Original article

Accuracy of intraocular lens power calculation in pediatric cataracts with less than a 20 mm axial length of the eye

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Abstract

Introduction: Selection of an appropriately-powered IOL is a complex issue, especially in eyes with an axial length of less than 20 mm in pediatric cataract.**Objective:** To assess the accuracy of IOL power calculation formulae in pediatric cataracts in eyes with an axial length of less than 20 mm. **Materials and methods:** The records of children less than 15 years old with congenital cataract who had undergone primary IOL implantation were analyzed. ***Main outcome measures***: The variables studied were axial length, keratometric values and the prediction error. The data were analyzed for prediction error determination using the SRK II, SRK T, Holladay 1 and Hoffer Q IOL power calculation formulae. The formula that gave the best prediction error was identified. **Results:** Twenty-eight eyes of 19 children were included in the study. The absolute prediction error was found to be 1.84 ± 2.09 diopters (D) with SRK II, 2.93±3.55D with SRK T, 3.63±4.06D with Holladay 1, and 4.83±5.02D with Hoffer Q. The number of eyes with the absolute prediction error within 0.5 D was 6 (21.42%) with SRK II, 4 (14.28%) with SRK T, 1 (3.57%) with Holladay 1, and 3 (10.71%) with Hoffer Q. The absolute prediction error with SRK II formula was significantly better than that with other formulae ($P < .001$). The axial length influenced the absolute prediction error with Hoffer Q formula ($P = 0.04$). The mean keratometry influenced the prediction error with SRK T formula ($P = 0.02$), Holladay 1 formula ($P = 0.02$) and Hoffer Q formula ($P = 0.02$). **Conclusion:** Although the absolute prediction error tends to remain high with all the present IOL power calculation formulae, SRK II was the most predictable formula in this study.

Keywords: pediatric cataract surgery; axial length; intraocular lens calculation formulae; prediction error

Introduction

Primary intraocular lens (IOL) implantation in the capsular bag has become the most common and accepted method of optical corrections in infants and young children at the time of cataract surgery, mainly due to the advances in microsurgical techniques, improved IOL designs and high molecular weight visco-elastics (Ram et al, 2001; Lambert et al, 2001; Wilson et al, 2003; Chak et al, 2006; Gupta et al, 2011; Astle et al, 2009; Hug, 2008; Lin et al, 2010; Trivedi et al, 2005; Kekunnaya et al, 2012). Despite the advances, the unique challenge faced by the paediatric cataract surgeon is that of increased uncertainty regarding the IOL power calculation.

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The IOL calculation formula are generally designed for adult patients and may not be reliable in the smaller eyes of young children, who have steeper corneas with a high keratometry value (K), a shorter axial length (AL) and a shallow anterior chamber depth (ACD). These eyes undergo a rapid increase in the AL, dimension of cornea, ACD, and capsular bag, but there is a decrease in the steepness of the cornea and in the power of the crystalline lens and cornea (Tsimhoni et al, 2007a; Gordon et al, 1985). This tends to result in a myopic shift postoperatively, if an emmetropic power IOL is implanted. Although under-correction of the IOL power is routinely carried out, the accuracy of the final refractive outcome depends on the precision of the IOL power calculation. In the case of younger children, the prediction error (PE) in the IOL power is affected by the errors in the biometry under general anesthesia, position of the implanted IOL, and age-related under-correction planned by the surgeon (Moore et al, 2008; Norrby, 2008). So, the selection of an appropriately-powered IOL becomes a complex issue.

