ORIGINAL ARTICLE

Refractive Changes after Intraocular Lens Implantation in Post-cataract Extraction Children in a Philippine Tertiary Hospital

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ABSTRACT

Objective. To determine refractive changes in children post-cataract extraction and intraocular lens (IOL) implantation at a Philippine tertiary hospital.

Methods. This is a retrospective cohort study involving patients aged 1 to 10 years in the Department of Ophthalmology of a Philippine tertiary hospital who underwent cataract extraction and IOL implantation between 2004 to 2013.

Results. We included 55 eyes of 34 patients in the analysis. Thirty-eight eyes (69%) eyes underwent primary IOL implantation. The mean duration of follow-up was 3.5 ± 2.1 years. The median refractive changes were -2.00 (-2.50, -0.50) diopters (D) for the 1- to 3-year-old group, -1.25 (-1.50, -0.25) D for the 4- to 7-year-old group, and -1.00 (-1.63, -0.25) D for the 8- to 10-year-old group. Only the 1- to 3-year-old group had significant difference between the initial post-operative refraction and the latest follow-up refraction ($p<0.001$). For the primary implantation group, patients in the 1- to 3-year-old group had the highest median refractive change at -2.00 (-3.125, -1.00) D while patients in the 8- to 10-year-old group had the highest median refractive change at -2.12 (-2.56, -1.69) D in the secondary implantation group. Refractions of eyes with IOL-implanted and normal eyes showed a median difference of -1.00 (-0.25, -3.5) D.

Conclusion. The determination of the power of IOL implants in pediatric patients who underwent cataract extraction remains challenging despite availability of recommendations.

Keywords: Refractive changes, intraocular lens implantation, children, cataract, target refraction

INTRODUCTION

Intraocular lens (IOL) implantation has become the standard treatment following cataract removal in children older than 1 year of age and is acceptable for infants older than 6 months based on the Infant Aphakia Treatment Study.[1] However, a major challenge in implanting IOL in children is choosing the appropriate IOL power since refractive change towards myopia or near-sightedness (minus power) occurs in children because of their rapid eye growth especially during infancy. Axial length increases rapidly from birth up to until 2 to 3 years of age, then slows down and only stabilizes at age 8 to 10 years.[2] These refractive changes should be taken into consideration when deciding the post-operative refraction target and the IOL power to use to achieve that refraction in pediatric patients. Most studies recommend aiming for higher post-operative hyperopia (plus power) for younger children in order to offset the larger

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myopic shift.[3-9] It is also important to consider the effect of ethnicity, especially in Asian children with refractive myopia who are affected by the myopia epidemic.[10,11] This poses an added challenge of a possible larger degree and faster rate of childhood myopic shift in our patients. All these factors should be considered in choosing the IOL power and predicting the target refraction of our Filipino patients. However, most literature that recommends target refraction were done among Caucasian children.

This study aimed to determine the refractive changes after IOL implantation in Filipino children aged 1–10 years seen at the Department of Ophthalmology of a Philippine tertiary hospital. The consultants of the Section of Pediatric Ophthalmology and Strabismus subscribe to different recommendations in choosing the IOL power and post-operative refraction. However, it was not the goal of this study to determine which recommendation works best for Filipino children. Instead, this study aimed to provide real world data among our patients which will be used to guide in the creation of a protocol for the section in choosing the IOL power to implant and in determining our target refraction per age group. We also aimed to determine whether there was a significant difference in the refractive change between the eye implanted with IOL and the other non-cataractous eye in patients with monocular cataract, as this would further affect choice of IOL power.

METHODS

This study was approved by the University of the Philippines Manila Research Ethics Board. We reviewed records of patients aged 1 to 10 years who were operated on for unilateral or bilateral cataract with IOL implantation immediately after cataract extraction (primary implantation) or on a later date (secondary implantation) from 2004 to 2013 seen by the Section of Pediatric Ophthalmology and Strabismus at the Department of Ophthalmology of UP-PGH. All eyes with post-operative refraction data (within 3 months after IOL implantation) and from at least 1-year follow up were included for analysis. Excluded were eyes with prior penetrating corneal or scleral injury; which underwent other intraocular procedures aside from cataract extraction before, during, or after IOL implantation except for surgeries to clear the visual axis (e.g., membranectomy); with glaucoma, uveitis, retinal detachment, endophthalmitis, persistent miosis, corectopia, or dislocated IOL post-operatively; and which underwent implantation of IOL outside the sulcus or posterior chamber (e.g., iris or scleral fixated).

