The change in axial length in the pseudophakic eye compared to the unoperated fellow eye in children with bilateral cataracts

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PURPOSE To compare the change in ocular axial length of the pseudophakic eye versus the fellow eye in children with bilateral cataracts who had surgery in only one eye.

METHODS In this prospective cohort study, 50 eyes of 25 children with bilateral lamellar cataracts were analyzed. A complete ophthalmic examination and evaluation of axial length measurements by contact ultrasound biometry were performed in all eyes undergoing cataract surgery with IOL implantation and in contralateral eyes. The primary outcome measure was the percentage rate of growth between the final and initial measurements, defined as the initial minus the final measurement, with the difference being divided by the initial measurement and the result multiplied by 100.

RESULTS Children aged 4-10 years of age were followed for a mean of 28.5 months. The values for axial length percentage rate of growth were significantly lower in pseudophakic eyes than in the unoperated, contralateral eyes (0.64% vs 2.09%, $P < 0.05$). Final visual acuity, follow-up time, and initial axial length did not affect the results. Pseudophakic eyes with posterior capsule opacification that underwent neodymium YAG laser showed a significantly higher rate of growth than unoperated eyes.

CONCLUSIONS Axial length in children older than 4 years showed a trend toward stabilization, with lower changes in axial length measurements in pseudophakic eyes and a higher rate of axial growth in contralateral eyes. (J AAPOS 2014;18:173-177)

Several variables affect the anatomic and functional outcomes of cataract surgery with intraocular lens (IOL) implantation in children, including patient age, cataract morphology, surgical technique, posterior capsule opacification, intra- and postoperative complications, IOL type, IOL material, and refractive power of the IOL. The advantage of IOL implantation in children is that it provides permanent optical correction for amblyopia treatment. Yet the eye continues to grow, requiring adjustments to refractive correction until adulthood.[1] For this reason, calculating the refractive power of the IOL to be implanted in children with cataract is challenging. Investigators who have studied the development of the human eye have demonstrated greater axial growth during the first years of life, with a progressive decrease until adolescence.[2,3] The influence of pseudophakia in the rate of ocular axial growth has been analyzed.[4,5] The purpose of this study was to analyze axial length change over time in pediatric pseudophakic eyes.

Methods

This prospective study was approved by the Research Ethics Committee of the Federal University of São Paulo, Brazil, and adhered to the principles of the Declaration of Helsinki. Enrolled children were 4-10 years of age with bilateral lamellar cataracts and initial best-corrected visual acuity ≤20/80 in one eye and were evaluated at the Congenital Cataract Section of the Department of Ophthalmology at Federal University of São Paulo from 2000 to 2008. According to current practice at our institution, the second eye was submitted to surgery only when visual acuity decreased to <20/80 (thus accommodation was preserved for near tasks in the unoperated, contralateral eye). Patients that presented with traumatic cataract, anatomic changes in the anterior segment except opacification of the crystalline lens, retinal or vitreous abnormalities, previous diagnosed glaucoma, or glaucoma following cataract surgery were excluded.

The preoperative ophthalmic examination included visual acuity assessment with optical correction using the Snellen chart or the Lea symbols chart, depending on the child's level of cooperation. Ocular motility examination, biomicroscopy, keratometry,

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applanation tonometry, direct and indirect ophthalmoscopy, cycloplegic retinoscopy, ultrasonography, and ultrasound biometry were performed in both eyes.

Ocular axial length measurements were obtained by A-scan ultrasound biometry (Humphrey Ultrasound Biometer, Model 820, Humphrey Instruments Inc, San Leandro, CA), with contact technique involving applanation of the cornea. Biometry of pseudophakic eyes was performed with velocity constants set at 1532 m/second for patients with poly(methyl methacrylate) (PMMA) IOLs and at 1550 m/second for contralateral eyes.

All children underwent cataract surgery with IOL implantation in one eye. All eyes were operated on using a phacoemulsification technique, with aspiration of the lens nucleus and cortical material followed by IOL implantation in the capsular bag, keeping the posterior capsule intact. The limbal incision was enlarged and a single-piece IOL with a 7 mm optical zone and a 13.5 mm total diameter was implanted.

The primary outcome measure was the percentage rate of growth, defined as the measurement of the initial axial length minus the measurement at the end of the follow-up period, with this difference being divided by the initial axial length measurement and the result multiplied by 100. Percentage rate of growth was used in this study because initial axial length in each patient varied.