There have been various studies on the accuracy and comparison of IOL calculations in the paediatric age group; however, studies on refractive outcomes and PE, especially on the shorter AL, have not been done. Only a few studies have mentioned the effect of AL on PE: one with a short AL subgroup of < 22mm (Nihalani et al, 2010; Andreo et al, 1997), another with < 20 mm (Moore et al, 2008; Olsen, 2001) and the third with < 19 mm (Neely et al, 2005). In adult IOL power calculation, various studies have shown that the theoretical formulae are better than the regressional formulae (Maclaren et al, 2007; Olsen, 2007; Gavin et al, 2008; Roh et al, 2011; Hoffer, 1993; Eleftheriadis et al, 2001). But in the paediatric group, different studies have shown different results, SRK II shown to be more accurate (Kekuniya et al, 2012); and some studies have shown Hoffer Q to be more accurate (Nihalani et al, 2010) where the AL was one of the variables. Hence, this study is intended to assess the predictability of desired refractive outcomes in the immediate postoperative period in pediatric patients with a short AL, of < 20mm, undergoing cataract surgery with primary placement of IOL within the posterior capsular bag. Comparison of the results will also be made with the commonly-used IOL calculation formulae, including the Sanders-Retzlaff-Kraff II (SRK II), Sanders-Retzlaff-Kraff T (SRK T), Holladay 1 and Hoffer Q. This information should help surgeons to better predict the desired power of an IOL during pediatric cataract surgery in eyes with a relatively small AL.

Materials and methods

This study was approved by the Institutional Review Board of the Shroff's Charity Eye Hospital, Daryaganj, New Delhi and was fully compliant with the principles of the Declaration of Helsinki. The records of all children with eyes with an AL of less than 20 mm who had undergone cataract surgery with primary IOL implantation at our hospital between January 1, 2007 and December 31, 2012 were analyzed retrospectively. This included the patients with a minimum follow-up of six weeks. Cases with a history of ocular trauma and past ocular surgery, sulcus fixated IOLs, secondary IOL implantation and evidence of any ocular co-morbidity were excluded.

Preoperatively, a detailed history and complete ocular examination was done for all the children. Intra-operatively, a detailed examination under anesthesia (EUA) was performed in required cases. Intraocular pressure was measured with a Perkins hand-held applanation tonometer. Keratometry and AL were obtained under general anesthesia in required cases. Keratometry was performed using a Nidek KM 500 hand-held autokeratometer (Nidek Inc, Fremont, California, USA). A minimum of three readings were taken and an average of the readings was chosen for IOL power calculation. Biometry was done using the standard applanation technique (Alcon Laboratories, Fort Worth, Texas, USA). The A-Scan is equipped to provide IOL power using various IOL formulae, namely SRK II, SRK T, Holladay I, and Hoffer Q. Ten readings with a sharp retinal spike were taken. Calculations were made using the standard deviation (SD) of less than 0.1 mm and the average reading. The IOL power was calculated according to Enyedi's correction (Enyedi et al, 1998). All patients had records of keratometry, ACD, AL, and implanted IOL power. For all these patients, the appropriate IOL power calculation was obtained according to the various formulae.

Operative technique: A superior bridle suture was placed, a conjunctival peritomy done and a sclera-corneal tunnel made. The anterior capsule was stained with trypan blue 0.5 %. After injecting a viscoelastic in the anterior chamber, a continuous curvilinear capsulorrhexis was initiated with a cystitome and completed with pediatric capsulorrhexis forceps. Lens aspiration was performed through two side port corneal incisions using automated bimanual irrigation and aspiration. If a primary posterior capsulotomy was required, it was done before implanting the IOL and followed by an anterior vitrectomy. All the IOLs were implanted in the capsular bag. The IOL was implanted through a scleral tunnel. The tunnel incision and the two side ports were sutured with a 10–0 monofilament nylon suture. All children were examined on the first postoperative day. Topical steroids, antibiotics and homatropin were prescribed and steroids were tapered off over six weeks. The sutures were removed at four weeks postoperatively. A complete eye examination including a measurement of the intraocular pressure and a retinoscopy was done at that time. The retinoscopy was repeated at six weeks by a trained optometrist.

