mitigating strategies are available with a monofocal IOL in place. Classic monovision provided by disparate IOL powers is not typically feasible in pediatric patients due to the unknown remaining refractive shift. However, future intervention to allow monovision such as photorefractive keratectomy (PRK), laser-assisted in situ keratomileusis (LASIK), or contact lenses could provide simultaneous near and distance vision. Often monovision techniques remain limited in providing adequate depth of vision or a true level of near. Multifocal contact lenses are also an option, though the quality of vision may be worse than a similarly designed IOL and it exposes the patient to the risks of contact lens wear. The recent suggestion of multifocal contact lenses delaying the progression of myopia in pediatric patients [5, 6] raises the question of whether presbyopia-managing intraocular lenses may affect the level of postoperative refractive myopic shift in patients following cataract extraction.

A feature that has been described in pediatric patients with monofocal intraocular lenses is pseudo-accommodation. A study conducted in France showed 90% of pediatric patients demonstrated pseudo-accommodation compared to 7% of adult patients [7]. The threshold for pseudo-accommodation was 20/50 near vision in the presence of 20/25 corrected distance vision or better. All patients were able to achieve 20/25 near with appropriate diopter near add. The presence of higher order corneal aberrations, higher IOL power, and spherical equivalent were positively correlated with the presence of pseudo-accommodation in both adult and pediatric age groups. Shift in IOL position and pupil aperture size were not correlated with pseudo-accommodation. This suggests pediatric patients with monofocal IOLs may perform better than adult patients with a similar implant unaided at near, though this may decrease with age and a 20/50 definition of pseudo-accommodation is unlikely to be universally suitable for near tasks in pediatric or adult patients.

Neural plasticity has been described as an important component in adequately tolerating an IOL designed to provide depth of vision. Dysphotopsias are common side effects of presbyopia-correcting IOLs, typically described as halos or starbursts. An improvement in the degree patients are bothered by these dysphotopsias over the first several months postoperatively, in the absence of posterior capsule

opacification or other optically significant pathology, has been attributed to neuroadaptation. Functional magnetic resonance imaging collected by Rosa and colleagues provided evidence for this process [8]. A study of a trifocal diffractive IOL in 2016 showed improvement in near acuity from the 1-month to 3-month postoperative evaluations, also suggestive of this process [9]. These findings have been described in the adult population, but the pediatric age group would theoretically harbor a larger degree of neural adaptability than patients in their seventh decade and beyond, potentially representing a positive attribute in the use of presbyopia-correcting IOLs in the pediatric population.

Lens Discussion

Multifocal intraocular lenses (MFIOLs) are designed to provide adequate functional outcomes at all distances unaided. Although different IOL technologies use various strategies to achieve this goal, the main principle is to divide incoming light into different foci and simultaneously create near and distance images on the retina. This multifocal optical design is based on dispersion of incoming rays, requiring a neuroadaptive process to accurately distinguish these multiple images [10]. Furthermore, MFIOLs consist of two or more focal points, each serving fixed working distances to deliver a sharp image to the retina [11]. When an object is viewed at a certain distance, the unwanted effect of simultaneously redirected light on the out-of-focus image may lead to reduction in contrast of the in-focus image. This design may also lead to the perception of photic phenomenon such as glare and halos [10–12].

Multifocal IOLs can be classified as refractive, diffractive, or a combination. The number of focal points embedded in the lens is another defining property of MFIOLs. Starting with the early generations of MFIOLs, a commonly implemented design was a bifocal. More recently, intermediate vision has also become important to daily routines due to increased utilization of computers, smartphones, and other electronic devices. To address the need for intermediate vision, low-add MFIOLs, extended depth of focus (EDOF) lenses with echelette design, trifocal MFIOLs, and "mix-and-match" strategies have emerged to optimize distance, intermediate, and near vision. The pediatric population has also experienced this dramatic increase in intermediate vision demands, though younger children likely maintain the need for mostly near with reading and electronic tasks given their shorter arm length and positioning from electronic screen stimuli.