Initial measurements of axial length in all eyes were obtained during the preoperative evaluation. The follow-up period for the analysis of percentage rate of growth was determined at the time when cataract surgery was performed in the contralateral eye, when the final measurements were obtained.

Two groups were created for analysis of the axial length rate of growth: the pseudophakic eyes and the unoperated eyes. The values of the difference between the final and initial axial length measurements were expressed as percentage.

The following variables, which could affect axial length measurements or percentage change in axial length in pseudophakic eyes were analyzed: age, visual acuity, follow-up period, initial axial length, and presence of posterior capsule opacification.

The Wilcoxon test was used to compare the differences between initial and final axial length. The Mann-Whitney test was used to compare the pseudophakic eyes with the unoperated contralateral eyes with cataract and to analyze the percentage rate of growth in both groups. A P value of <0.05 was considered significant. The sample size was calculated in order to detect an estimated difference of one standard deviation in the rate of ocular growth between groups for a moderate to large effect considering a 90% of power and $P < 0.05$. Sample size calculation requested a total of 23 eyes in each group.

Results

During the study period, 860 children with cataract were examined, of whom 108 underwent cataract surgery with IOL implantation. A total of 50 eyes of 25 children (16 males [64%]) met the inclusion criteria. Of the 25 patients, 7 (28%) had autosomal dominant cataract, 17 (68%) had idiopathic cataract, and 1 (4%) was diagnosed with Down syndrome.

The interval between the initial and final axial length measurements ranged from 15 to 48 months (mean, 28.5 months). A total of 100 measurements were obtained for analysis, 50 measurements (25 each initial and final) in pseudophakic eyes and 50 (25 each initial and final) in contralateral, unoperated eyes.

Both eyes of each child were tested against each other at the time of the initial measurement, with no statistically significant difference regarding mean initial axial length (23.9 mm [pseudophakic eyes] vs 23.5 mm [unoperated eyes], $P > 0.05$). See Table 1.

The mean percentage rate of growth of final measurements was 0.64% in pseudophakic eyes and 2.09% in unoperated contralateral eyes. This difference was statistically significant ($P < 0.05$).

Axial length was also analyzed with respect to age, visual acuity, initial axial length, and presence of posterior capsule opacification. In the statistical analysis for percentage rate of growth for groups divided by age (12 patients, 4-6 years; 13 patients, 7-10 years), children aged 4-6 years showed significantly greater axial length percentage rate of growth (0.75 in pseudophakic eyes vs 2.4 in contralateral eyes, $P < 0.05$; Table 2).

To evaluate a possible influence of the axial length rate of growth in relation to visual acuity, pseudophakic eyes were divided into those with final visual acuity ≥20/80 and those with final visual acuity <20/80. Statistical analysis revealed no significant difference between these groups.

Ten pseudophakic eyes (40%) developed posterior capsule opacification on the visual axis during the follow-up period and underwent neodymium YAG (Nd:YAG) laser capsulotomy. Pseudophakic eyes that developed posterior capsule opacification showed greater changes in axial length than eyes that did not develop posterior capsule opacification (percentage rate of growth, 2.23% vs 0.42%, $P < 0.05$).

Eyes with initial axial length measurement ≥24 mm were compared in relation to percentage rate of growth, with eyes with initial axial length measurement <24 mm. The differences found were not statistically significant (percentage rate of growth, 2.05 vs 2.11; $P > 0.05$).

Regarding the interval time between measurements, the eyes were divided into two groups according to postoperative follow-up time, using the median of 27 months as a separatrix for statistical analysis. The results showed no significant differences in the percentage rate of growth (0.23 [≤27 months] vs 1.02 [>27 months], $P > 0.05$).

The refraction (spherical equivalent) of pseudophakic eyes at the last evaluation ranged from +3.25 D to −5.00 D, with a mean of −1.70 D.

Discussion

The present study analyzed variables that could influence the axial length rate of growth in children with bilateral cataracts. Patients were categorized as age 4-6 years or 7-10 years. Among children aged 4-6 years, the contralateral

Table 1. Initial and final axial length measurements in pseudophakic and contralateral eyes, axial length percentage variation, age at surgery, and follow-up period in children with bilateral cataracts