Data collection

The data included the patient's age at surgery, keratometry, axial length, power of the implanted IOL, IOL position and refractive status. The postoperative refraction was determined using retinoscopy at six weeks postoperatively for all patients. The refractive error was converted into the spherical equivalent (spherical equivalent = sphere + ½ cylinder) in diopters (D). Using the AL, keratometry, and the manufacturer's "A" constant obtained at the time of surgery, the expected refraction was calculated with each of the four formulae. The prediction error (PE) and absolute PE were calculated for each formula as follows:

PE = Target refraction - Actual refraction

Absolute prediction error = #" Target refraction – Actual refraction #"

Statistical Analysis: The descriptive statistics were used to represent the distribution of the PEs with each of the formulae. The Kruskal-Wallis test was used to evaluate the differences in the PEs from the four formulae. Multivariate regression models were also built to evaluate the effect of age, ACD, AL and keratometry on the absolute PE from each of the formulae. Statistical analyses were performed using the SPSS version 19 [SPSS, Inc, Chicago, Illinois, USA]. A p value of less than 0.05 was considered statistically significant.

Results

During the six-year period, 668 pediatric cataract surgeries had beene performed. Retrospectively, a detail review of all the case sheets was done and 28 eyes of 19 children with an AL of less than 20 mm who had undergone cataract surgery with primary IOL implantation in the bag were included in the study.

There were 13 boys and 6 girls. Nine children had undergone cataract surgeries in both eyes. In the rest, the left eye had been operated in 9 children and the right in 1 child. Thus there were

18 left and 10 right eyes. The mean age at the time of surgery was 6.6 ± 4.0 years (range: 2 to 14 years). The mean AL was 19.17 ± 0.87 mm (range: 17.1 - 19.98 mm), mean keratometry 44.56 ± 1.59 (range: 41.75 to 49.5) and mean ACD 2.61 ± 0.44 mm (range: 1.58 - 3.57mm). The eyes of most of the children, 21 (75 %), were in the AL between 19 to 20 mm group, followed by 4 (14.3 %) in the 17 to 18 mm group and 3 (10.7 %) in 18 to 19 mm group.

Table 1: IOL calculation formulae; Distribution of absolute PE with each formulae

Formula	Mean±SD	Median (1st and 3rd quartile)	Range	p value
SRK II	1.84 ± 2.09	1.25 (0.65, 1.93)	0.25 to 9.5	< 0.004
SRK T	2.93 ± 3.55	1.87 (1, 3.68)	0.25 to 16	
Holladay 1	3.63 ± 4.06	2.12 (1.25, 4.68)	0.25 to 18	
Hoffer Q	4.83 ± 5.02	3.12 (1.87, 6.25)	0 to 22	

The p value implies the p value for the significance of difference in the mean absolute PEs with the SRK II formula versus other formulae.

Table 1 shows the absolute PEs with each of the formulae. The PE tended to be large (range: 0 - 22D) with each of the formulae. On comparing the mean with the absolute PE, the SRK II formula showed the minimum PE (1.84 ± 2.09D). The result using the different formulae showed that the absolute PE with the SRK II formula was significantly lower than that with the use of the other formulae (p = 0.004).

Table 2: IOL calculation formulae; Distribution of mean PE with each formulae

Formula	Mean ± SD	Median (1st and 3rd quartile)	Range	p value
SRK II	0.56 ± 2.75	0.375 (- 1.34,1.18)	- 3.5 to 9.5	< 0.001
SRK T	2.45 ± 3.9	1.75 (- 0.06,3.68)	- 1.75 to 16	
Holladay 1	3.27 ± 4.41	2 (0.65,4.68)	- 2.25 to 18	
Hoffer Q	4.81 ± 5.04	3.12 (1.87,6.25)	- 0.25 to 22	

The p value implies the p value for the significance of difference in the mean absolute PEs with the SRK II formula versus other formulae.

Table 2 shows the mean PE with each of the formulae. The mean PE showed a wide variation for all the formulae. The average mean PEs were lowest for the SRK II formula. In addition, there was a significant difference in the PEs with the different formulae. Pair-wise comparisons of PEs from the different formulae showed results similar to that seen with the absolute PEs, with SRK II showing significantly lower PEs compared to that from the other formulae.