Refractive IOLs consist of annular optical zones of differing, or sometimes alternating, dioptric powers for distance and near foci, in order to create simultaneous images. The main limitation of this design is dependence on pupil size and sensitivity for decentration [10, 13]. This can be explained by varying pupil dynamics under photopic and scotopic conditions, affecting the balance of distance and near foci.

The AMO Array lens (Allergan, Irvine, CA) was the first refractive MFIOL to become United States Food and Drug Administration (FDA) approved in 1997. This foldable, silicone lens provided better results for uncorrected and corrected distance

visual acuity along with better distance-corrected near visual acuity over monofocal lenses [14–17]. Overall spectacle dependence was lower in multifocal groups; however, increased rates of halos and glare along with some loss of contrast sensitivity were reported [15–18]. This lens was upgraded to the ReZoom IOL (Advanced Medical Optics, Santa Ana, CA), which was approved by the FDA in 2005. The ReZoom is a three-piece, hydrophobic acrylic lens with a distance-dominant center and five alternating concentric zones with aspheric transitions, theoretically providing increased image quality at distance and intermediate focal lengths [19]. These modifications led to decreased complaints of glare and halos, along with favorable distance, intermediate, and near visual acuity results [20, 21].

Another hydrophobic acrylic, refractive MFIOL commercially available in Europe is the Lentis Mplus (Oculentis, Berlin, Germany). Instead of using symmetric concentric multifocal rings, this lens has a rotationally asymmetric segmental, bifocal design with a surface-embedded near section. It offers good uncorrected and distance-corrected near visual acuity with high contrast sensitivity, although image quality continues to be affected by IOL tilt and decentration [22, 23]. A newer generation is now available in the European market, offering a toric option, the Lentis Mplus Toric (Oculentis, Berlin, Germany) for eyes with more than 1.50 diopters (D) of preexisting corneal astigmatism [24].

Diffractive MFIOLs use diffractive micro zones, or steps, on the posterior lens surface to direct light evenly between distant and near focal points. The 3M 815LE Lens (3M Corp, St Paul, Minnesota, USA) was one of the first generation diffractive MFIOLs that was then purchased by Alcon Laboratories and renamed ReSTOR (Alcon, Fort Worth, Texas, USA). It is a single-piece, hydrophobic acrylic, bifocal lens initially with a +4.0 D additional power for near vision in the IOL plane (approximately +3.2 D at the spectacle plane). It consists of 12 concentric diffractive rings utilizing an apodization principle and was the first diffractive MFIOL to obtain FDA approval in 2005 [25]. An apodized, diffractive MFIOL is one with steps that grow closer peripherally, helping to smooth the diffractive characteristic. If the central zone is devoted to a near focal point, then under gradually lower lighting, more of the light is then devoted to the distance focus in an effort to decrease glare and halos in mesopic conditions. Early studies provided results with good uncorrected visual performance at distance and near with less helpful intermediate range performance, due to the relatively high add [26–29]. Halos and glare were the most commonly reported visual phenomena for this type of lens [26–29]. While maintaining its apodized structure, the next-generation ReSTOR AcrySof IQ (Alcon, Fort Worth, Texas, USA) was designed as a hybrid diffractive and refractive lens and was granted with FDA approval in 2007. The addition of asphericity was intended to reduce the visual phenomena, with the ability of increased range of focus and improved image quality. The aspheric design further reduced the positive spherical aberration of the cornea to improve contrast sensitivity [10, 11]. Early results for this lens also showed good visual acuities at distance and near and maintained contrast sensitivity. The intermediate acuity was acceptable [30, 31]. The AcrySof IQ ReSTOR +3.00 D was later introduced to improve uncorrected intermediate range vision while maintaining optimal near and distance visual acuity results

