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Long-term Outcomes of Under Correction versus Full Correction after Unilateral Intraocular Lens Implantation in Children

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Abstract

Purpose—To evaluate the impact of full correction versus under correction on the magnitude of the myopic shift and postoperative visual acuity after unilateral intraocular lens (IOL) implantation in children.

Design—Retrospective case control study

Methods—The medical records of 24 children who underwent unilateral cataract surgery and IOL implantation at 2 to <6 years of age were reviewed. The patients were divided into two groups based on their 1 month postoperative refraction: Group 1 (full correction) -1.00 to $+1.00$ D; and Group 2 (under correction) $\geq +2.00$ D. The main outcome measures included the change in refractive error per year and visual acuity for the pseudophakic eyes at last follow-up visit. The groups were compared using the independent groups t-test and Wilcoxon rank-sum test.

Results—The mean age at surgery (Group 1, 4.2 ± 0.9 years, $n=12$; Group 2, 4.5 ± 1.0 years, $n=12$; $p=0.45$) and mean follow-up (Group 1, 5.8 ± 3.7 years; Group 2, 6.1 ± 3.5 years; $p=0.69$) were similar for the two groups. The change in refractive error (Group 1, -0.4 ± 0.5 D/yr; Group 2, -0.3 ± 0.2 D/yr; $p=0.70$) and last median logMAR acuity (Group 1, 0.4; Group 2, 0.4; $p=0.54$) were not significantly different between the two groups.

Conclusions—We did not find a significant difference in the myopic shift or the postoperative visual acuity in children aged 2 to <6 years of age following unilateral cataract surgery and IOL

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implantation if the initial postoperative refractive error was near emmetropia or undercorrected by 2 diopters or more.

Intraocular lens (IOL) implantation is currently the preferred means of optically rehabilitating children 2 years of age or older undergoing cataract surgery.^{1, 2} However, there is no consensus regarding the optimal initial postoperative refractive goal for children undergoing IOL implantation. Some surgeons recommend under correction whereas others recommend full correction.

The myopic shift that occurs in pediatric pseudophakic eyes is largely due to axial elongation.^{3, 4} The eyes of most children continue to experience some axial elongation throughout childhood, although the magnitude of this change decreases dramatically after infancy.⁵⁻⁷ For this reason, some clinicians favor implanting an IOL in young children that initially targets emmetropia because they are concerned that the child may not wear an overrefraction postoperatively, which may result in the child developing or having a worsening of their amblyopia.^{8, 9} They also believe that it is impossible to accurately predict how much the refractive error will change over time in these eyes and they have noted that some of these eyes only undergo a minimal myopic shift.⁸ Other clinicians favor targeting these children for an initial under correction and then correcting their residual refractive error with spectacles.¹⁰⁻¹³ They argue that most of these children will undergo a sizeable myopic shift in their pseudophakic eyes and so by initially under correcting them they will have a lower refractive error in these eyes when they are older.^{14, 15} As a result, these patients may be less dependent on a spectacle or contact lens overrefraction later in life. In addition, the reduced anisometropia in these children as their pseudophakic eye undergoes axial elongation and approaches emmetropia may improve their stereopsis and result in less aniseikonia later in life.^{16, 17}

We performed a retrospective analysis from two institutions to determine if the initial postoperative correction in children 2 to <6 years of age undergoing unilateral cataract surgery and IOL implantation affected the magnitude of the myopic shift and the visual outcome in these eyes.

Methods

A retrospective medical record review was performed for children from two institutions who had undergone unilateral cataract surgery and IOL implantation when 2 to < 6 years-of-age and who had an initial postoperative refractive error of -1 to +1 D (Group 1) or an under correction of ≥ 2 D (Group 2). Only children who had been followed after cataract surgery for ≥ 18 months and who had their visual acuity assessed when ≥ 7 years-of-age were included in the analysis. Patients with traumatic cataracts were excluded.