Figure 1 shows the distribution of the absolute PE using the various formulae. The number of eyes with an absolute PE within 0.5 D was 6 (21.42 %) with SRK II, 4 (14.28 %) with SRK T, 1 (3.57 %) with Holladay 1, and 3 (10.71 %) with Hoffer Q. The number of eyes with an absolute PE within 1 D was 13 (46.42 %) with the SRK II formula, 13 (46.42 %) with SRK T, 6 (21.42 %) with Holladay 1, and 5 (17.85 %) with Hoffer Q. The number of eyes with an absolute PE within 2 D was 23 (82.14 %) with the SRK II formula, 16 (57.14 %) with SRK T, 14 (50 %) with Holladay 1, and 7 (25 %) with Hoffer Q. In addition, there was a significant difference in the absolute PEs among them.

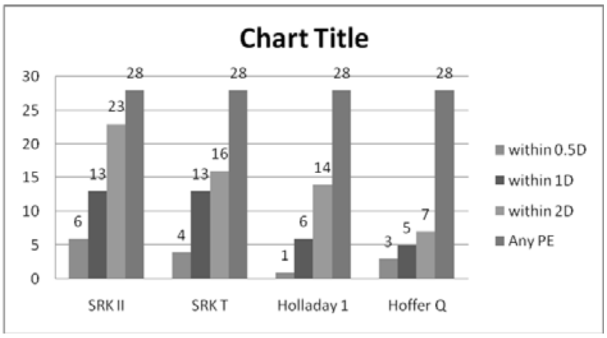

Figure 1: IOL power calculation formulae in children; Distribution of the absolute PE using various formulae.

The results of multivariate analysis for the effect of age, AL, ACD and mean keratometry value on the absolute PE with each of the formulae are shown in Table 3. The PE with the SRK II formula was not affected by any factor such as age (p = 0.09), mean keratometry value (p = 0.10), ACD (p - 0.08) and axial length (p = 0.19) of the child at the time of surgery. The age and ACD did not have any influence on the absolute PE of any formulae. The AL influenced the absolute PE with Hoffer Q (p = 0.04). The mean keratometry value influenced the PE with SRK T (p = 0.02), Holladay 1 (p = 0.02) and Hoffer Q (p = 0.01).

Table 3: Results of the multivariate analysis showing the influence of age, AL, mean K and ACD on the absolute PEs with the various formulae

Formula	Age		AL		ACD		Mean K	
	F	p value	F	p value	F	p value	F	p value
SRK II	2.07	0.09	2.19	0.19	3.54	0.08	3.62	0.10
SRK T	0.85	0.57	3.19	0.10	1.01	0.55	8.09	0.02
Holladay 1	0.52	0.83	3.19	0.10	0.998	0.56	8.26	0.02
Hoffer Q	0.34	0.94	4.67	0.04	1.48	0.35	13.11	0.01

The cases were divided into two groups, Group I with less than or equal to 7 years of age and the Group II with more than 7 years of age at the time of surgery. Table 4 shows the characteristics of the two groups. Only the difference in mean keratometry value between two groups was statistically significant. While comparing the two groups in terms of Absolute PE, the PE was less for all formulae in the Group II, but it was not statistically significant.

Table 4: Distribution of age, AL, mean K, ACD and the absolute PEs of various formulae between two age groups

	Group I (≤ 7 year)	Group II (> 7 years)	p value
Number of eyes	17	11	
Mean age	3.71 ± 2	11.09 ± 1.81	
AL	19.32 ± 0.88	18.92 ± 0.82	0.45
ACD	2.61 ± 0.51	2.62 ± 0.31	0.65
Mean K value	44.37 ± 1.33	44.61 ± 1.99	0.003
Absolute PE for			
SRK II	2.28 ± 2.5	1.15 ± 0.97	0.109
SRK T	3.3 ± 4.31	2.36 ± 1.93	0.47
Holladay 1	3.84 ± 4.93	3.31 ± 2.34	0.65
Hoffer Q	4.80 ± 6.05	4.84 ± 3.14	0.87