[32]. This model provided a +3.00 D correction in the IOL plane or +2.6 D in the spectacle plane. Comparative studies between the +3.00 D and +4.00 D models showed improved intermediate vision with the +3.00 D model without meaningful loss of distance or near acuities [33–35]. Despite favorable contrast sensitivity outcomes, glares and halos continued to be reported [34, 35]. The AcrySof MFIOL line received FDA approval for a +2.50 D model, as well as toric versions in 2014 [36]. After FDA approval in late 2019, the most recent addition to the AcrySof family is the Panoptix IOL (Alcon, Fort Worth, TX, USA), a hydrophobic acrylic lens consisting of 15 diffractive rings along with a refractive only outer annulus zone [37]. Its trifocal optics provide approximate focal points of 60 cm for intermediate focus and 40 cm for near focus [38]. Early results demonstrated good visual outcomes for corrected and uncorrected distance, near, and intermediate distances [39].

The Tecnis multifocal IOL (Johnson & Johnson Surgical Vision, Santa Ana, CA) was approved by the FDA in 2010, as a single-piece acrylic diffractive following its earlier generations of Array and ReZoom lenses. This lens has an aspheric anterior surface with a bifocal add of +4.0 D on the IOL plane. The Tecnis multifocal IOL also has a fully diffractive posterior surface as opposed to the apodized diffractive design of the ReSTOR MFIOL. Overall, this pattern splits the light so that it is distributed evenly between the near and distant foci to mitigate the dependence on pupil size [40–42]. Early results demonstrated better uncorrected and distance-corrected near vision over the monofocal group with good uncorrected and corrected distance visual acuity [43, 44]. Furthermore, high patient satisfaction was achieved despite a slight loss of contrast sensitivity and reported glare and halos [43, 44]. The FDA later approved two models with less add power, +3.25 D and +2.75 D, in 2015 to better address intermediated vision. In a large, prospective, comparative case series between the three Tecnis MFIOLs (+4.00 D, +3.25 D and +2.75 D), the low-add options provided less spectacle dependence for near and distance vision along with higher patient satisfaction compared to previous high-add model. Contrast sensitivity was similar between the groups, and more than one-third of subjects reported experiencing glares or halos in each group [45].

In comparative studies between different designs of diffractive and refractive MFIOLs, all groups demonstrated high distance acuity, but diffractive designs provided better corrected and uncorrected near visual acuities [46–48]. Patient satisfaction was high in all groups despite a similar level of diminished contrast sensitivity and the presence of glare and halos [46, 47]. Additionally, a randomized, prospective, double-masked trial examined the ReSTOR +3.00 D and +4.00 D with the Tecnis MFIOL suggested that newer-generation aspheric, especially low-add hybrid apodized or full diffractive lenses are well-tolerated for working-age cataractous patients in visual outcomes, reading performance, and quality of life results. The ReStOR +4.00 D model, not surprisingly, showed the lowest distance-corrected intermediate visual acuity (DCIVA) and uncorrected intermediate visual acuity (UIVA) [49].

Other examples of diffractive MFIOLs not commercially available in the US market include the AT LISA (formerly known as the Acri.Lisa; Carl Zeiss Meditec, Dublin, CA) and FineVision (PhysIOL, Liège, Belgium). The AT LISA was

introduced as an aspheric, single-piece, bifocal MFIOL with a near add of +3.75 D at the lens plane. Its hybrid refractive-diffractive MFIOL design divides usable light 65% for distance and 35% for near [50]. Good outcomes of corrected and uncorrected distance and near vision has been reported along with similar drawbacks on diminished intermediate image [50–52]. AT LISA tri (Carl Zeiss Meditec, Germany) was then brought to market as a trifocal with a four-point haptic design to provide improved intermediate range of focus and better contrast sensitivity outcomes despite some visual phenomena [53, 54]. A toric version of this lens, AT LISA tri toric IOL (Carl Zeiss Meditec, Germany), has become available in Europe with promising clinical outcomes [55]. The FineVision lens is a relatively new, hydrophilic acrylic, full diffractive lens with double loop haptics. Its trifocal design with add powers of 1.75 D and 3.5 D reflects focal points of 40 cm for near and 80 cm for intermediate ranges [38]. Studies on the FineVision lens have shown good visual outcomes for all distances [56, 57].