IOL power was calculated using axial lengths obtained using ultrasonography or partial coherence interferometry and keratometry readings. All of the patients were prescribed spectacles following IOL implantation. Patching compliance was rated as excellent, good, fair, poor, or not recorded. Visual acuity was assessed using a Snellen eye chart.

The outcome variables that were analyzed for both Groups 1 and 2 (pseudophakic and fellow eyes) included: the refraction closest to 1 month after IOL implantation and the refraction at the last examination, the change in refraction and the change in refraction per year (D/yr), the adjusted rate of refractive growth (RRG2)¹⁸ and the last visual acuity (logMAR). All refractions are expressed in spherical equivalents. The characteristics of the two groups were compared using the independent groups t-test and outcome measures except for changes in refractive error per year which were compared using the Wilcoxon rank-sum test. Refraction predictions using each of the two current descriptions of the

pseudophakic refractive growth curve^{8,18} were also compared to the actual last refractions of the combined cohort. Finally, we compared the change in refraction and the change in refraction per year between the pseudophakic eyes and the fellow eyes using a paired t test.

Results

Twenty-four patients were studied; 12 patients in each group (Institution 1 enrolled 5 patients in Group 1 and 6 patients in Group 2; Institution 2 enrolled 7 patients in Group 1 and 6 patients in Group 2). The mean age at surgery for both groups and the mean postoperative follow-up intervals for Group 1 were similar for the two groups ($p=0.48$ and $p=0.82$ respectively) (Table 1).

The age of onset of the cataracts was largely unknown, although two patients had posterior lentiglobus which is usually acquired and three patients had types of cataracts which are usually congenital (persistent fetal vasculature, zonular and anterior polar). Both the anterior polar and persistent fetal vasculature cataracts were documented to progress over time prior to being removed surgically. Different patching regimens were prescribed for individual patients based on considerations such as the age of the patient and degree of amblyopia: 0 hours/day ($n=5$), 1–2 hours/day ($n=1$), 3–7 hours/day ($n=7$), and ≥ 8 hours/day ($n=5$). The patching regimen prescribed was not recorded in the medical record for 6 patients. Patching compliance was rated as excellent ($n=5$), good ($n=2$), fair ($n=6$) and poor ($n=1$). Patching compliance was not documented in the medical record for the remaining 10 patients.

Eight of the patients developed a visual axial opacity and underwent one additional intraocular surgery to clear the visual axis. One patient had a late wound dehiscence that was repaired surgically.

Figure 1 shows the targeted refraction compared to the initial refraction. The targeted refractive error was: plano ($n=12$), +0.50 D ($n=2$), +0.75 ($n=1$), +1.00 ($n=5$), +2.00 ($n=2$) and +3.00 ($n=2$). The absolute prediction error was 1.4 ± 0.9 D.

At the postoperative refraction performed closest to 1 month after cataract surgery (Group 1, 35 ± 28 days; Group 2, 22 ± 14 days; $p=.17$), there was a 3.4 D difference between the mean refractive errors for the pseudophakic eyes in the two groups compared to a 3.3 D difference at the last follow-up. At the first postoperative refraction, there was more anisometropia (treated eye minus fellow eye) in Group 2 (Group 1, -0.7 ± 2.7 D, Group 2, 1.6 ± 1.2 D) whereas, at the last follow-up, there was more anisometropia in Group 1 (Group 1, -1.3 ± 1.9 D, Group 2, 0.7 ± 0.9 D).

Figure 2 plots the myopic shift of individual patients between the initial and final refraction. The mean myopic shift for the pseudophakic eyes was nearly the same in both groups (Group 1, -1.9 ± 1.7 D; Group 2, -2.0 ± 1.6 D; $p=0.88$). The mean change in refractive error per year for the pseudophakic eyes was also similar for both groups (Group 1, -0.4 ± 0.5 D/yr; Group 2, -0.3 ± 0.2 D/yr; $p=0.70$). However, the power was only 0.32 to detect a 1.0 D difference between the means for the change in the refractive error of the two groups with probability of a Type I error = 0.05 (two-sided) with the sample sizes and standard deviations observed using the independent groups t-test.

