Ten-year refractive and visual outcomes of intraocular lens implantation in infants with congenital cataract

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A B S T R A C T

Introduction: There is no consensus regarding optimal target refraction after intraocular lens implantation in infants. This study aimed to clarify relationships of initial postoperative refraction with long-term refractive and visual outcomes.

Methods: This retrospective review included 14 infants (22 eyes) who underwent unilateral or bilateral cataract extraction and primary intraocular lens implantation before the age of 1 year. All infants had ≥10 years of follow-up.

Results: All eyes exhibited myopic shift over a mean follow-up period of 15.9 ± 2.8 years. The greatest myopic shift occurred in the first postoperative year (mean=-5.39 ± +3.50 dioptres [D]), but smaller amounts continued beyond the tenth year (mean=-2.64 ± +2.02 D between 10 years postoperatively and last follow-up). Total myopic shift at 10 years ranged from -21.88 to -3.75 D (mean=-11.62 ± +5.14 D). Younger age at operation was correlated with larger myopic shifts at 1 year (P=0.025) and 10 years (P=0.006) postoperatively. Immediate postoperative refraction was a predictor of spherical equivalent refraction at 1 year (P=0.015) but not at 10 years (P=0.116). Immediate postoperative refraction was negatively correlated with final best-corrected visual acuity (BCVA) (P=0.018). Immediate postoperative refraction of ≥+7.00 D was correlated with worse final BCVA (P=0.029).

Conclusion: Considerable variation in myopic shift hinders the prediction of long-term refractive outcomes in individual patients. When selecting target refraction in infants, low to moderate hyperopia (<+7.00 D) should be considered to balance the avoidance of high myopia in adulthood with the risk of worse long-term visual acuity related to high postoperative hyperopia.

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New knowledge added by this study

- The greatest myopic shift occurred in the first year after cataract surgery, but smaller shifts continued beyond the tenth year. Overall, 50% of eyes exhibited myopic shift >-2.00 dioptres between the tenth postoperative year and last follow-up.
- Considerable variation in refractive change after intraocular lens implantation in infants aged <1 year hinders the prediction of long-term refractive outcomes in individual patients. Immediate postoperative refraction was not correlated with spherical equivalent refraction at 10 years postoperatively.
- Immediate postoperative refraction of ≥+7.00 dioptres was correlated with worse final visual acuity.

Implications for clinical practice or policy

- When selecting target refraction in infants, low to moderate hyperopia (<+7.00 dioptres) should be considered to balance the avoidance of high myopia in adulthood with the risk of worse long-term visual acuity related to high postoperative hyperopia.

Introduction

Appropriate optical correction after cataract extraction in infants is important for efforts to avoid amblyopia. Primary intraocular lens (IOL) implantation allows constant in situ optical correction during the critical years of visual development, while avoiding the expenses and compliance issues associated with contact lenses.[1] Disadvantages include increased rates of surgical complications and re-operations,[2] as well as the inability to modify IOL power during ocular growth. A recent report by the American Academy of Ophthalmology suggested that IOL implantation can be safely conducted in children aged >6 months.[3] However, because of the unpredictable nature of ocular growth, it remains challenging to select a target refraction in infants that allows achievement of optimal long-term visual and refractive outcomes.

Surgeons target various initial hyperopia values, ranging from +5.00 dioptres (D) to +10.50 D,[4-9] to compensate for the rapid myopic shift that occurs during infancy. However, prediction of the myopic shift remains difficult; significant hyperopia in infants requires stringent optical correction to prevent amblyopia, and some studies have linked high initial hyperopia to worse visual acuity.[10,11] This retrospective study aimed to clarify the relationships of initial postoperative refraction with 10-year spherical equivalent refraction (SER) and long-term best-corrected visual acuity (BCVA) after IOL implantation in infants.

Methods

Inclusion and exclusion criteria

This retrospective study included patients who underwent unilateral or bilateral congenital cataract extraction and primary IOL implantation before the age of 1 year between 1997 and 2009 at a single secondary and tertiary referral eye centre. Only patients with ≥10 years of follow-up were included. Eyes with associated ocular co-morbidities (eg, persistent foetal vasculature and glaucoma) were excluded.

Surgical technique and follow-up

The patients' baseline characteristics (eg, age, axial length [determined by applanation A-scan biometry], and keratometry) were recorded. Intraocular lens powers were calculated using the Sanders–Retzlaff–Kraff II formula. The operating surgeon selected the target refraction and IOL power, considering the patient's age (all cases) and refractive error in the fellow eye (unilateral cases). All operations were performed using similar techniques, including the creation of a 3.0-mm scleral tunnel, anterior continuous curvilinear capsulorhexis, and lens removal by automated irrigation and aspiration. Heparin-surface-modified polymethyl methacrylate IOLs or acrylic foldable IOLs were implanted. The IOL was placed in the capsular bag or in the sulcus. All wounds were sutured. In some cases, primary posterior curvilinear capsulorhexis and anterior vitrectomy were performed. Because of reports that a significant number of eyes in young infants required secondary posterior capsule opening despite primary posterior capsulotomy,[12,13] this procedure was omitted in some eyes to increase the likelihood of achieving capsular IOL implantation. Postoperatively, all eyes were treated with intensive topical steroid and antibiotic medication. Patients were assessed on postoperative day 1, week 1, week 2, and week 4; they were then assessed every 3 to 6 months. When clinically significant posterior capsular opacification developed, secondary posterior capsulotomy was performed promptly. Glasses were used for postoperative optical correction; in some cases, contact lenses were also used. Amblyopia treatment by patching was performed as necessary.