Extended range of vision (EROV) or extended depth of focus (EDOF) IOLs is a relatively new concept proposed to enhance the focal range with improved image quality via an echelette design. Their mechanism works by focusing incoming light on an elongated longitudinal plane. Their unique diffractive pattern eliminates spherical aberrations within the IOLs allowing corneal spherical aberrations to create an extended depth of focus [10, 58, 59]. This elongated focus plane diminishes overlapping of near and far images to eliminate the common halo effect of traditional MFIOLs, though a "starburst" photopsia is more characteristic of this design. The Tecnis Symfony IOL (Johnson and Johnson Surgical Vision, Santa Ana, CA) is the only FDA-approved EDOF IOL, certified in 2016. The Symfony is also available as a toric lens. Recent adult studies report good uncorrected visual results on a wide focal range with few optical phenomena [59, 60].

By definition, accommodative intraocular lenses (AIOLs) are designed to produce a dynamic increase in the dioptric power of the eye with efforts to bring focus to near or intermediate range from a distance target [61, 62]. However, it may be helpful to first distinguish real accommodation and pseudo-accommodation. Pseudophakic accommodation is the ability of true dynamic refractive variations during near and intermediate vision to produce a clear image, whereas pseudo-accommodation includes increased depth of focus along with multifocality or aberrations and subjective adaption to defocus during near tasks [63]. Given the difficulty in consistently distinguishing these two categories, the American Academy of Ophthalmology (AAO) recently published a task force statement suggesting related clinical studies should use objective instrumentation and methodology to obtain accurate accommodation measurements [64]. The task of accommodation via an IOL may be achieved through alternations of the axial position, curvature, or refractive index [61, 62]. By initiation of accommodative effort, the ciliary muscle contracts along with a shift of the zonular diagram that subsequently leads to increased vitreous cavity pressure and forward movement of the lens complex, which can be adapted, in part or whole, to allow AIOLs to increase total refractive power of the eye. The Crystalens (Bausch and Lomb, Inc., Rochester, NY) is the only accommodative IOL currently approved by the FDA. The Crystalens design is a

monofocal, biconvex, silicone lens with relatively rigid haptics driving anterior displacement of the optic due to anterior-posterior hinges of the haptic with ciliary contraction, producing accommodation. Although there are some controversial results, accommodative IOLs provide similar results to monofocal IOLs regarding distance visual acuity and contrast sensitivity with better results in terms of near vision than monofocal IOLs [65, 66]. The Crystalens tends to have higher rates of posterior capsule opacification (PCO) [66]. A rare but visually significant complication of the Crystalens is the "Z syndrome," which is described as decentration and tilting of the lens secondary to capsular fibrosis resulting in one haptic hinge anteriorly displaced and one posteriorly displaced. This condition can usually be managed by neodymium-yttrium-aluminum garnet (Nd:YAG) laser [67, 68].

Toric presbyopia-correcting IOLs are available in many of the above lens designs, including ReSTOR Toric, Panoptix Toric, Tecnis Multifocal Toric, Tecnis Symfony Toric, Trulign (Crystalens Toric), and AT Lisa tri Toric. In certain situations, pediatric patients may have visually significant cylinder that may warrant treatment. However, in many cases, the expected shift in corneal astigmatism from "with-the-rule" to "against-the-rule" in adulthood may warrant a conservative approach rather than a more aggressive approach to treating corneal astigmatism, though, if necessary, IOLs with combined capability are now widely available.