Discussion

The present study showed SRKII to be the most predictable with the least PE and Hoffer Q to be the most variable with the highest PE. Various study groups have looked at the predictability with the commonly used IOL calculation formulae in children in all age groups (Nihalani et al, 2010; Andreo et al, 1997; Mezer et al, 2004; Tromans et al, 2001; Neely et al, 2005; Tsimhoni et al, 2007b; Trivedi et al, 2011; Vasavada et al, 2009; Trivedi et al, 2007; Vasavada et al, 2006). However, most of the studies have concluded that all the IOL power calculations fare equally in terms of predictability of the IOL power (Nihalani et al, 2010; Andreo et al, 1997; Mezer et al, 2004; Tromans et al, 2001; Neely et al, 2005; Tsimhoni et al, 2007b; Trivedi et al, 2011; Vasavada et al, 2009; Trivedi et al, 2007; Vasavada et al, 2006).

Neely et al (2005) did a retrospective review of 101 consecutive cases, and found that SRK II, SRK T, and Holladay 1 formulas had no significant difference in IOL power predictability in pediatric patients. They reported refractive outcomes ranging from - 4.06 D to + 3.86 D of the desired spherical equivalent and a mean absolute PE of 1.16 D. They also noted that the SRK II formula showed the least variability, with Hoffer Q being the most variable, especially among the youngest children with axial lengths of less than 22 mm. Similarly, Andreo LK et al (1997) did a retrospective study of 47 eyes and found that all four IOL power calculation formulae predicted the mean refractive outcome within 1.4 D. There was minimal difference between SRK II, SRK T, Holladay 1, and Hoffer Q formulae in short, medium, and long eyes in achieving adequate predicted refraction. The mean errors noted in their study were between 1.23 and 1.33 D in long eyes, 0.98 and 1.03 D in medium eyes, and 1.41 and 1.8 D in short eyes. But in their study axial lengths of less than 22.0 mm were evaluated in the group with short eyes. Both the studies concluded that theoretical formulas did not outperform the regression formula. This is similar to the present study where the theoretical formula did not outperform the SRK II formula; but in those studies the short AL was of < 22 mm. Kekunnaya R et al (2012) did a retrospective study of 128 eyes of 84 children below 2 years of age. The mean AL was 19.9 ± 1.7 mm (range: 16.26 - 25.56) and concluded that although the PE remains high with all present IOL formula, SRK II was the most predictable formula. This finding is also similar to that of our study.

Various studies have found the theoretical formulae to be more accurate. Nihalani et al (2010) reported, in their study of 135 eyes of 96 children with an age range of 4.4 months to 18 years, that Hoffer Q was the most predictable formula in calculating the IOL power. They also reported higher prediction errors in eyes with AL d" 22 mm than in eyes with AL > 22 mm. Sixty-nine children had an AL d" 22 mm. Further, for eyes with significant deviation in the prediction error (< 0.5 D), there was usually an under-correction with other formulae, except with Hoffer Q, which was almost as likely to overcorrect. Similarly, Tromans et al (2001) analyzed 52 eyes of 40 infants and children and found that ALs of < 20 mm can give rise to greater prediction errors. There were 11 patients with ALs < 20mm and the absolute PE was 2.63 ± 2.65 (range: 0 - 9.19). The range is similar to that of our study, but contrary to that our study, the SRK T formula had the least prediction error.

Mezer et al (2004) studied the accuracy of the formulae in 59 eyes. They analyzed the data of refraction up to six months postoperatively and concluded that all IOL power formulae were inaccurate in prediction. But significant changes in the refraction takes place in six months, especially in children; hence, it is probably better to assess the accuracy of IOL power calculation at four to six weeks postoperatively.