Outcome measures and statistical analysis

Spherical equivalent refraction at 2 weeks postoperatively was regarded as immediate postoperative refraction. Serial refractions at each year of postoperative follow-up were recorded, and SERs were calculated as the algebraic sum of the sphere and half the cylindrical power. Postoperative axial length was measured using non-contact optical biometry, which was less invasive than applanation biometry.

Statistical analysis was performed using Microsoft Excel and SPSS (Windows version 21.0; IBM Corp, Armonk [NY], United States). Best-corrected visual acuities were converted to logarithm of the minimum angle of resolution (logMAR) values for statistical analysis. Correlations between continuous variables were assessed by Spearman correlation. Differences between groups were analysed by the Mann–Whitney *U* test. Preoperative axial length and keratometry were compared with values at the last follow-up using the paired-samples

先天性白內障幼兒在植入人工晶體十年後的屈光狀態及視力

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引言：至目前為止，醫學界就先天性白內障幼兒在植入人工晶體後的最佳目標屈光狀態仍未達成共識。本研究旨在釐清人工晶體植入手術後的初始屈光狀態與長遠屈光狀態及視力之間的關係。

方法：這項回顧性研究包括14名幼兒（22隻眼睛），他們在一歲前曾進行單眼或雙眼白內障摘除手術及初次人工晶體植入手術。所有幼兒在完成手術後超過十年均有覆診。

結果：所有眼睛在平均覆診時間15.9 ± 2.8年內出現近視轉移，最大程度的近視轉移在手術後一年出現（平均值=-5.39 ± +3.50屈光度[D]），但十年後仍慢慢繼續增加（第十年至最近一次覆診之間的平均值=-2.64 ± +2.02 D）。十年的總近視轉移全距為-21.88至-3.75 D（平均值=-11.62 ± +5.14 D）。接受手術的年紀與手術後一年及十年的近視轉移程度呈正相關，年紀愈輕，在手術後一年（P=0.025）及十年（P=0.006）的近視轉移程度愈大。手術後的即時屈光度能預測手術後一年的等效球鏡屈光度（P=0.015），但不能預測手術後十年的等效球鏡屈光度（P=0.116）。手術後的即時屈光度與最終的最佳修正視力呈負相關（P=0.018）。手術後的即時屈光度≥+7.00 D與較差的最終最佳修正視力呈正相關（P=0.029）。

結論：近視轉移的變化甚大，妨礙預測個別患者的長遠屈光狀態。為幼兒選擇目標屈光度時，應考慮採用低至中度遠視（<+7.00 D），以在避免於成年後患上深度近視及因手術後深度遠視造成的長期視力下降風險兩者之間取得平衡。

Wilcoxon signed-rank test. The independent-sample Kruskal–Wallis test was used to compare 10-year SER and BCVA values among groups with immediate postoperative refraction ≤+3.50 D, +3.50 to +7.00 D, and ≥+7.00 D. Partial correlation analysis was performed to detect correlations of immediate postoperative refraction with spherical refraction at 1 year and 10 years after adjustment for age at operation. Multiple linear regression was performed for multivariate analysis of statistically significant factors identified during univariate analysis. P values <0.05 were considered statistically significant.

Results

Twenty-two eyes of 14 patients were included in this study. One eye in one patient with bilateral cataract was excluded because it was surgically treated after the patient reached 1 year of age. One eye in another patient with bilateral cataract was excluded because it exhibited secondary glaucoma. During surgery, heparin-surface-modified polymethyl methacrylate IOLs were implanted in three eyes, whereas acrylic foldable IOLs were implanted in 19 eyes. The IOL was placed in the capsular bag in 18 eyes and in the sulcus in four eyes. Additionally, primary posterior curvilinear capsulorhexis and anterior vitrectomy were performed in 13 eyes. For postoperative optical correction, all 14 patients wore glasses; four patients (including two with unilateral cataract) also wore contact lenses. Thirteen patients underwent amblyopia treatment by patching.

The Table summarises the baseline characteristics, refractive outcomes, and visual outcomes of eyes included in this study. All 22 eyes exhibited myopic shift, ranging from -21.88 to -3.75 D at 10 years. Figures 1 and 2 show the amounts of myopic shift and SER, respectively, at 1 to 10 years postoperatively and at last follow-up. The greatest myopic shift occurred in the first postoperative year, but smaller shifts continued beyond the tenth year. Ninety percent of eyes exhibited myopic shift >-2.00 D between the third postoperative year and last follow-up (mean myopic shift: -6.40 ± +3.29 D; range, -12.00 to -1.63 D). These proportions were 82% between the sixth postoperative year and last follow-up (mean myopic shift: -4.14 ± +2.35 D; range, -9.38 to -1.13 D), and 50% between the tenth postoperative year and last follow-up (mean myopic shift: -2.64 ± +2.02 D; range, -0.125 to -6.75 D).