Several new lens technologies are under development with potential benefit for presbyopia correction and use in pediatric cataract surgery specifically. Numerous additional emerging technologies are being investigated that may play a role in adjustable IOL power, but these are not specifically applicable for postoperative presbyopia management. One that may affect both monofocal adjustment and presbyopia-correcting adjustments would be in the style of the PreciSight Lens (InfiniteVision Optics, Strasbourg, France). This is a multicomponent IOL (MCIOL) that has an intracapsular base with a central portion to hold an exchangeable optic, theoretically exchangeable anytime postoperatively to optimize the desired optical correction [69]. A more novel mechanism would be in the style of the Perfect Lens (Perfect Lens, LLC, Irvine, CA), a femtosecond laser adjustment of an IOL that can adjust monofocal power, switch between monocular and multifocal, and can be adjusted repeatably without degradation of material [70]. Work on this technology is ongoing, but certainly represents an exciting frontier in presbyopia-managing IOLs for the pediatric population.

Premium IOLs have managed to provide encouragingly high rates of patient satisfaction over the years. Despite notable improvements, the major drawbacks of the multifocal intraocular lenses include visual symptoms (halos, glares), varying stages of diminished contrast sensitivity, and mesopic visual function [10, 11]. For optimal visual cortex function, clear image focus onto the retina is essential. Although these postoperative visual functions have largely been studied and described in the adult population, pediatric patients may be more or less vulnerable depending on the level of neuroadaptation.

Early visual near rehabilitation after cataract extraction has paramount importance to restore visual function and prevent amblyopia. Contrary to adults; children may not be able to perceive visual disturbances caused by light dispersion of

multifocal intraocular lens designs. Similarly, we cannot estimate the effect of having an out-of-focus image on final image quality or the ability of pediatric patients to adapt to this. Reports of decreased contrast sensitivity have been published for amblyopic patients [71, 72]. This could lead to an underestimation of diminished image quality after pediatric cataract surgery within the amblyogenic years [73, 74]. Currently there are two reports on amblyopia and MFIOL implantation, both in anisometropic adults without strabismus, which suggest improvements in visual acuity levels and binocular function [75, 76]. However, it would be premature to claim similar results for a pediatric population.

Challenges of Implementation

Postoperative refractive status is a complex, often changing, landscape in pediatric patients. The typically shorter axial length (AL) and higher keratometry (K) values change during the early years of life, leading to subsequent shifts in refractive error. Given this compensatory change (increasing AL and decreasing mean Ks) is even more brisk within the first 2 years, a greater degree of uncertainty is expected when surgery is performed at younger ages [77–81]. These features are important to selection of proper IOL power. Current common practice is to leave younger children with age-dependent amounts of hyperopic refractive error to allow myopic shift [14]. No specifically pediatric IOL calculation formulae currently exist (for further discussion see Chap. 9). Thus, after a desired postoperative refraction is selected, an IOL power selection can be made using an adult formula, although no consensus exists for which formula is best suited to this population [77–84].

Refractive outcomes for presbyopia-correcting IOLs remain challenging in the pediatric population compared to adults given axial growth prediction error, keratometry changes, difficulty in obtaining accurate biometry, and determination of the optimal preoperative IOL calculation. If a presbyopia-correcting IOL is implanted during childhood, the lens can only achieve the desired refraction for a limited time given the myopic shift with continued growth. However, from a theoretical perspective, targeting an immediate postoperative refraction of +3.00 D in a child could allow for immediate emmetropia to a degree via the near focus if a +4.00 multifocal IOL were used. Axial growth may continue during the second decade of life [85]. A large change would cause dependence on corrective aids or further surgery performed in early adulthood to address their refractive error [73, 85, 86].

The surgeon should always consider intraoperative challenges of pediatric cataract surgery over standard phacoemulsification. Proper implantation along with centration is a key factor affecting successful function of presbyopia-correcting IOLs [87]. Besides a well-centered anterior capsulotomy, a continuous and strong posterior capsulotomy is needed to prevent additional lens tilt and decentration that may eventually lead to diminished image quality. A thorough anterior vitrectomy is often employed in pediatric surgery to minimalize the risk of visual axis opacification postoperatively, which can also decrease risk of lens decentration due to lens

epithelial proliferation. The often-opened posterior capsule can make subsequent IOL exchange or explantation technically more challenging than those performed in adults with an intact posterior capsule. This can be a factor when considering a secondary presbyopia-correcting IOL exchanged for a primary monofocal or in the setting of primary aphakia, given all modern presbyopia-correcting IOLs are designed for implantation within the capsular bag.