Various studies have shown the effect of different variables in the PE. In the present study, the data were analyzed as continuous variables, as much clinically important information is lost with the use of ordinal data. No correlation of the PE with the age, AL, and mean keratometry value for the SRK II formula was found in our study. This is contrary to the results of Nihalani et al (2010) who reported that the smaller the AL, the higher was the PE. However, the AL was associated with a higher PE with Hoffer Q only ($p = 0.04$). Keratometry values influenced the PE results of the SRK T, Holladay 1 and Hoffer Q formula ($p = 0.02$, $p = 0.02$ and $p = 0.01$ respectively). Only SRK II was unaffected by both the AL and keratometry values. Age and ACD had no bearing on the PE with all the formulae. Other authors have made similar observations in terms of age and ACD (Nihalani et al, 2010; Andreo et al, 1997; Mezer et al, 2004; Tromans et al, 2001; Neely et al, 2005; Tsimhoni et al, 2007b; Trivedi et al, 2011; Vasavada et al, 2009; Trivedi et al, 2007; Vasavada et al, 2006). Tsimhoni et al (2007b) did a mathematical analysis of the predicted IOL power among the SRKII, SRKT, Holladay 1, Hoffer Q and Haigis formulae over a range of ALs from 16 to 28 mm and K values from 40 to 55 D for different refractive goals (plano and

+ 6.00D) and found significant differences in the accuracy of IOL power prediction among the commonly used formulae in the pediatric age group. In another mathematical analysis, (Tsimhoni et al, 2008) the same group found that even a small AL measurement error in pediatric eyes may lead to large errors in IOL calculations but that keratometry did not influence the IOL calculation. Hoffer Q was the most sensitive with 7.6D/mm and SRK II the least with 2.5D/mm. In the present study, Hoffer Q was influenced by the AL ($p = 0.04$), but the keratometry value influenced all formulae except SRK II. Moore et al (2008) compared the formulae retrospectively in 203 eyes of 153 children. They reported that there was no significant difference in the accuracy of the various IOL power formulae. However, they found that in a multiple regression model, age and keratometry were the only two variables significantly associated with the mean absolute PE, but not in the subgroup of AL < 20 mm (n = 41), where age and keratometry were not associated with absolute PE. In the present study, keratometry was associated with SRKT, Holladay 1 and Hoffer Q but not with SRK II; and Hoffer Q was associated with AL.

Thus, the existing literature suggests that a significant amount of inaccuracy exists in the IOL power calculation in children. There are limited studies comparing the various IOL power formulae in children eyes with < 20 mm of AL. In addition, they comprise only a subgroup in a few studies where an AL of less than 22 mm was taken as that for short eyes.

The ± 0.5 D was considered as clinically significant so as to be as close to the target refraction as possible. Most of the adult studies present the results of prediction error within 0.5 D or 1.0 D (Hoffer, 1993; Holladay et al, 1998; Retzlaff et al, 1990). In this study, the predictability of all 4 formulae within 0.5, 1.0 D and 2 D was evaluated. This showed that the most predictable formula SRK II still gave a PE higher than 0.5 in 78.58 %, 1.0 D in 53.58 % and 2D in 17.86 % of the eyes. In addition, even with the SRK II formula, the mean prediction ranged from - 3.5 D to 9.5 D. These findings are similar to the findings of Kekunnaya R et al (2012).

In the present study, even though the PE for all the four formulae was less in the more than 7 years age group, it was not statistically significant. Only the difference in the K value of the cornea was statistically significant. To the best of our knowledge, there has been no study showing such a difference between the two age groups.

There is a need to modify the current IOL power calculation formulae to make them more accurate and relevant for pediatric eyes. We also suggest continuous analysis of data to make adjustments to the IOL power calculation and thus customize the formula for pediatric eyes.

This study also has some limitations because of being retrospective in nature. The sample size was small. Also, the involvement of multiple surgeons and optometrists in the study may have influenced the results.

Conclusions

All IOL power calculation formulae tend to have a low accuracy in children with an AL less than 20 mm. The SRK II formula was the best in the present study. Its accuracy is just over 50 % for a PE of 1 D and over 80 % for a PE of 2D.

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