Factors affecting myopic shift at 1 year and at 10 years

In univariate analysis, a larger myopic shift at 1 year postoperatively was correlated with younger age at operation (R^2=0.585, P=0.004), more hyperopic immediate postoperative refraction (R^2=-0.533, P=0.011), and a need for secondary posterior capsulotomy (U=20, z=-2.066, P=0.04). One-year

TABLE. Baseline characteristics and follow-up results of patients who underwent unilateral or bilateral cataract extraction and primary intraocular lens implantation before the age of 1 year*

	Unilateral	Bilateral	Total
No. of patients	4	10	14
Gender	3 female; 1 male	5 female; 5 male	8 female; 6 male
No. of eyes	4	18	22
Age at operation, mo	4.0 ± 1.9 (1.8-6.2)	5.8 ± 2.5 (3.7-10.5)	5.3 ± 2.4 (1.8-10.5)
Follow-up period, y	16.0 ± 1.4 (14.4-18.0)	15.9 ± 3.3 (10.0-20.5)	15.9 ± 2.8 (10.0-20.5)
Preoperative axial length, mm	18.61 ± 0.50 (18.08-19.08)	19.21 ± 1.04 (17.72-21.10)	19.12 ± 0.99 (17.72-21.10)
Target refraction, D	2.63 ± 1.30 (1.86-4.13)	5.39 ± 1.59 (2.37-7.38)	4.96 ± 1.83 (1.86-7.38)
Immediate postoperative refraction, D	3.47 ± 3.35 (0-6.87)	5.61 ± 2.61 (0.875-9.375)	5.21 ± 2.80 (0-9.375)
1-Year SER, D	-2.25 ± 1.83 (-3.75 to 0.13)	0.29 ± 3.16 (-7.00 to 4.88)	-0.17 ± 3.10 (-7.00 to 4.88)
10-Year SER, D	-13.04 ± 5.77 (-19.63 to -8.88)	-5.38 ± 4.23 (-15.50 to -1.25)	-6.48 ± 5.11 (-19.63 to -1.25)
SER at last follow-up, D	-13.78 ± 6.51 (-22.50 to -6.75)	-7.81 ± 4.59 (-15.63 to -1.50)	-8.89 ± 5.36 (-22.50 to -1.50)
1-Year myopic shift, D	-5.72 ± 3.26 (-9.50 to -1.75)	-5.32 ± 3.63 (-13.38 to -0.25)	-5.39 ± 3.50 (-13.38 to -0.25)
10-Year myopic shift, D	-15.38 ± 5.17 (-20.88 to -10.63)	-10.99 ± 5.01 (-21.88 to -3.75)	-11.62 ± 5.14 (-21.88 to -3.75)
Total myopic shift at last follow-up, D	-17.25 ± 4.92 (-23.75 to -13.25)	-13.41 ± 5.50 (-22.5 to -5.375)	-14.11 ± 5.50 (-23.75 to -5.375)
Axial length at last follow-up, mm	24.76 ± 2.50 (23.07-28.46)	24.81 ± 1.90 (21.00-27.42)	24.80 ± 1.95 (21.00-28.46)
Change in axial length at last follow-up, mm	6.41 ± 3.03 (3.99-9.80)	5.72 ± 1.94 (2.09-8.55)	5.83 ± 2.05 (2.09-9.80)
logMAR best-corrected visual acuity	0.25 ± 0.18 (0.16-0.52)	0.42 ± 0.30 (0-1.0)	0.39 ± 0.30 (0-1.0)

Abbreviations: D = dioptres; logMAR = logarithm of the minimum angle of resolution; SER = spherical equivalent refraction

* Data are shown as mean ± standard deviation (range), unless otherwise specified

myopic shift was not correlated with initial axial length (R^2=0.038, P=0.878), and it did not differ between unilateral (median=-5.81 D) and bilateral cases (median=-4.38 D) [U=41.5, z=0.469, P=0.652]. Multiple linear regression was performed for statistically significant factors identified during univariate analysis. Only age at operation remained statistically significant (P=0.025); immediate postoperative refraction (P=0.191) and a need for secondary posterior capsulotomy (P=0.781) were not significant in multivariate analysis.

The total amount of myopic shift at 10 years postoperatively was correlated with age at operation (R^2=0.579, P=0.006), but it was not correlated with immediate postoperative refraction (R^2=-0.339, P=0.133) or initial axial length (R^2=0.291, P=0.241). There was no difference in the amount of myopic shift at 10 years between unilateral (median=-14.62 D) and bilateral cases (median=-10.50 D) [U=40.5, z=1.357, P=0.185] or between eyes that required secondary posterior capsulotomy (median=-11.25 D) and eyes that did not (median = -6.19 D) [U=24, z=-1.645, P=0.112].

Factors affecting spherical equivalent refraction at 1 year and at 10 years

Spherical equivalent refraction at 1 year did not significantly differ between unilateral (median=-2.69 D) and bilateral cases (median=+1.13 D) [U=59, z=1.959, P=0.053] or between eyes that required secondary capsulotomy (median=+0.31 D) and eyes that did not (median=+1.42 D) [U=32.5, z=-1.143, P=0.261]. Partial correlation analysis showed that after adjustment for age at operation, immediate postoperative refraction (R^2=0.522, P=0.015) was a statistically significant predictor of SER at 1 year.

In contrast, SER at 10 years postoperatively was significantly more myopic in unilateral cases (median=-10.63 D) than in bilateral cases (median=-4.81 D) [U=49.5, z=2.264, P=0.017]. This finding may be related to surgeon preference for less hyperopic target refractions in unilateral cases, which can match the refraction of the fellow eye and potentially prevent significant postoperative anisometropia. Indeed, after adjustment for age, immediate postoperative SER was significantly less hyperopic in unilateral cases than in bilateral cases (P=0.025). A need for secondary posterior capsulotomy (U=28, z=-1.325, P=0.205) was not correlated with SER at 10 years. After adjustment for laterality, both age at operation (P=0.066) and immediate postoperative refraction (P=0.116) were not statistically significant predictors of SER at 10 years. There was no significant difference in 10-year SER among eyes with immediate postoperative refraction ≤+3.50 D, +3.50 to +7.00 D, and ≥+7.00 D (P=0.439), as shown in Figure 3.

