Prediction Error After Lens Implantation in Children With Axial Length Less than 22 mm Below 2 Yrs

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Abstract

Purpose: To compare the accuracy of IOL power calculation in children less than 2 years of age with axial length less than 22 mm using the SRK-T, SRK-II, and Hoffer-Q formulae.

Design: Retrospective comparative study.

Methods: We retrospectively analysed 68 eyes of 39 children below 2 years of age with axial length less than 22 mm who underwent cataract surgery with primary IOL implantation. We assessed the accuracy of predicted refraction using SRK-T, SRK-II and Hoffer-Q formulae in each of the eyes by calculating and comparing mean prediction error and mean absolute prediction error with each formula. Children with a minimum follow up of 6 weeks were enrolled to study the absolute prediction error.

Results: Mean absolute prediction error was significantly different among the three formulae used for IOL power calculation in each eye (Friedman test, p-value=0.0009). There also existed statistically significant difference between SRK-T and SRK-II, SRK-T and Hoffer-Q, SRK-II and Hoffer-Q (Signed rank test, p-value= 0.0001). Absolute prediction error was minimum with SRK-II (1.85± 1.85) while it was maximum with Hoffer-Q (3.70± 4.01). Mean absolute prediction error with SRK-T was 2.09± 2.73. The clinical accuracy of absolute prediction error within ± 0.5D and ± 1 D was seen in 22 % and 40% of the eyes respectively with SRK-T while it was seen in 19 % and 38% of the eyes with SRK-II. Pearson correlation coefficient showed strong negative correlation between mean absolute prediction error with each of the three formulae and age at the time of surgery and also axial length. Lesser the age at surgery, more is the absolute prediction error. The shorter the axial length, more is the prediction error. There was no correlation of any of the formulae with mean keratometry reading. There existed positive correlation of SRK-II, Hoffer-Q and IOL power implanted. Higher the IOL power, more is the prediction error.

Conclusion: The accuracy of SRK-T and SRK-II was comparable in calculating IOL power in children with axial length less than 22 mm and below 2 years of age.

Keywords: paediatric cataract, IOL formulae, prediction error

Introduction

Primary IOL implantation is considered as a standard of care by most paediatric ophthalmologists when children are undergoing cataract surgery beyond age of 2 years. In contrast the advisability of IOL implantation in children less than 2 years of age is still being questioned. The reason for this debate is that most of the modern IOL power calculation formulae have different accuracy in eyes with short axial lengths and steep keratometry readings and thus refractive outcomes become more inaccurate in eyes less than 2 yrs of age.1 In addition the small dimension of the infant eye with a small capsular bag, decreased scleral rigidity, and increased tissue reactivity make IOL implantation technically difficult.2-4 Although advanced microsurgical techniques and use of acrylic foldable intraocular lenses have made IOL implantation practically simpler, but still there is no gold standard for accurately predicting the target refraction. This made us design a retrospective study to assess the accuracy of various formulae used for IOL power calculation in these children – SRK-II, SRK-T and Hoffer-Q.

Methodology

This retrospective comparative study included 68 eyes of 39 children with congenital or developmental cataract, below 2 years of age with axial length less than 22 mm who underwent cataract surgery with IOL implantation at our institute between May 2007 to August 2014. The study was approved by the institutional review board. Children with minimum follow up of 6 weeks were included in the study. All patients with traumatic cataract, acquired cataract, PHPV, glaucoma uveitis, corneal diameter less than 10 mm, any retinal or optic nerve pathology were excluded from the study. A thorough history was obtained from the parents and details were entered in the proforma designed for paediatric cataract patients. The preoperative visual status, wherever possible particularly the fixation status was recorded and presence of nystagmus noted. A dilated fundus examination was done in each case and in cases with dense cataract where fundus was not visible, a B-scan was ordered. All children were sent to a paediatrician for systemic evaluation and all developmental parameters including head circumference.
were noted and documented in the proforma. Keratometry and axial length measurements were performed under anaesthesia immediately before surgery by a trained optometrist. The keratometry measurements were taken using a Nidek KM 500 (Nidek Co. Ltd., Japan) handheld keratometer and the mean of 3 readings was used for IOL power calculation. The axial length was measured using a standard application technique by OcuScan RxP Ophthalmic Ultrasound (Alcon Laboratories, FortWorth, Texas, USA). Repeated measurements were performed until 10 measurements were obtained with sharp retinal spikes and 0.1 mm deviation, and the average was used for IOL calculation. IOL power calculation was undercorrected, depending on age at surgery for residual hyperopic error, or with consideration to the refractive status of the other eye. In our study we used Dahan’s recommendations to undercorrect to aim for residual hypermetropia.¹ In some cases, due to unavailability of acrylic foldable lenses of the required power, the amount of undercorrection needed to be modified. IOL power calculation was obtained according to formulae – SRK-II, SRK-T, Hoffer-Q. The IOL power that was implanted was the one obtained using SRK-T formula.