Patients	Initial and final axial length, mm				Percentage rate of growth		Age at surgery, years	Follow-up period, months
	Pseudophakic eyes[a]		Contralateral eyes[b]		Pseudophakic eyes	Contralateral eyes		
1	21.74	21.44	21.01	21.55	1.38	−2.57	4	33
2	23.56	24.33	23.04	24.30	−3.27	−5.47	4	36
3	22.46	22.74	22.78	23.65	−1.25	−3.82	4	15
4	23.42	23.36	23.65	24.05	0.26	−1.69	6	19
5	25.99	25.49	26.43	26.76	1.92	−1.25	6	18
6	25.04	25.47	25.12	25.87	−1.72	−2.99	5	24
7	26.64	26.57	26.44	26.91	0.26	−1.78	5	21
8	23.79	23.90	23.67	23.96	−0.46	−1.23	4	34
9	25.54	25.78	25.60	25.70	−0.94	−0.39	6	27
10	23.64	24.98	23.27	23.87	−5.67	−2.58	5	44
11	22.77	22.75	22.17	23.17	0.09	−4.51	4	21
12	23.19	23.09	23.40	23.50	0.43	−0.43	5	31
13	25.97	25.83	22.39	22.40	0.54	−0.04	10	15
14	25.50	24.86	24.96	25.13	2.51	−0.68	8	40
15	25.62	26.47	24.80	25.74	−3.32	−3.79	7	48
16	19.46	19.44	19.47	19.77	0.10	−1.54	7	25
17	25.59	25.54	25.49	26.37	0.20	−3.45	8	29
18	26.03	25.91	23.70	24.21	0.46	−2.15	10	24
19	22.33	22.49	21.44	22.69	−0.72	−5.83	9	27
20	23.07	23.05	22.83	23.14	0.09	−1.36	9	34
21	23.84	24.49	23.94	24.04	−2.73	−0.42	9	33
22	21.34	22.33	21.35	21.93	−4.64	−2.72	8	28
23	23.19	22.34	22.59	22.67	3.67	−0.35	10	35
24	24.10	24.44	23.95	24.17	−1.41	−0.92	7	31
25	23.05	23.45	22.90	22.96	−1.74	−0.26	9	20
Mean	23.9	24.02	23.5	23.94	−0.64	−2.09	6.76	28.48

[a]Wilcoxon test: Tcalc = 121.00; NS Tcrit ($P \leq 0.05$) = 89.
[b]Wilcoxon test: Tcalc = 0.00 * Tcrit ($P = 0.05$) = 89.

Table 2. Mean values of axial length percentage rate of growth in pseudophakic and contralateral eyes by age group

Patients	Percentage rate growth	
	Pseudophakic eyes	Contralateral eyes
4-7 years	0.75	2.39
7-10 years	0.54	1.81
4-10 years[a]	0.64	2.09

[a]Mann-Whitney test Ucalc = 170.50: Z(U) = 2.755; critical value: 1.96 ($P < 0.05$).

eyes showed greater rate of growth than the pseudophakic eyes, suggesting greater stability of the measurements and lower axial length rate of growth in pseudophakic eyes. In the 50 eyes analyzed in our study, all children were >4 years of age and visual acuity was not associated with axial length rate of growth because there was no statistically significant difference in the results when analyzed according to the final visual acuity obtained, ≥20/80 or <20/80. In 12 of the 25 pseudophakic eyes, final visual acuity was ≥20/40. A limitation of our study was that the sample size was not adequate for multivariate analysis among these variables.

The biometric formulas have not been developed for IOL power calculation in children, whose eye size and dimensions differ from those of adult eyes. IOL power in children depends on variables associated with eye growth and also on individual and family characteristics. Axial length in normal, phakic eyes has been shown to grow 2.4-3.3 mm in the first year of life, decreasing to 1.2-2.2 mm in the second year of life.[6] Aphakic eyes, however, may show a different rate of growth.[7,8] In pseudophakic eyes, the presence of IOL might alter eye growth patterns, slowing or accelerating this process.[9-12]

In this study, the mean value of initial axial length measurements in eyes undergoing surgery with IOL implantation (pseudophakic eyes) was 23.9 mm and the mean value of final measurements was 24.0 mm ($P > 0.05$), suggesting a relative stabilization or deceleration in axial length rate of growth in this group. In the unoperated, contralateral eyes the mean initial axial length was 23.5 mm and the mean final length was 23.9 mm, indicating a significant increase in axial length in this group ($P < 0.05$).

The percentage variation was statistically significant between pseudophakic eyes and contralateral eyes (0.64% vs 2.09%, $P < 0.05$), demonstrating that eyes undergoing cataract surgery with IOL implantation had a lower rate of axial growth than that observed in contralateral eyes. Initial axial length was longer in pseudophakic eyes. After surgery, these eyes experienced a lower rate of axial length growth, whereas the contralateral eyes had a statistically significant greater rate of growth. According to Lal and colleagues,[13] the interocular axial length difference (IALD) between eyes in children with unilateral cataracts was significantly larger than in bilateral cases, and IALD was more predictable in unilateral than in bilateral cases. In the present study, the rate of growth in pseudophakic eyes was slower after surgery than in fellow eyes, achieving a smaller IALD.