All included patients underwent preoperative keratometry using a Nidek KM 500 handheld autokeratometer (Nidek, Inc, Fremont CA) and immersion biometry using a portable OTI-Scan 300 (Optos, Florida, USA) from 2004 to 2006 and *Eye Cubed*™ (*Ellex*, Adelaide, Australia) from 2007 onwards. The Sanders-Retzlaff-Kraff-T formula was used to calculate IOL power. The power of IOL used was determined by the section consultants. All patients underwent lens aspiration, posterior capsulotomy, with or without anterior vitrectomy, and with primary or secondary IOL implantation using an MA60AC or SA60AT Alcon Acrysof MP Foldable IOL (Alcon Laboratories, Inc, Fort Worth, TX). The surgery was done in the same institution by a fellow or a senior resident of the section. Two standard clear corneal incisions were made for access. Anterior capsulorrhexis was performed with a continuous curvilinear tear using forceps. Posterior capsulotomy was done for younger children who cannot undergo laser capsulotomy, either with forceps or an anterior vitrector. For primary IOL implantation, the IOL was implanted in the sulcus or the bag with the necessary associated adjustment in the IOL power employed. For the secondary IOL implantation, the IOL was implanted in the sulcus. After the IOL implantation, the bigger incision was sutured with nylon 10-0 sutures to maintain anterior chamber volume post-operatively. After the operation, patients were examined on days 1 and 7, then on monthly intervals, unless there was a need for a more regular follow up.

Refractive change was determined by the fellow or the resident of the section using the difference of refraction, expressed as spherical equivalent for simpler statistical analysis, recorded on initial follow-up after the IOL implantation and on the latest follow up. Spherical equivalence was computed using the following standard formula:

$$\text{Spherical equivalent} = \text{spherical refractive error} + \frac{\text{cylinder refractive error}}{2}$$

By employing algebraic addition, the cylinder power and its axis could be deleted. Eyes from bilaterally affected patients were treated as separate data. The rate of change per year was determined by dividing mean refractive change by the mean number of years of follow up. The follow-up period was defined as the time interval between the date of IOL implantation to the last date that the patient was seen in our institution. Data were tabulated using Microsoft Excel version 2016 (Microsoft Corporation, Redmond, WA, USA) and were subjected to Wilcoxon rank sum and Kruskal-Wallis tests using Stata 14 (StataCorp, College Station, TX: StataCorp LP).

RESULTS

We included 55 eyes of 34 patients in the analysis. Ninety-two patients with a total of 129 eyes were excluded for incomplete data on medical chart, presence of corneal perforating injury, other type of IOL implanted, development of post-operative glaucoma or other complication, no refraction within three months after IOL implantation or less than one year of follow-up. Eighteen patients (53%) were male and 13 (38%) had unilateral cataract. Thirty-eight eyes (69%) eyes underwent primary IOL implantation. Clinical data of patients is summarized in Table 1. Mean follow up period was 3.5 ± 2.1 years.

The patients in the 1- to 3-year-old group had the highest median refractive change at -2.00 (-2.50, -0.50) diopters (D) with a mean follow-up period of 3.35 ± 1.74 years, followed by the 4- to 7-year-old group at -1.25 D (-1.50,-0.25) D (Table 2). The 8- to 10- year-old group still had refractive changes of -1.00 (-1.63, -0.25) D. There was a decreasing trend in median refractive change with increasing patient age. However, there are no statistically significant differences in the median refractive change (p=0.26) and median rate of change per year (p=0.54) between each group.

Only the 1- to 3-year-old group had significant difference between its initial post-operative refraction and the latest follow-up refraction (p<0.001) (Table 3).

For the primary implantation group, patients in the 1- to 3-year-old group had the highest median refractive change at -2.00 (-3.125,-1.00) D with a mean follow-up period of 3.01 ± 1.11 years, followed by the 4- to 7-year-old group at -1.25 (-1.50,-0.50) D (Table 4). The 8- to 10-year-old group still had refractive changes. Similarly, there was a decreasing trend in median absolute refractive change with increasing patient age.