Case-Based Application

Because consideration of a presbyopia-correcting IOL is unique to each patient, and discussed more often than utilized in our experience, the following case-based discussion will focus on three age ranges to help in applying the above principles, technology, and techniques into a clinical application, rather than recounting individual cases.

Case 1

A 4-month-old with unilateral fetal nuclear cataract.

Comment Infants would be unideal presbyopia-correcting IOL candidates. Based on the Infant Aphakia Treatment Study, children developed fewer complications, mainly visual axis opacification, when left aphakic. There remain certain instances that favor primary IOL implantation, such as demonstrated poor compliance with aphakic correction [88]. Additional factors not favoring presbyopia-correcting IOLs would be the need to overcorrect by up to 10 diopters to account for later growth. The ability of an infant brain to differentiate between multiple images remains to be demonstrated, and the amblyogenicity of unilateral cataracts does not favor this type of implant. The incidence of reoperation in this age group for obscuration of the visual axis, glaucoma, and other intraocular surgery indications would add a risk of lens decentration or damage. Perhaps most significant about this age group of cataractous eyes is the likelihood they have additional pathology likely to produce a subnormal visual potential even with aggressive occlusion therapy and refractive correction and would likely not be able to gain all the benefit of the presbyopia-correcting IOL technology.

Case 2

A 6-year-old patient with bilateral posterior subcapsular cataracts due to systemic corticosteroid therapy for unrelated systemic illness. Eyes are otherwise healthy with normal visual development. Normal fundus exam in both eyes.

Comment The older, though still amblyogenic, age group of 2–9-year-old patients represent a distinct scenario from infants <1 year of age. Eyes in this range have grown and matured enough to allow a technically easier surgery compared to infants. However, the still robust postoperative lens epithelial response can lead to visual axis opacification and lens tilt/decentration due to Soemmering's ring mass, the latter capable of skewing the optical properties of a presbyopia-correcting IOL. Brain development is still occurring with imperfectly understood impact from presbyopia-correcting IOLs, and the level of residual refractive shift makes power selection difficult. However, as eluded to above, there could be theoretical utility with an extended range of vision provided by an IOL if patients have targeted initial hyperopia. With regard to amblyopia, the decline in contrast sensitivity from presbyopia-correcting IOLs could negatively impact visual development. The case reports of amblyopic patients implanted as adults showed a favorable outcome with acuity and binocularity, but this is difficult to generalize to patients implanted in childhood. Without exception, this vignette is not complete without a thorough conversation with the patient's family and the patient and an evaluation of their visual needs and desires postoperatively. A strong desire for presbyopia management with an IOL would have to be expressed and justified. Given the need for planned hyperopia, a period of spectacle or contact lens correction would be necessary, but time-limited if the predicted shift with continued growth is accurate. Alternatively, the patient may elect to have keratorefractive surgery or an additional lens-based refractive surgery without explant of the initial presbyopia-correcting IOL. Overall, given present technology, the applicability is likely relatively unusual in this age group, though more likely than in younger children.

Case 3

A 13-year-old teenager developed bilateral posterior subcapsular cataracts. There was family history of similar cataract development in her 17-year-old sister. The sister had undergone uncomplicated cataract extraction but did not enjoy wearing reading glasses. The patient had an otherwise unremarkable eye exam.