The mean RRG2 for the pseudophakic eyes in both groups was similar (Group 1, -4.7 ± 4.9 ; range, -16.9 to $+1.8$; Group 2, -4.5 ± 2.7 ; range, -9.0 to -1.0 ; $p=.90$). However, the mean RRG2 for the entire cohort was significantly different ($p=.03$) from the RRG2 value (-6.4) reported by McClatchey and Hofmeister¹⁸ for pseudophakic patients operated after 6 months of age. Predictions of the final refraction using their RRG2 logarithmic model were on average 0.7 D more myopic than the last refractive errors we observed in our entire

cohort. Predictions based on the pseudophakic refraction curve from Superstein et al.⁸ were on average 0.8 D more hyperopic than the refractions we observed.

While the mean refractive errors of the fellow eyes were less hyperopic in Group 1 compared to Group 2 at the initial refraction and at the last refraction, the difference was not statistically significant (Table 1). The mean change in refractive error of the fellow eyes was nearly identical in both groups as was the mean change in refractive error per year.

When we compared all of the pseudophakic eyes to all of the fellow eyes, the mean change of the refractive error per year was statistically greater in the treated eyes (-0.4 ± 0.3 D/yr) than the fellow eyes (-0.1 ± 0.4 D/yr) ($p=.026$) (Table 2).

The last visual acuity was not significantly different for the pseudophakic eyes for the two groups (Group 1, median logMAR 0.4; Group 2, median logMAR 0.4; $p=0.54$). However, the power was only 0.23 to detect a 2-line difference between the mean visual acuity of the two groups with probability of a Type I error = 0.05 (two-sided) with the sample sizes and standard deviations observed using the independent groups t-test.

Discussion

In a cohort of young children following unilateral cataract surgery and IOL implantation, we did not find a significant difference in either the rate of myopic shift or the postoperative visual acuity in pseudophakic eyes with an initial postoperative refractive error near emmetropia or under corrected on average by more than 3 diopters after a mean follow-up of nearly 6 years. In addition, both groups of children had about the same amount of ametropia in their pseudophakic eyes at the last follow-up examination, albeit the eyes that were initially near emmetropia are now myopic whereas the eyes that were initially under corrected remain hyperopic.

One of the unique challenges associated with IOL implantation during childhood is selecting the most appropriate IOL power to implant to optimize both the visual and refractive outcomes. There are at least two reasons why this is difficult. First, it is not known how large of a myopic shift will occur. While on average, pediatric eyes have been shown to experience a myopic shift extending into the second decade of life, there is great variability in the magnitude of the myopic shift.¹⁹ Most of the myopic shift that occurs in pediatric eyes is believed to arise secondary to axial elongation. There are likely many factors that influence the degree of axial elongation that occurs in a child's eye including hereditary factors, the type of cataract and the age at which cataract surgery is performed.^{14, 20, 21} Second, there is the inherent difficulty of selecting the IOL power that will achieve the targeted refractive outcome immediately after cataract surgery. Errors may arise from IOL formulas that were developed for adult eyes and from the difficulty of accurately measuring axial lengths and corneal curvature in children. For pediatric cataracts, IOL power is typically calculated using one of 4 formulas: SRK II, SRK T, Hoffer Q or Holladay 1. Recent studies have found that these formulae can differ in accuracy and that each formula is prone to error in predicted IOL power.^{22, 23} As a result, the mean absolute predictive error is generally much higher in pseudophakic children than adults. In children, the mean absolute predictive error has been reported to be between 1.0–1.5 D.^{24–27} The mean absolute predictive error in our study, 1.4 D, was similar to what has been reported in other pediatric studies. In contrast, the mean absolute predictive error in adults has been reported to be as low as 0.25 D.^{28, 29}