For the secondary implantation group, patients in the 8-10 years group had the highest median refractive change at -2.12 (-2.56, -1.69) D with a mean follow-up period of 5.6 years, followed by the 1-3 years group at -1.75 (-2.50, -0.25) D (Table 5). There was no significant difference between the median refractive changes of the primary IOL group and the secondary IOL group (p=0.18).

In the 13 patients with unilateral involvement, the refractive changes were compared between the eye with an implanted IOL and the normal eye (Table 6). Of the 13 patients, only 9 had available data on the refraction of their normal eyes. Eyes with implanted IOL had greater median refractive change of -1.00 (-0.25,-3.5) D than their fellow normal eyes. However, there was no statistically significant difference between the refractive changes in the eyes with implanted IOL and the normal eyes. (P = 0.33). The resultant median difference in refraction between eyes was -1.00(-0.25, -3.5). The rate of change in refraction in eyes with IOL implanted was -0.66 (0, -0.84) per year while -0.29 (-0.05,-0.29) per year in normal fellow eye.

DISCUSSION

One of the most challenging aspects of pediatric cataract surgery is deciding the intraocular lens power of the intraocular lens implant, given that a child's eye undergoes large and unpredictable refractive changes especially towards myopia, particularly in the early years of life. Our data showed that there was significant over-all refractive change towards myopia in the 1- to 3-year-old group compared to patients who were older at the time of IOL implantation (p<0.001), a trend also found for patients who underwent primary IOL implantation.

The findings of this study reflected the results of other studies on the use of IOL in children.[3-9] Refractive changes remained larger in children who underwent IOL implantation at a younger age compared to older children. However, the amount of refractive change significantly differs clinically in each study. Dahan and Drusedau in South Africa,

Table 1. Summary of the clinical data of the patients who underwent cataract extraction with IOL implantation from 2004 to 2013 at the Department of Ophthalmology of a Philippine tertiary hospital

Age at IOL implantation (years)	No. of Patients	No. of Males	No.of Eyes	Unilateral involvement	IOL implantation (eye)	
					Primary	Secondary
1–3	14	8	23	5	11	12
4–7	12	5	17	7	14	3
8–10	8	4	15	1	13	2
Total	34	18	55	13	38	17

IOL, Intraocular lens

Table 2. Median refractive change and median rate of change in refraction in each age group

Age at IOL implantation (years)	No. of Patients (No of Eyes)	Mean follow-up period after IOL implantation (years)	Median refractive change (spherical equivalent)	Median rate of change per year (diopter per year)
1–3	14 (23)	3.35 ± 1.74	-2.00 (-2.50, -0.50)	-0.56 (-0.18, -1.00)
4–7	12 (17)	4.37 ± 2.24	-1.25 (-1.50, -0.25)	-0.17 (-0.08, -0.32)
8–10	8 (15)	2.92 ± 1.92	-1.00 (-1.63, -0.25)	-0.31 (-0.15, -0.63)

IOL, Intraocular lens

Table 3. Paired comparison of initial post-operative refraction and the latest follow-up refraction

Age at IOL implantation (years)	Median initial post-operative refraction (diopter)	Median latest follow-up refraction (diopter)	p-value
1–3	+3.50 (+1.75, +4.12)	+1.25 (+0.25, +2.50)	0.006*
4–7	+0.50 (-0.50, +1.00)	-0.75 (-1.75, +0.50)	0.11
8–10	+0.50 (-0.38, +0.88)	-0.25 (-1.50, +0.50)	0.18

IOL, Intraocular lens

Table 4. Median refractive change and rate of change in refraction of primary implantation group

Age at IOL implantation (years)	No. of Patients	No. of Eyes	Mean (SD) follow-up period after IOL implantation (years)	Median (IQR) refractive change (spherical equivalent)	Median (IQR) rate of change per year (diopter per year)
1–3	7	11	3.01 ± 1.11	-2.00 (-3.125, -1.00)	-0.58 (-0.48, -1.15)
4–7	9	14	4.81 ± 2.32	-1.25 (-1.50, -0.50)	-0.19 (-0.10, -0.31)
8–10	7	13	2.37 ± 1.59	-0.625 (-1.50, -0.11)	-0.21 (-0.09, -0.66)