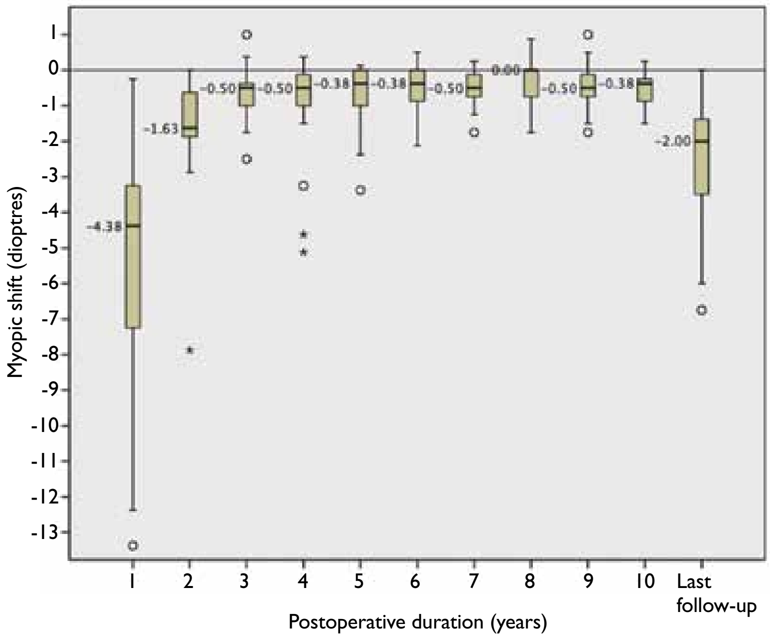

FIG 1. Magnitude of myopic shift per year from 1 to 10 years postoperatively, and between 10 years postoperatively and last follow-up, after primary implantation of intraocular lens in infants aged <1 year. Boxes: quartile 1 to quartile 3 (interquartile range). Lines: medians. Whiskers: maximum and minimum values excluding potential outliers and extreme values. Circles: potential outliers, more than 1.5 interquartile ranges but at most 3 interquartile ranges below quartile 1 or above quartile 3. Asterisks: extreme values, more than 3 interquartile ranges below quartile 1 or above quartile 3

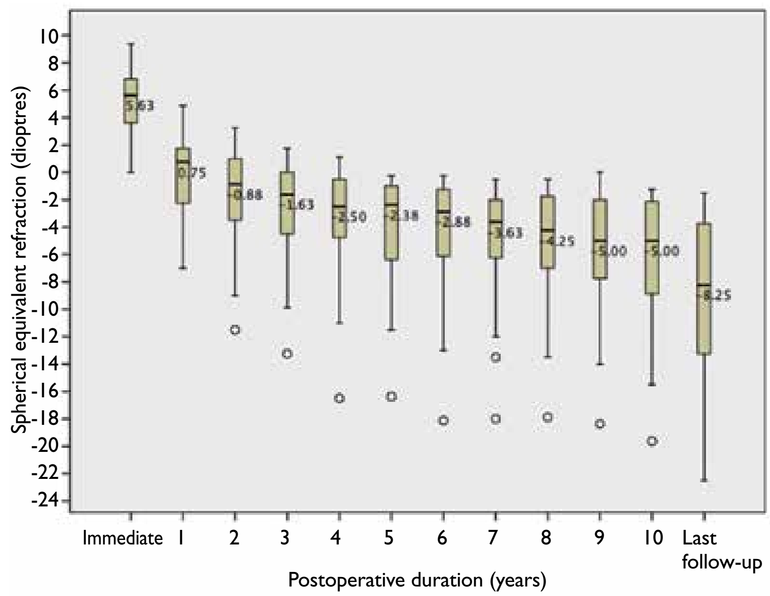

FIG 2. Spherical equivalent refraction immediately after operation, at 1 year to 10 years, and at last follow-up after primary intraocular lens implantation in infants aged <1 year. Boxes: quartile 1 to quartile 3 (interquartile range). Lines: medians. Whiskers: maximum and minimum values excluding potential outliers and extreme values. Circles: potential outliers, more than 1.5 interquartile ranges but at most 3 interquartile ranges below quartile 1 or above quartile 3

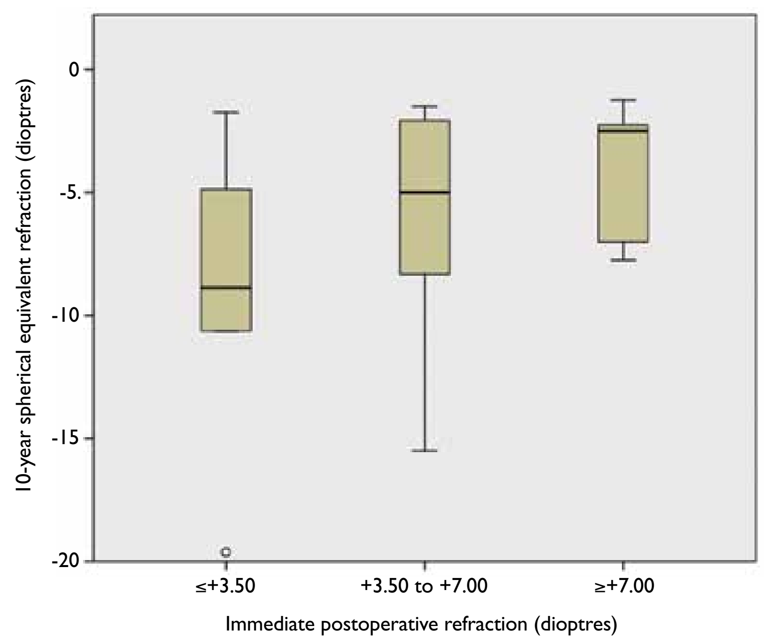

FIG 3. Ten-year spherical equivalent refraction in eyes with immediate postoperative refraction ≤+3.50 dioptres (D), +3.50 to +7.00 D, and ≥+7.00 D. Boxes: quartile 1 to quartile 3 (interquartile range). Lines: medians. Whiskers: maximum and minimum values excluding potential outliers and extreme values. Circles: potential outliers, more than 1.5 interquartile ranges but at most 3 interquartile ranges below quartile 1 or above quartile 3