In a small retrospective review of 16 eyes, Lowery and co-workers³⁰ reported worse acuity in the pseudophakic eyes of children who underwent cataract surgery and IOL implantation who had an initial postoperative refractive error in the lower quartile of their series (+0.73

D) compared to the median quartile (+2.57 D). In contrast, we did not find a correlation between the initial refractive error and the long-term visual outcome in our series. Our studies differed in that we only included patients who were between the ages of 2 to <6 years at the time of cataract surgery, whereas Lowery and co-workers analyzed patients who underwent cataract surgery between the ages of 8 months to 8.5 years.

Most other retrospective case reviews of pediatric pseudophakia have compared the visual results in pseudophakic eyes to aphakic eyes treated with contact lenses or glasses or to children treated at different ages. In one of the largest reviews of pseudophakic children (n=276), Zwaan et al³¹ reported postoperative visual acuities to be 20/40 or better in 44% and 20/80 or better in 70% of pseudophakic eyes. However, no information was provided regarding the initial postoperative refractive errors in these eyes. McClatchey et al¹⁵ reported a mean best corrected visual acuity of 20/55 in 100 pseudophakic eyes. Similarly, they did not provide any data regarding the initial postoperative refractive errors in these eyes. The postoperative visual acuity in our series was similar to these large series. However, our series is unique in that our analysis was based on evaluating the relationship between the initial postoperative refractive error and the last postoperative visual acuity.

We chose to study children who were still in the age group at risk of developing amblyopia, but at an age that axial growth tends to be decelerating.³ While a small refractive error should not affect the visual outcome of children with unilateral pseudophakia wearing their optical correction, it may have an adverse effect on the visual outcome for children non-compliant with wearing their overrefraction. Wearing an overrefraction is particularly important for children who are hyperopic in their pseudophakic eye because this eye will be defocused in both the distance and at near when not wearing the overrefraction. In contrast, wearing an overrefraction is less important for children who are emmetropic or myopic in their pseudophakic eye since this eye will be in focus at all times either at near or in the distance. For this reason, some clinicians favor implanting an IOL targeting emmetropia.

Children in the undercorrection group had more anisometropia during the immediate postoperative period than the children in the emmetropia group. However, at the last follow-up, children in the undercorrection group had less anisometropia than children in the emmetropia group. Reducing anisometropia may enhance binocularity by minimizing aniseikonia. However, the potential advantage of less anisometropia in the undercorrection group at the last follow-up examination is offset by the ongoing need for these children to wear a refractive correction to correct the hyperopic refractive error in their pseudophakic eyes at a mean age of 11 years.

Different authorities have recommended varying under corrections for children undergoing cataract surgery and IOL implantation when 2 to 5 years of age (Table 3). The range of under corrections recommended for 2-year-old children is particularly wide (range, +3.50 D to +7.00 D) whereas the range is narrower for 5-year-old children (+2.00 to +3.00 D). Our study suggests that the initial postoperative refractive error may not affect the visual outcome or the rate of myopic shift, but it may determine the need to wear an overrefraction later in life.

The annual rate of myopic shift that we observed in both study groups is less than has been observed in most other longitudinal studies of refractive changes in children following primary IOL implantation in children 2 to 6 years of age (Table 3). This may be because the patients in our study were, on average, older than the children in some of these other studies.^{10, 13} In addition, there may be other unknown factors accounting for these differences arising from patient selection. For instance, a larger annual rate of myopic shift has been reported in pediatric eyes following cataract surgery and IOL implantation in eyes

with cataracts arising from trauma compared to eyes with developmental cataracts.²⁰ We excluded children with traumatic cataracts from our study.