IOL, Intraocular lens

Table 5. Median refractive change and rate of change in refraction of secondary implantation group

Age at IOL implantation (years)	No. of Patients	No. of Eyes	Mean (SD) follow-up period after IOL implantation (years)	Median (IQR) refractive change (spherical equivalent)	Median (IQR) rate of change per year (diopter per year)
1–3	7	12	3.66 ± 2.04	-1.75 (-2.50, -0.25)	-0.38 (-0.13, -0.91)
4–7	3	3	2.24 ± 0.66	-0.25 (-2.125, +1.625)	-0.10 (-0.53, -1.44)
8–10	1	2	5.60	-2.125 (-2.56, -1.69)	-0.16 (-0.03, -0.34)

IOL, Intraocular lens

Table 6. Comparison of refraction between the eyes with implanted IOL and the other normal eye among patients with unilateral involvement

Age at IOl implantation (Years)	Follow-up (years)	Refractive change in eye with implanted iol (diopter)	Refractive change in normal eye (Diopter	Median difference (Diopter)
1–3	3.46 ± 1.36	-3.75 (-7.5, -3)	-0.25 (-0.75, -0.125)	-3.5 (-6.75, -2.88)
4–7	2.63 ± 2.08	+0.50 (-0.25, +1.38)	-0.50 (-1.06, -0.18)	+0.38 (-0.44, +1.56)
8–10	3.98 ± 1.33	-3.125 (-3.81, -2.44)	-0.75 (-1.125, -0.38)	-2.38 (-3.44, -1.31)
Mean±SD/Median (1Q, 3Q)	3.20 ± 1.80	-1.75 (-1.75, -3.75)	-0.25 (0,-1.25)	-1.00 (-0.25, -3.5)
Median refractive change rate (diopter/year)	—	-0.66 (0, -0.84)	-0.29 (-0.05, -0.29)	—

IOL, Intraocular lens

Crouch et al. in USA, Yam et al. in China and Astle et al. in Canada reported high refractive changes at -6.39 ± 3.68 diopters (D), -5.96 diopters, -5.43 D (-11.88, +0.50) and -5.53 D, respectively in their 0- to 2-year-old age groups.[3,5,6,8] The study by Plager et al. reported a lower refractive change of -4.60±3.48 D, which can due to having older members in their youngest group (2–3 vs 0–2 years).[7] However, their reported refractive changes remained clinically higher than those in our study and those reported by Sachdeva et al. in India at -2.00 D (-2.50, -0.50) and -3.25 D, respectively.[9] Ethnicity may have played a role in the difference in the refractive changes. However, even the 0–2 years group of Enyedi et al. in the USA reported low refractive changes in their 0-2 years group at -3.25 D.[4] The reason was not apparent but this highlights that ethnicity may need to be considered in the determination of IOL power, and that studies in other ethnicities be conducted especially in low-to-medium income countries where the burden of childhood cataract is high.

The large variations in refractive changes in this study were also similar to other studies. Despite the decreasing trends seen as patients grew older, variations remained high as shown in the quartiles and standard deviations of the refractive changes, even in the >8 years groups.[3,4,7,8] This may explain the absence of statistically significant differences in refractive changes between age groups and between primary and secondary IOL implantation groups in this study.[4] This may have also caused the high refractive change of -3.125 in eyes which received IOL compared to the other normal eye. This showed that IOL power determination remain challenging even in the >8 years group as further evidenced by the presence of the highest refractive change in the 8–10 years group in the secondary IOL implantation group. Theoretically, implanting an IOL when the child is older and has slower eye growth can better approximate the target post-operative refraction than primary IOL implantation.