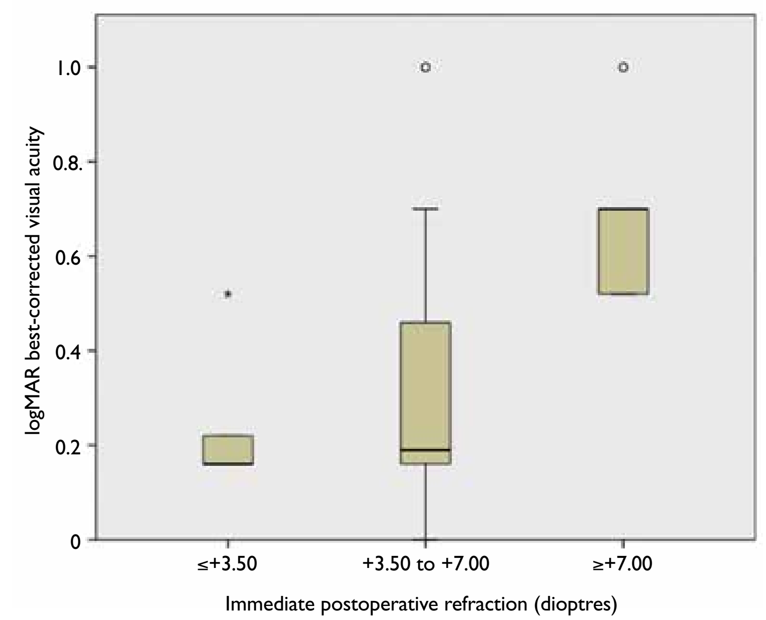

FIG 4. Logarithm of the minimum angle of resolution (logMAR) best-corrected visual acuity in eyes with immediate postoperative refraction ≤+3.50 dioptres (D), +3.50 to +7.00 D, and ≥+7.00 D. Boxes: quartile 1 to quartile 3 (interquartile range). Lines: median. Whiskers: maximum and minimum values excluding potential outliers and extreme values. Circles: potential outliers, more than 1.5 interquartile ranges but at most 3 interquartile ranges below quartile 1 or above quartile 3. Asterisks: extreme values, more than 3 interquartile ranges below quartile 1 or above quartile 3

Subgroup analysis was performed for bilateral cases only. Multiple regression analysis showed that at 1 year, both age at operation (P=0.014) and immediate postoperative refraction (P=0.024) remained significant predictors of SER after unilateral cases had been excluded. At 10 years postoperatively, age at operation was a significant predictor of SER (P=0.015), whereas immediate postoperative refraction was not (P=0.135).

Axial length and keratometry

Mean preoperative axial length was 19.12 mm, whereas mean axial length at 10 years was 24.82 mm. There were no differences in initial axial length (U=32, z=0.894, P=0.421) or total axial length change (U=22, z=-0.224, P=0.875) between unilateral and bilateral cases. Final axial length was significantly greater than preoperative axial length (z=3.823, P<0.0005). Total axial length change was strongly correlated with total myopic shift (R^2=-0.791, P<0.0005). There was no difference between preoperative and final keratometry values (z=0.081, P=0.936). The total change in the mean keratometry value was not correlated with total myopic shift (R^2=-0.168, P=0.490).

Final best-corrected visual acuity

At the last follow-up, 11 eyes (50%) had a final BCVA of 0.18 logMAR or better, six eyes (27%) had moderate amblyopia with BCVA of 0.3 to 0.6 logMAR, and five eyes (23%) had severe amblyopia with BCVA of 0.7 to 1.0 logMAR. There was a statistically significant correlation between immediate postoperative refraction and final BCVA (R^2=0.440, P=0.041). Best-corrected visual acuity was worse in eyes that required secondary capsulotomy (U=74.5, z=1.995, P=0.049). Multiple regression revealed that a need for secondary capsulotomy was no longer a significant predictor for BCVA (P=0.299), whereas immediate postoperative refraction remained a significant predictor for BCVA (P=0.018). Best-corrected visual acuity was significantly worse in eyes with immediate postoperative refraction of +7.00 D or higher than in eyes with lower levels of immediate postoperative hyperopia (P=0.029) [Fig 4]. There were no significant correlations of final BCVA with age at operation (R^2=-0.041, P=0.856), SER at 10 years (R^2=0.011, P=0.963), SER at last follow-up (R^2=-0.122, P=0.589), or laterality (U=48.5, z=-1.087, P=0.300).

Complications and re-operations

Seventeen eyes underwent 21 re-operations in total, 17 of which were secondary posterior capsulotomies. All nine eyes that did not undergo primary posterior capsulorhexis and anterior vitrectomy required secondary capsulotomy; one of the nine eyes required secondary capsulotomy twice. Seven of 13 eyes with primary posterior capsulorhexis and anterior vitrectomy required secondary capsulotomy. Three eyes underwent injection of intracameral tissue plasminogen activator, one eye underwent dissection of fibrinous membrane, and one eye required removal of anterior capsular phimosis. Notably, anterior capsular phimosis did not develop in any other eyes. One eye developed secondary glaucoma and was excluded from this study.