The logarithmic model advocated by McClatchey and Hofmeister¹⁸ attempts to compensate for the inherent problem of comparing children of varying ages and lengths of follow-up by characterizing their refractive growth with a single parameter, RRG2, that is relatively independent of surgery age and length of follow-up. The mean RRG2 was virtually identical in our two study groups, but significantly less negative than the RRG2 reported for pseudophakic children by McClatchey and Hofmeister.¹⁸ Conversely, the refraction curve of Superstein and coworkers⁸ predicted smaller myopic shifts than we found in our series. These differences likely reflect the baseline characteristics of patients enrolled in our respective studies.

Our study has a number of limitations. First, it is retrospective and there was no standardized protocol for assessing visual acuity or refractive errors. Second, the length of follow-up was not uniform. However, we only enrolled patients who were followed until they were at least 7 years of age, so the age-dependent variation of the final visual acuity assessment should be relatively unimportant by this age. Third, there may have been a selection bias to enroll certain types of patients that may have confounded our results. For example, our study likely had a bias for enrolling compliant patients since we only enrolled patients who were followed until at least 7 years of age. Therefore, our failure to find a relationship between initial refractive error and final visual acuity may not be generally applicable. Finally, our sample size was relatively small, which limited the power of the study.

In conclusion, we were unable to demonstrate that the initial postoperative refractive error had an impact on the postoperative visual acuity or the rate of myopic shift in children age 2 to <6 years following unilateral cataract surgery and IOL implantation. Until larger prospective studies are performed, we recommend that the initial targeted refractive error be based on considerations such as the likelihood of the child wearing an overrefraction after cataract surgery and the most desirable long-term refractive error.

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Biography

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Figure 1. Targeted Refraction vs Initial Refraction after Unilateral IOL Implantation in Children 2 to <6 Years of Age

The targeted refractive error versus the actual spherical equivalent refractive error at the postoperative refraction closest to 1 month after Intraocular lens implantation in 24 children who underwent unilateral intraocular lens implantation between the ages of 2 to <6 years.

Figure 2. Longitudinal Changes in Refractive Errors After Unilateral IOL Implantation in Children 2 to <6 Years of Age

Plots of the longitudinal changes in spherical equivalent refractive errors for 24 children who underwent unilateral intraocular lens implantation between the ages of 2 to <6 years.

Table 1

Comparison of Groups of Pediatric Eyes Following Intraocular Lens Implantation When 2 to <6 Years of Age Categorized According to Initial Post-op Refraction

Characteristic	Initial Post-op Refraction (D)				p-value**	95% CI for Difference Between Groups†
	-1 to +1 (n = 12)		≥ +2 (n = 12)			
	Mean (SD)*	Range	Mean (SD)	Range		
Age at Surgery (yrs)	4.2 (0.9)	2.5 – 5.9	4.5 (1.0)	2.3 – 5.7	0.43	-1.1 – 0.5
Age at Initial Post-op Refraction (yrs)	4.3 (0.9)	2.6 – 6.1	4.6 (1.0)	2.3 – 5.8	0.48	-1.1 – 0.5
Age at Last Refraction (yrs)	10.0 (4.1)	5.7 – 19.4	10.7 (3.8)	4.0 – 17.8	0.69	-4.0 – 2.7
Duration of Follow-up (yrs)	5.8 (3.7)	2.0 – 13.5	6.1 (3.5)	1.7 – 12.9	0.82	-3.3 – 2.7
Treated Eye						
Initial Post-op Refraction (D)	-0.1 (0.6)	-1.0 – 1.0	3.3 (0.9)	2.0 – 5.5		
Last Refraction (D)	-2.0 (1.7)	-4.5 – 1.1	1.3 (1.6)	-1.8 – 3.6		
Change in Refraction (D)	-1.9 (1.7)	-5.0 – 0.6	-2.0 (1.6)	-5.5 – -0.4	0.88	-1.3 – 1.5
Change in Refraction per Year (D/yr)	-0.4 (0.5)	-1.6 – 0.2	-0.3 (0.2)	-0.7 – -0.1	0.70	-0.4 – 0.2
Last Visual Acuity (logMAR)	0.4 (0.3, 0.5)	0.1 – 1.0	0.4 (0.3, 1.3)	0 – 1.3	0.54	-0.8 – 0.2
Fellow Eye						
Initial Post-op Refraction (D)	0.5 (2.6)	-4.8 – 6.5	1.7 (2.0)	-0.5 – 6.5	0.24	-3.1 – 0.8
Last Refraction (D)	-0.7 (2.0)	-4.0 – 3.0	0.6 (1.6)	-2.1 – 3.3	0.08	-2.9 – 0.2
Change in Refraction (D)	-1.3 (2.0)	-6.3 – 1.1	-1.1 (2.1)	-6.8 – 1.4	0.83	-1.9 – 1.6
Change in Refraction per Year (D/yr)	-0.3 (0.4)	-1.2 – 0.4	-0.04 (0.3)	-0.5 – 0.8	0.15	-0.5 – 0.1
Anisometropia‡						
At Initial Post-op Visit (D)	-0.7 (2.7)	-7.3 – 4.6	1.6 (1.2)	-1.0 – 3.1	0.02	-4.1 – -0.5
At Last Visit (D)	-1.3 (1.9)	-4.8 – 1.8	0.7 (0.9)	-0.6 – 1.9	0.005	-3.3 – -0.7