Children are at a higher risk of postoperative inflammatory response than adults and thus have a relatively higher incidence of posterior capsule opacification. Apple and colleagues[14] and Tartarella and colleagues[15] reported that the incidence of posterior capsule opacification in children is inversely related to patient age. Some authors[16-20] have proposed that primary posterior capsulotomy combined with anterior vitrectomy should be performed in children up to 6 years of age. In our study, there were 10 cases (40%) of posterior capsule opacification of the visual axis with an indication for Nd:YAG laser posterior capsulotomy. Pseudophakic eyes that developed posterior capsule opacification and underwent Nd:YAG laser showed a greater percentage variation in axial length rate of growth.

Rasooly and BenEzra[2] analyzed the effects of congenital and traumatic cataract on axial length in 64 phakic and aphakic children and concluded that there was an increased growth in eyes with cataract, which agrees with our findings. The authors suggested that such growth may be related to the presence of amblyopia in cases of unilateral cataract and discussed a possible influence of visual acuity on eye growth during childhood. In a series of 125 eyes of patients with unilateral and bilateral cataract surgery before 1 year of age, Weakley and colleagues[10] reported a correlation between the rate of refractive growth and visual acuity outcome and concluded that eyes with poorer acuity had a greater rate of refractive growth.

An IOL can correct high hyperopia resulting from aphakia and may promote a refractive outcome suitable for the treatment of amblyopia in children; bifocal or multifocal glasses with residual refractive power for distance and addition diopters for near are necessary for the recovery and development of visual acuity. Zhou and colleagues[21] examined refractive changes and axial length in 12 pediatric pseudophakic eyes (mean age, 7.16 years). The mean axial growth was 0.4 mm, whereas unoperated eyes had a mean axial growth of 0.7 mm. The authors concluded that IOL implantation did not influence the elongation of axial length in children aged 3-10 years. Filipek and colleagues[22] examined 105 pseudophakic eyes and 53 eyes without surgery in children aged 4-18 years. Mean elongation of axial length was 0.6 mm, with no significant differences between groups.

Patterns of axial length growth may vary individually and the presence of genetic predisposition to or family history of high refractive error may affect the theoretical calculations of the refractive power of the IOL.[23-25] The present study analyzed the axial length rate of growth in eyes with initial axial length >24 mm, which could represent a group of patients with high myopia. The results showed no correlation between the initial measurement and the axial length rate of growth in pseudophakic eyes or in contralateral eyes with cataract.

The interval between the initial and final measurements varied from patient to patient, depending on when cataract surgery was indicated for the contralateral eye. This may be seen as a limitation of our study because all children would ideally have had their axial length measured at the same time interval. To minimize this limitation, this variable was also analyzed by dividing the sample according to postoperative follow-up time and using the median of 27 months as a separatrix for statistical analysis. The results showed no significant differences regarding the follow-up period. According to Awner and colleagues,[26] in a group of 21 patients <4 years of age with unilateral pseudophakia, there was an increasing change in refraction with a myopic shift of 2.90 D after an average of 24 months' follow-up. The authors suggested an approach to IOL power selection that would allow rapid visual rehabilitation and not require IOL replacement at later time.

Using the measurement values obtained as a percentage of axial length rate of change, we developed a protocol for the calculation of IOL power to use in children >4 years of age. This is a customized calculation method because the result is directly related to the axial length measurements of an individual. Theoretically, axial length after IOL implantation grows at a rate of 1.30% in children undergoing surgery at 4-6 years of age and at a rate of 0.54% in children undergoing surgery at 7-10 years of age. These rates of axial growth may be applied to IOL power calculations as follows: the percentage is added to the axial length measured in each child resulting in a predicted axial length; the IOL refractive power is then recalculated using the new axial length. This calculation will generate a residual hyperopic refractive result in postoperative refraction, followed by a predicted gradual regression to emmetropia at about 12 years of age. Table 3 shows the customized correction for IOL refractive power calculation in children according to the axial length rate of growth in age groups of children >4 years of age.

Table 3. Suggested customized correction for IOL power calculation according to the axial length rate of growth in children over 4 years old with bilateral cataracts

Age of child	Customized correction
4-7 years	+ 1.30% axial length
7-10 years	+ 0.54% axial length

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