Discussion

Two important goals in the management of congenital cataract include achievement of good long-term visual acuity and minimisation of refractive error in adulthood. This study focused on long-term outcomes after primary IOL implantation in infants, all of whom had ≥10 years of follow-up. Myopic shift was present in all eyes, and its magnitude considerably varied. Immediate postoperative refraction was not a statistically significant predictor of SER at 10 years. Moreover, there was a statistically significant negative correlation between immediate postoperative refraction and final BCVA. Finally, immediate postoperative refraction of +7.00 D or higher was correlated with worse final BCVA.

Refractive change in a growing eye

Refractive change in a normal growing eye involves a complex interaction among axial length elongation, corneal curvature flattening, and the reduction of crystalline lens power.[14] Additional effects on ocular growth (eg, related to the presence or laterality of congenital cataract, age at corrective surgery, initial axial length, postoperative visual input, and compliance with postoperative amblyopia therapy) remain uncertain.[15] The presence of an intraocular lens magnifies myopic shift in a growing eye—the intraocular lens exhibits constant power and moves anteriorly away from the retina during ocular growth, hindering the extrapolation of data from phakic eyes.[5] Figure 5 shows the mean SER during the first decade of life in pseudophakic eyes from patients in the present study, compared with normal eyes from the ongoing population-based Hong Kong Children Eye Study.[16] At 10 years after corrective surgery, the mean SER was -6.48 D in pseudophakic eyes, whereas it was -0.72 D in normal eyes of age-matched children. The mean axial length at 10 years was 24.82 mm in pseudophakic eyes, whereas it was 23.79 mm in normal eyes of age-matched children.[16] These data imply the presence of a greater myopic shift and greater increase in axial length among pseudophakic eyes which continues beyond the first 2 years of life; notably, these increases are relative to the mean growth of normal eyes in Hong Kong children, who exhibit a higher prevalence of myopia compared with other populations.[16]

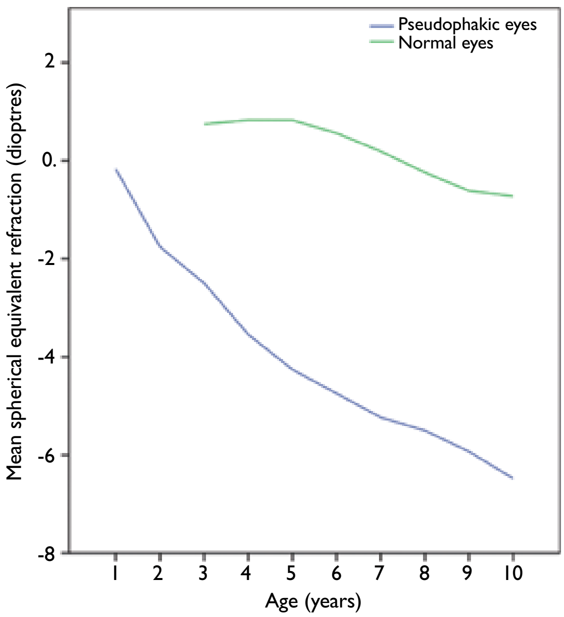

FIG 5. Mean spherical equivalent refraction during the first decade of life in pseudophakic eyes from patients in the present study compared with normal eyes from the Hong Kong Children Eye Study

Refractive change after primary intraocular lens implantation in infants

Several other studies of myopic shift have revealed considerable refractive change after primary IOL implantation in infants aged <1 year. At 5 years postoperatively, the Infant Aphakia Treatment Study revealed a mean myopic shift of -8.97 D for infants surgically treated at the age of 1 month and -7.22 D for infants surgically treated at the age of 6 months,[9] whereas Negalur et al[17] found a median myopic shift of -8.43 D after the same duration of follow-up in infants operated before the age of 6 months. Fan et al[18] reported a mean myopic shift of -7.11 D at 3 years postoperatively in infants operated before the age of 1 year; Lu et al[19] reported a mean myopic shift of -6.46 D at 2 years in 22 eyes, as well as a mean myopic shift of -8.67 D at 6 years in three eyes, among infants operated between the age of 6 and 12 months. In our study, which had a longer follow-up period, the mean 10-year myopic shift was -11.62 ± 5.14 D and myopic progression continued beyond 10 years postoperatively. These findings highlight the importance of using long-term data to guide management decisions, including the selection of target refraction and the determination of appropriate timing for enhancement procedures (eg, IOL exchange).