Technique of Surgery
All cataract surgeries were performed by a single surgeon. Corneoscleral tunnel was made and anterior chamber was entered using 3mm keratome. Air was injected from the main port, then trypan blue dye 0.6% (Bluerhex, Dr. Agarwal’s lab, Chennai, India) was used for staining of capsule and washed. Viscoelastic substance sodium hyalurone 14mg/ml (Healon GV, Advanced Medical Optics, Inc. Santa Ana, California, USA) was injected to maintain the depth of anterior chamber. Anterior capsulorhexis was performed from the main port using cystitome to raise the flap and it was completed using uttrata forceps. Two sideport incisions were made and hydrodissection was performed from the main port. Bimanual irrigation and aspiration was done and then a high molecular weight viscoelastic Healon – GV was injected in the anterior chamber before posterior capsulotomy was done. The manual posterior capsulorhexis was done using 26 gauge needle to initiate the flap and it was completed using the rhexis forceps. The size of posterior capsulorhexis was 4-4.5 mm. This was followed by automated anterior vitrectomy. IOL implantation in the bag was done. Hydrophobic acrylic foldable lenses (Acrysof SP, Acrysof IQ, Alcon laboratories, FortWorth, Texas, USA,) were usually preferred in most of the cases with an optic diameter of 6mm and overall diameter of 13 mm. Rigid PMMA IOLs (IO-Care,Gujrat,India) with an optic diameter of 5-5.5 mm and overall diameter of 12 mm were used for implantation in some cases. The viscoelastic was removed from the anterior chamber and presence of any vitreous strand was checked for using iris repositor and then the scleral tunnel was closed using 10-0 interrupted monofilament nylon sutures. At the end of surgical procedure, gentamicin sulphate (20 mg) and dexamethasone sodium phosphate (2mg) were given subconjunctivally.
Postoperatively the patient was prescribed topical antibiotics moxifloxacin 0.3% six times a day along with prednisolone acetate 1% every hourly in the first week. Topical drops were tapered over the next 6 weeks according to the inflammatory response. Cycloplegic was used: 1% atropine ointment two times a day for 3 days followed by homatropine drops 2% three times a day for 6 weeks. The children were followed up on day 1, day 7, 2 weeks, 4 weeks, 6 weeks, then 3 monthly intervals. At each follow up visit, complete ocular examination including slit lamp biomicroscopy and indirect ophthalmoscopy was done to note corneal clarity, IOL positioning and media clarity. Retinoscopy was done at 6 weeks and then at every subsequent follow up visit by single optometrist to avoid any subjective variation. In required cases amblyopia therapy was initiated after 2 weeks of surgery. Examination under anesthesia was done at 6 weeks with suture removal. IOP was recorded in every case by Perkin’s application tonometer. Cycloplegic refraction was done and corneal diameters were also measured at the same time. Spectacles were prescribed by giving the near add (2-2.5D).