Based on reported refractive changes, it was recommended to aim for larger immediate (within three months after surgery) post-operative hyperopia (plus power), also known as undercorrection or under powering, in order to offset the larger myopic shift in younger patients.[3-9] The four studies done in Caucasian children recommended to aim for -1.00 to -2.00 at age of 8 years and older on the post-operative refractions based on the refractive changes in their studies to allow near binocularity even without correction and relatively clear uncorrected vision at distance.[3-5,7] Crouch et al. and Plager et al. came up with recommendations for target immediate post-operative refraction based on the refractive changes they documented from their patients.[5,7] However, Astle et al. found these previous recommendations low and recommended that target post-operative refraction for the 1–2 years group be increased to +7.00 to +8.00.[3] Enyedi et al., based on their result, recommended target values between (+5.00 to +6.00).[4] Also known as the "rule of seven," Enyedi et al.'s target post-operative refraction was determined by subtracting 7 from the age of patients aged 7 years and younger

Table 7. Summary of mean refractive change per age group from different studies from highest reported refractive changes to lowest

Authors	Location	Eyes	Age at time of IOL implantation (years)	Mean duration of follow-up (years)	Median/mean refractive change (diopter)	Median/mean rate of change (diopter per year)
Dahan and Drusedau[8]	Johannesburg, South Africa	156	0–1.5	6.93 ± 3.42	-6.39 ± 3.68	-
			1.6–3	3.46 ± 1.62	-2.73 ± 1.40	-
			3.1–8	3.83 ± 2.30	-2.60 ± 1.84	-
Crouch et al.[5]	Utah, USA	52	1–2	6.35	-5.96	-0.93
			3–4	4.42	-3.66	-0.82
			5–6	6.17	-3.40	-0.55
			7–8	4.38	-2.03	-0.46
			9–10	5.56	-1.88	-0.33
			11–14	5.58	-0.97	-0.17
			15–18	4.50	-0.38	-0.084
Yam et al.[6]	Hong Kong, China	32	0–2	3.33	−5.53 ± 3.09	-0.14 ± 0.09 (mos.)
			3–5	4.33	−4.68 ± 2.15	-0.11 ± 0.07 (mos.)
			6–8	5.42	−2.60 ± 0.60	-0.04 ± 0.01 (mos.)
			9–11	4.33	−0.42 ± 0.63	-0.10 ± 0.01 (mos.)
			>12	4.58	−0.09 ± 0.57	0.00 ± 0.07 (mos.)
Astle et al.[3]	Alberta, Canada	163	0–2	2.94	-5.43 (-11.88, +0.50)	-1.85
			>2–4	3.77	-4.16 (-11.12, +1.40)	-1.10
			>4–7	2.46	-1.58 (-5.41, +2.28)	-0.64
			>7–18	2.38	-0.71 (-6.91, +2.38)	-0.30
Plager et al.[7]	Indiana, USA	38	2–3	5.8 ± 0.75	-4.60 ± 3.48	-0.81 ± 0.63
			6–7	5.3 ± 1.03	-2.68 ± 1.89	-0.54 ± 0.46
			8–9	6.8 ± 1.20	-1.25 ± 1.28	-0.17 ± 0.18
			10–15	5.7 ± 1.09	-0.61 ± 0.68	-0.10 ± 0.11
Enyedi et al.[4]	North Carolina, USA	83	0–2	2.50	-3.00 ± 2.70	-0.10 ± 0.07 (mos.)
			2–4	2.50	-1.50 ± 2.70	-0.05 ± 0.07 (mos.)
			4–6	1.90	-1.50 ± 2.30	-0.06 ± 0.14 (mos.)
			6–8	3.00	-1.80 ± 2.90	-0.04 ± 0.10 (mos.)
			> 8	1.80	-0.37 ± 1.60	-0.03 ± 0.12 (mos.)
Sachdeva et al.[9]	Hyderabad and Visakhapatnam, India	84	0–2		-3.25	-0.55
			2–4	3.75	-2.30	-0.62
			4–6		-1.52	-0.80
This study	Manila, Philippines	55	1–3	3.35 ± 1.74	-2.00 (-2.50, -0.50)	-0.56 (-0.18, -1.00)
			4–7	4.37 ± 2.24	-1.25 (-1.50, -0.25)	-0.17 (-0.08, -0.32)
			8–10	2.92 ± 1.92	-1.00 (-1.63, -0.25)	-0.31 (-0.15, -0.63)