Our results showed that myopic shift was greatest in the first postoperative year and was correlated with age at operation, which is consistent with findings in the literature.[9,10,17-21] Because age at operation is most frequently associated with the magnitude of refractive change, many surgeons prefer to adjust initial hyperopia according to age. McClatchey et al[22] recommended targets of +5.00 to +8.00 D in infants aged <1 year, whereas Valera Cornejo et al[4] selected targets of +7.00 to +9.00 D in infants of the same age-group. The results of the Infant Aphakia Treatment Study suggested that, to achieve emmetropia at 5 years, immediate postoperative hyperopia should be +10.50 D from 4 to 6 weeks of age and +8.50 D from 7 weeks to 6 months of age.[9] However, our results showed considerable variation in myopic shift at 10 years (range, -21.88 to -3.75 D); after adjustment for age, immediate postoperative refraction was not a statistically significant predictor of SER at 10 years. Other studies have shown that initial refraction and IOL undercorrection were not significantly associated with the magnitude or rate of myopic shift[9,18,22,23]; they also revealed large and unpredictable variations in refractive outcomes after IOL implantation in young infants.[10,20-22,24,25] At the 3-year follow-up, refractive change ranged from +2.00 to -15.50 D in a study by Gouws et al[26] and from -0.47 to -10.69 D in a study by Fan et al.[18] Although we observed a trend towards more myopic 10-year refractions in groups with lower initial postoperative hyperopia, there were no significant differences because of substantial variability in the data (Fig 3). The Infant Aphakia Treatment Study showed that the actual and expected amounts of myopic shift differed in a large percentage of patients; 50% of patients exhibited differences of +3.00 to +14.00 D from expected values.[9] Therefore, age-adjusted suggested targets only compensate for the mean expected myopic shift; large interpatient variability will often result in unanticipated long-term outcomes for individual patients. Correlation analysis in our study revealed that age at operation only explained 58% of the variance in myopic shift at 10 years. This correlation is presumably influenced by other factors that contribute to myopic progression, such as genetics, ethnicity, outdoor exposure, education level, and extent of near work.[27]

Long-term best-corrected visual acuity

The achievement of optimal long-term BCVA is another important goal of surgical treatment for congenital cataract. In our study, immediate postoperative refraction of ≥+7.00 D was correlated with worse BCVA. Similarly, in a study of infants who underwent surgery between the ages of 2 and 21 months, with ≥4 years of follow-up, Magli et al[10] found that BCVA was higher in infants with initial spherical refraction between +1.00 and +3.00 D than in infants with initial spherical refraction >+3.00 D. In a study that included older children who underwent surgery at or before the age of 8.5 years, Lowery et al[11] found that low early postoperative hyperopia (+1.75 to +5.00 D) yielded better long-term BCVA, compared with refractions <+1.75 or >+5.00 D in unilateral cases; no difference was observed in bilateral cases. Another study of older children (surgically treated between the ages of 2 and 6 years) revealed no difference in BCVA between initial postoperative refractive errors of near emmetropia versus undercorrection of +2.00 to +5.50 D[23]; no patients had initial refraction values >+5.50 D. High initial postoperative hyperopia requires good compliance with refractive correction; in infants, such hyperopia also requires amblyopia treatment because younger children are at higher risk of developing amblyopia. Hyperopia is more amblyogenic than myopia because young children have higher demands for near vision[28]; moreover, hyperopia causes defocusing in both distance and near vision, particularly among patients who exhibit pseudophakia related to accommodation loss. Studies have shown variable compliance with optical correction and amblyopia treatment after congenital cataract surgery[19,29]; the use of high-plus spectacles is associated with various optical aberrations. Additionally, contact lenses are suboptimal because one of the original aims of intraocular lens implantation is to avoid the need for contact lens. Myopia is comparatively less amblyogenic because it allows retention of near vision, particularly if the amount of myopia remains low until later in childhood when visual development is more mature.[30] Therefore, parental motivation and the likelihood of compliance should be included in decisions regarding postoperative refraction. Ideally, high myopia in adulthood should be minimised. However, this goal should be balanced with the risks of amblyopia and long-term poor vision. Therefore, the selection of high hyperopia (>+7.00 D) as an initial postoperative target refraction should be avoided when possible.

Strengths and limitations

A major strength of our study was the long follow-up period. Additionally, it only included infants who underwent IOL implantation before the age of 1 year because the refractive change in this group exhibits the greatest variability and is most challenging to predict.[5]

There were some limitations in this study. First, it used a retrospective design and included a small number of patients. Second, there was no objective monitoring of compliance with optical correction or amblyopia treatment. Third, few unilateral cases were included, which may have hindered the detection of larger myopic shifts in post–IOL implantation in unilateral cases. Notably, some previous studies revealed larger myopic shifts after IOL implantation in such cases.[4,17,21,22]

In conclusion, the large and variable refractive change after IOL implantation in infants aged <1 year hinders the prediction of long-term refractive outcomes in individual patients. When selecting target refraction in infants, low to moderate hyperopia (<+7.00 D) should be considered to balance the avoidance of high myopia in adulthood with the risk of worse long-term visual acuity related to high postoperative hyperopia.

Author contributions

Concept or design: All authors.
Acquisition of data: JJT Chan.
Analysis or interpretation of data: JJT Chan.
Drafting of the manuscript: JJT Chan.
Critical revision of the manuscript for important intellectual content: All authors.

All authors had full access to the data, contributed to the study, approved the final version for publication, and take responsibility for its accuracy and integrity.

Conflicts of interest

As an editor of the journal, JC Yam was not involved in the peer review process. Other authors have disclosed no conflicts of interest.

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Ethics approval

Ethics approval was granted by the Research Ethics Committee (Kowloon Central/Kowloon East), Hospital Authority (Ref No.: KC/KE-19-0059/ER-4). The requirement for patient consent was waived by the ethics board due to the retrospective nature of the study. The study is conducted in accordance with the ethical principles of the Declaration of Helsinki.