Data Collection
All the relevant data including the age at surgery, axial length, keratometry, IOL power implanted, type of IOL, was entered in the excel sheet designed for the study. Post operative refraction at the end of 6 weeks was done after suture removal under anaesthesia by retinoscopy and was converted into spherical equivalent. The predicted refraction was calculated using all the three formula and the prediction error was calculated as below:

\[ \text{Prediction error} = \text{Target refraction} - \text{Actual refraction} \]

\[ \text{Absolute prediction error} = |\text{Target refraction}-\text{Actual refraction}| \]

Statistical Analysis
Statistical analysis was performed using STATA software. Descriptive statistics were used to study the distribution of prediction error and absolute prediction error with each of the three formulae. Friedman test was used to analyze the statistical difference in the prediction error and absolute prediction error among the three formulae used on each eye. In view of significant difference obtained with Friedman test, the Wilcoxon signed rank test was used then to evaluate the difference in prediction error between any two of the three formulae used on each eye. Pearson correlation coefficient was used to study the correlation of both mean prediction error, and mean absolute prediction error with various variables- age at surgery, axial length, keratometry, IOL power implanted. p-value less than 0.05 was considered statistically significant.

Results
We retrospectively analyzed sixty eight eyes of 39 children. The age at surgery ranged from 2 months to 24 months with a mean age of 13.5± 7.38 months . There were 24 males and 15 females. 32 children had bilateral cataract and 7 had unilateral cataract . Majority of cases presented with total cataract (37%) followed by lamellar cataract (30%). Axial length ranged from 16.93 to 21.91 with a mean axial length of 19.82 ± 1.42 mm. There were 68 eyes with axial length shorter than 22 mm of which 20 eyes were of patients more...
Discussion

Although the evolution of surgical techniques has made primary implantation quite popular and possible in paediatric population below 2 years of age, the postoperative target refraction accuracy and emmetropisation of refractive error are still the two debatable issues. In children less than 2 years of age, axial length and keratometry change rapidly as compared to more than 2 years of age. Therefore it has been found practical to rely on axial length alone when IOL power is to be chosen for infants. The majority of change in axial length occurs in the first 2 years of life making the IOL implantation more challenging as there is a myopic shift expected as the child grows, so these children should be undercorrected substantially to aim for emmetropisation or mild myopia in adult life. In our study we used Dahan’s recommendations to undercorrect to aim for residual hypermetropia. It is also impossible to accurately predict how much the refractive error will change over time in these eyes. The high residual hypermetropia plus the near add makes it difficult for the infants to wear glasses hence making it a risk factor for amblyopia. So the undercorrection done was modified according to age at surgery, laterality of cataract, refractive status and axial length of the other eye and also the calculated dioptic power of IOL as for cases with high IOL power more than 40D, more undercorrection was done at times due to unavailability of such high IOL powers. The other issue is the reliability of formulae used in predicting post operative refraction. Previous reports on the predictability of IOL calculation formulae in children are based on the comparisons of mean prediction error and mean absolute prediction error. In adults, Hoffer-Q has been proven by Hoffer to be more accurate as compared to Holladay and SRK-T in eyes with axial length less than 22 mm. There are few studies done on adult eyes with shorter axial length to determine the accuracy of IOL calculation formulae in these shorter adult eyes. Most of the studies have shown Hoffer-Q to be the best and most reliable in eyes with axial length less than 20 mm, Holladay–I performs equally better for eyes with axial length of 21-21.5 mm and SRK-T also shows comparable results in eyes with axial length 21.5-22 mm. But what about the accuracy of these formulae in predicting refractive outcomes in children below 2 years of age and with axial length less than 22 mm? There is no gold standard for which calculation formulae should be used to predict accurately the target refraction in children. This study shows the accuracy of the three formulae which are commonly used in calculating IOL power in adults – SRK-II, SRK-T, Hoffer-Q, in predicting post operative refractive outcomes in paediatric population below 2 years of age.