Table 8. Recommended target refraction per age

Authors	Year Published	1–2 years	3–4 years	5–6 years	7–8 years	>8 years
Astle et al.[3]	2007	+7.00 – +8.00	+5.00 – +7.00	+1.95	—	+0.97
Plager et al.[7]	2002	—	+4.00 – +5.00	+2.25 –+3.00	+1.00 – +1.50	—
Crouch et al.[5]	2002	+3.50 – +4.00	+2.50	+2.00	+1.00	0
Enyedi et al.[4]	1998	+5.00 – +6.00	+3.00 – +4.00	+1.00 – +2.00	0.00 – -2.00	-1.00 – -2.00

requiring IOL implantation (e.g., the target refraction of a 2-year-old patient requiring IOL implantation is 5 since 7 - 2 = 5, so that patient can ideally have a refraction of -1.00 to -2.00 at 8 years of age).[4] Enyedi et al.'s recommendation is being used in India's largest eye institutions, the LV Prasad Eye Institute and its applicability was validated in Indian children by Sachdeva et al.[9] They found that Enyedi et al.'s recommendation resulted in 33% of the children still having refraction of more than +1.00 at 7 years of age. Only half had refraction of 0.00 ± 1.00 D (9% with 0 D, 13% with $\leq$+1.00 D and 26% with -0.01 to -1.00 D).[9] Considering that our results had lower refractive changes (by -1.00) compared to those of Sachdeva et al. and they still had a 33% hyperopia (plus power) at 7 years, following Enyedi et al.'s recommendation will likely result in more patients with refraction of more than +1.00 at age 7 years in our section.[4,9]

Recommendations on the target post-operative refraction based on documented refractive changes in studies are very helpful considering all the variables. However, these recommendations shall not prevent the surgeon from individualizing the case of each patient based on the severity of amblyopia from the cataract, compliance to additional corrective options (glasses and contact lens), ability to follow up, financial constraints and surgeon's preference.[9]

In monocular cataracts, determination of IOL power is more difficult since the refractive change in the fellow normal eye is added consideration. Anisometropia or difference in refraction of more than 2.50-3.00 D can additionally cause amblyopia.[3] In this study, there was a difference of 1.50 D, which was not amblyogenic, between the eyes with IOL implant and the normal eyes. However, this difference still needs to be considered in the determination of the target post-operative refraction in our future patients. This difference was also reported by Enyedi et al. and Astle et al. at -2.15 D (0-2 years) and -0.96 D (for all age groups), respectively.[3,4] Eyes with IOL implant have been found to have more refractive change than their fellow normal eyes since unlike a natural lens that can change its power to compensate for the axial elongation in normal phakic eyes, IOL power remains constant in operated eyes.[3]

This study is limited by its retrospective nature, number of eyes included and the variabilities in the IOL power determination, post-operative refraction measurement, surgical techniques employed and the interval between surgery, initial post-operative refraction measurements and the succeeding refraction measurements. Standardization was limited in the IOL power determination, refraction measurement and surgical techniques since a scheduled rotation was being followed in the service. Despite these limitations, this is the only study, to our knowledge, that determined refractive changes after IOL implantation in Filipino children who underwent extraction of congenital cataract. The authors recommend the conduct of a prospective study that will adopt a standardized protocol to address the variability in IOL power determination, refraction measurement and surgical techniques since the number of consultants, rotators and surgeons in the section cannot be controlled as part of the training requirement. The authors also recommend to include eyes which underwent surgery for traumatic cataract and eyes which developed glaucoma to determine if the nature of the cataract and glaucoma need to be considered in the determination of IOL power among Filipino children as done by Astle et al.[3] A prospective multicenter study may also be undertaken and used as a basis for a local practice guideline following the creation of a standardized protocol on IOL power determination, refraction measurements and intervals between refraction measurements during follow-up consultations.

CONCLUSION

This study confirmed that there is more refractive changes for patients less than three years of age compared to older patients at the time of IOL implantation, in Filipino children. Determination of the IOL power to implant remains challenging due to presence of varied factors, including significant refractive changes during the first two to three years, inherent variation even in older children, refractive changes between the operated eye and the normal eye, and ethnicity.

Statement of Authorship

All authors participated in the data collection and analysis and approved the final version submitted.

Author Disclosure

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