* The values are mean (standard deviation) except for Last Visual Acuity where the values are median (quartiles).

** p-value for the independent groups t test, except for Last Visual Acuity for which the Wilcoxon rank-sum test was used.

† The 95% confidence interval for the difference of the means between the initial refraction groups ($(-1 \text{ to } +1) - (\geq +2)$) except for Last Visual Acuity where the confidence interval is for the difference of the medians.

‡ Anisometropia was calculated as the refraction in the treated eye minus the refraction in the fellow eye.

Table 2

Comparison of Treated and Fellow Eyes of 24 Children Following Unilateral Intraocular Lens Implantation When 2 to <6 Years of Age

Characteristic	Treated Eyes		Fellow Eyes		p-value [*]	95% CI for Difference Between Groups ^{**}
	Mean (SD)	Range	Mean (SD)	Range		
Change in Refraction (D)	-1.9 (1.6)	-5.5 – 0.6	-1.1 (2.0)	-6.8 – 1.4	0.052	-1.7 – 0.01
Change in Refraction per Year (D/yr)	-0.4 (0.3)	-1.6 – 0.2	-0.1 (0.4)	-1.2 – 0.8	0.026	-0.4 – -0.03

* The p-value for the paired t-test.

** The 95% confidence for the difference between the means of treated and fellow eyes (Treated – Fellow).

Table 3
Myopic Shift Following Primary Intraocular Lens Implantation in Children 2 to 6 Years of Age

Author	# of Eyes	Age at Surgery (years)	Median Follow-up (years)	Myopic Shift (diopters)	Mean rate of change (D/year)	Recommended Undercorrection (diopters)
Astle ¹³	30	2-4	3.8	-4.16	-1.10	2-4 y/o +5.00 to +7.00
Piager ¹⁰	9	2-3	5.8	-4.60	-0.81	3 y/o 4y/o 5 y/o +5.00 +4.00 +3.00
Crouch ¹²	7 11	3-4 5-6	4.42 6.17	-3.66 -3.40	-0.82 -0.56	2 y/o 3-4 y/o 5 y/o +3.50 +2.50 +2.00
Enyed ¹¹	23 16	2-4 4-6	2.2 1.9	-1.50 -1.50	-0.60 -0.72	2 y/o 3 y/o 4 y/o 5y/o +5.00 +4.00 +3.00 +2.00
Present Study	24	2-5	5.9	-1.95	-0.35	NA