References

1. Kumar P, Lambert SR. Evaluating the evidence for and against the use of IOLs in infants and young children. Expert Rev Med Devices 2016;13:381-9.
2. Infant Aphakia Treatment Study Group; Lambert SR, Lynn MJ, et al. Comparison of contact lens and intraocular lens correction of monocular aphakia during infancy: a randomized clinical trial of HOTV optotype acuity at age 4.5 years and clinical findings at age 5 years. JAMA Ophthalmol 2014;132:676-82.
3. Lambert SR, Aakalu VK, Hutchinson AK, et al. Intraocular lens implantation during early childhood: a report by the American Academy of Ophthalmology. Ophthalmology 2019;126:1454-61.
4. Valera Cornejo DA, Flores Boza A. Relationship between preoperative axial length and myopic shift over 3 years after congenital cataract surgery with primary intraocular lens implantation at the National Institute of Ophthalmology of Peru, 2007-2011. Clin Ophthalmol 2018;12:395-9.
5. McClatchey SK, Parks MM. Theoretic refractive changes after lens implantation in childhood. Ophthalmology 1997;104:1744-51.
6. Enyedi LB, Peterseim MW, Freedman SF, Buckley EG. Refractive changes after pediatric intraocular lens implantation. Am J Ophthalmol 1998;126:772-81.
7. Astle WF, Ingram AD, Isaza GM, Echeverri P. Paediatric pseudophakia: analysis of intraocular lens power and myopic shift. Clin Experiment Ophthalmol 2007;35:244-51.
8. Yam JC, Wu PK, Ko ST, Wong US, Chan CW. Refractive changes after pediatric intraocular lens implantation in Hong Kong children. J Pediatr Ophthalmol Strabismus 2012;49:308-13.
9. Weakley DR Jr, Lynn MJ, Dubois L, et al. Myopic shift 5 years after intraocular lens implantation in the Infant Aphakia Treatment Study. Ophthalmology 2017;124:822-7.
10. Magli A, Forte R, Carelli R, Rombetto L, Magli G. Long-term outcomes of primary intraocular lens implantation for unilateral congenital cataract. Semin Ophthalmol 2015;31:1-6.
11. Lowery RS, Nick TG, Shelton JB, Warner D, Green T. Long-term visual acuity and initial postoperative refractive error in pediatric pseudophakia. Can J Ophthalmol 2011;46:143-7.
12. Vasavada A, Chauhan H. Intraocular lens implantation in infants with congenital cataracts. J Cataract Refract Surg 1994;20:592-8.
13. Plager DA, Yang S, Neely D, Sprunger D, Sondhi N. Complications in the first year following cataract surgery with and without IOL in infants and older children. J AAPOS 2002;6:9-14.
14. Gordon RA, Donzis PB. Refractive development of the human eye. Arch Ophthalmol 1985;103:785-9.
15. Indaram M, VanderVeen DK. Postoperative refractive errors following pediatric cataract extraction with intraocular lens implantation. Semin Ophthalmol 2018;33:51-8.
16. Yam JC, Tang SM, Kam KW, et al. High prevalence of myopia in children and their parents in Hong Kong Chinese population: the Hong Kong Children Eye Study. Acta Ophthalmol 2020;98:e639-48.
17. Negalur M, Sachdeva V, Neriyanuri S, Ali M, Kekunnaya R. Long-term outcomes following primary intraocular lens implantation in infants younger than 6 months. Indian J Ophthalmol 2018;66:1088-93.
18. Fan DS, Rao SK, Yu CB, Wong CY, Lam DS. Changes in refraction and ocular dimensions after cataract surgery and primary intraocular lens implantation in infants. J Cataract Refract Surg 2006;32:1104-8.
19. Lu Y, Ji YH, Luo Y, Jiang YX, Wang M, Chen X. Visual results and complications of primary intraocular lens implantation in infants aged 6 to 12 months. Graefes Arch Clin Exp Ophthalmol 2010;248:681-6.
20. O'Keefe M, Fenton S, Lanigan B. Visual outcomes and complications of posterior chamber intraocular lens implantation in the first year of life. J Cataract Refract Surg 2001;27:2006-11.
21. Hoevenaars NE, Polling JR, Wolfs RC. Prediction error and myopic shift after intraocular lens implantation in paediatric cataract patients. Br J Ophthalmol 2011;95:1082-5.
22. McClatchey SK, Dahan E, Maselli E, et al. A comparison

of the rate of refractive growth in pediatric aphakic and pseudophakic eyes. Ophthalmology 2000;107:118-22.

23. Lambert SR, Archer SM, Wilson ME, Trivedi RH, del Monte MA, Lynn M. Long-term outcomes of undercorrection versus full correction after unilateral intraocular lens implantation in children. Am J Ophthalmol 2012;153:602-8.e1.
24. Barry JS, Ewings P, Gibbon C, Quinn AG. Refractive outcomes after cataract surgery with primary lens implantation in infants. Br J Ophthalmol 2006;90:1386-9.
25. Plager DA, Kipfer H, Sprunger DT, Sondhi N, Neely DE. Refractive change in pediatric pseudophakia: 6-year follow-up. J Cataract Refract Surg 2002;28:810-5.
26. Gouws P, Hussin HM, Markham RH. Long term results of primary posterior chamber intraocular lens implantation for congenital cataract in the first year of life. Br J Ophthalmol 2006;90:975-8.
27. Morgan IG, French AN, Ashby RS, et al. The epidemics of myopia: aetiology and prevention. Prog Retin Eye Res 2018;62:134-49.
28. Pascual M, Huang J, Maguire MG, et al. Risk factors for amblyopia in the vision in preschoolers study. Ophthalmology 2014;121:622-9.e1.
29. Drews-Botsch CD, Hartmann EE, Celano M, Infant Aphakia Treatment Study Group. Predictors of adherence to occlusion therapy 3 months after cataract extraction in the Infant Aphakia Treatment Study. J AAPOS 2012;16:150-5.
30. O'Hara MA. Pediatric intraocular lens power calculations. Curr Opin Ophthalmol 2012;23:388-93.