Comment Children beyond the amblyogenic age range, approximately 9–18 years old, are the best candidates for presbyopia-correcting IOLs. Continued axial growth is still common, but these patients would be closest to the age of eligibility for keratorefractive treatment of their resultant refractive error. Patients in this age group receiving presbyopia-correcting IOLs will have a myopic shift in refraction, but the magnitude of this and the degree to which the patients would need to embrace spectacle correction would be variable based on tasks and personal preferences.

While current literature is limited regarding presbyopia-correcting IOL implantation in the pediatric population, there are a handful of studies on multifocal IOLs in the literature. Jacobi et al. published the first study in 2001 using the AMO Array Lens in 35 eyes of 26 patients between 2 and 14 years [89]. This study had an

average follow-up of 27.4 ± 12.7 months and reported a statistically improved best-corrected distance visual acuity, stereopsis, and spectacle independency at the last visit. Only 18% of patients had postoperative complaints of visual phenomena. In 2010, Cristóbal et al. published their results on 3M Lens implantation in five patients with unilateral cataract [90]. These patients were 4–6 years of age and the follow-up period of the study was 21 months. Five patients demonstrated improved visual acuity and four had improved stereoacuity. No patients reported glare or halos. Another retrospective study included 26 pediatric patients (34 eyes) aged between 2 and 15 years who underwent ReSTOR Lens implantation with a +4.00 D model [91]. At a mean follow-up of 25.73 ± 10.5 months, patients showed good results for distance and near vision with improvement in stereopsis. It should be noted these studies have self-reported data on visual disturbances and relatively short follow-up periods for postoperative pediatric cataract results. Wilson et al. published the first case report with long-term follow-up [92]. This report included three siblings with bilateral posterior subcapsular cataracts who underwent lens extraction and implantation of Array Multifocal IOL at 16, 19, and 16 years of age. A recall examination was performed at 12, 11, and 9 years, respectively. Four out of six eyes were noted to have a minimal refractive shift of ≤0.50 D. The third and oldest patient had 0.75 D of myopia in both eyes. Two patients denied glare, whereas one did not drive at night because of glare she experienced. The sibling experiencing glare was not interested in an IOL exchange. Another individual case report described a 7-year-old patient implanted with an apodized, diffractive, multifocal IOL [93]. At a 7-year-follow-up the patient had good visual acuity outcomes. A case report on bilateral implantation of AcrySof IQ PanOptix Lens in a 9-year-old boy was the first report on trifocal lens implantation in a pediatric patient. He had very good distance, intermediate, and near uncorrected visual outcomes [94]. The first comparative study between monofocal and multifocal intraocular lenses in a pediatric population was published in 2014 by Ram et al. [95]. This was a prospective, nonrandomized clinical trial of 42 eyes of 21 children who received a monofocal IOL or diffractive and refractive multifocal IOL. The mean age in both groups was approximately 7 years old with 1 year of follow-up. Corrected distance visual acuity levels were comparable for both groups, whereas the multifocal group showed significantly better distance-corrected near visual acuity results without decrease in contrast sensitivity. Prospective randomized trials with longer follow-up periods should be directed toward evaluation of presbyopia-correcting IOL implantation profiles in pediatric eyes in order to assess data and safety monitoring.

The unifying goal of pediatric cataract surgery remains preservation/development of the best visual acuity over as many focal points as early as possible for as long as possible from the fewest interventions with the fewest complications and with the lowest possible spectacle burden. Presbyopia-correcting IOLs potentially relate to each element of this mantra, though the details of their application remain incompletely understood. Many elements of preoperative planning can be difficult for the pediatric cataract surgeon, and each patient brings unique elements to consider a customized treatment, produced through counseling conversations with the patient and family as well as careful planning of the optimal surgical approach in

order to maximize each element of the goal previously stated. As with many elements in medicine, the optimal solution for each patient is likely to be a balance of priorities tailored individually instead of a truly perfect solution across all facets. Evaluation of new technology is an important component of advancing a discipline. Without studies and experience, the improvement of the technique and outcomes would have a tendency to remain stagnant, a result no advocate of the pediatric cataract patient would endorse as acceptable.

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