Table 1. Clinical characteristics of children operated for paediatric cataract with shorter eyes

| Parameter               | Mean ± Standard Deviation | Range  |
|-------------------------|---------------------------|--------|
| Age (Months)            | 13.55 ± 7.38              | 2 to 24|
| Sex, n (%)              |                           |        |
| Male                    | M= 61.50%                 |        |
| Female                  | F = 38.46 %               |        |
| Laterality, n (%)       |                           |        |
| Bilateral               | B/L=82.05%                |        |
| Unilateral              | U/L=17.94%                |        |
| Keratometry, D          | 44.40 ± 1.85              | 40.62 to 49.50 |
| Axial Length, mm        | 19.82 ± 1.42              | 16.93 to 21.91 |
| IOL Power Implanted, D  | 28.40 ± 4.92              | 20 to 40 |
| Under correction done, D| 4.88 ± 2.97               | 1 to 17 |
| Post Operative refraction(SE) | 3.35 ± 2.38 | -2.5 to 9 |

(N : Number, D : Dioptre, mm : Milimeter)
Kekunnaya and associates studied the accuracy of IOL power calculation formulae in children less than 2 years of age. They compared the absolute prediction error with each of the formulae in 128 eyes of 84 children with mean age of 11.7± 6.2 months with axial length of 19.9± 1.7 mm and found that SRK-II was the least variable of the four formulae used – SRK-II, SRK-T, Hoffer-Q, Holladay, and gave the minimum absolute prediction error (2.27± 1.69D) while Hoffer-Q was the most variable with absolute prediction error of 4.61± 3.12. They have mentioned the range of absolute prediction error from 0-14.3 D. In their study the number of eyes with absolute prediction error within ±0.5D was 21.1% with SRK-II, 6.3% with SRK-T and 3.9% with Hoffer-Q. They found significant difference between absolute prediction error with SRK-II as compared to other formulae.

### Table 2. Distribution of Mean Prediction Error with all the Three Formulae in eyes with axial length less than 22 mm in children less than 2 years of age

| Formula | Mean ± Standard Deviation (Diopter) | Median (1st, 3rd Quartile, Diopter) | Range | p- Value |
|---------|-----------------------------------|-----------------------------------|-------|----------|
| SRK II | -0.28 ± 2.61                     | -0.06 (-1.81,1)                  | -8 to 11 | 0.00001 (Friedman test) |
| SRK T  | 1.54 ± 3.08                      | 1 (-0.25 , 2)                   | -2.25 to 16.5 |        |
| HOFFER – Q | 3.35 ± 4.14                | 2.375 (1.18, 4.5)              | -2 to 21.5 |        |

### Table 3. Distribution of Absolute Mean Prediction Error with all the Three Formulae in shorter eyes in children less than 2 years of age

| Formula | Mean ± Standard Deviation (Diopter) | Median (1st, 3rd Quartile, Diopter) | Range   | p- Value |
|---------|-----------------------------------|-----------------------------------|---------|----------|
| SRK II | 1.85 ± 1.85                      | 1.5 (0.75,2.5)                  | 0 to 11 | 0.00001 |
| SRK T  | 2.09 ± 2.73                      | 1.31 (0.5 , 2.06)              | 0 to 16.5 | 0.00001 |
| HOFFER – Q | 3.70 ± 4.01                 | 2.375(1.25, 4.5)               | 0.375 to 21.5 | 0.00001 |

### Table 4. Clinical accuracy of prediction error within ± 0.5 & ± 1 with each of the formula

| Formula | Mean Prediction Error ± 0.5 | Deviation | Mean Prediction Error ± 1.00 | Deviation |
|---------|----------------------------|-----------|-----------------------------|-----------|
|         | Over Correction | Under Correction | Over Correction | Under Correction |
| SRK II  | 19%          | 45%       | 41%                        | 38%       |
| SRK T   | 22%          | 63%       | 22%                        | 40%       |
| HOFFER – Q | 11%          | 83%       | 8%                         | 26%       |

### Table 5. Showing the correlation between absolute prediction error and variables of age at surgery, axial length, mean keratometry, IOL Power Implanted

| Formula | Age | Axial Length | Mean Keratometry | IOL Power Implantation |
|---------|-----|--------------|------------------|-------------------------|
|         | Coefficient | P Value | Coefficient | P Value | Coefficient | P Value | Coefficient | P Value |
| SRK II  | -0.39 | 0.0009 | -0.45 | 0.0001 | -0.02 | 0.847 | 0.36 | 0.002 |
| SRK T   | -0.32 | 0.007 | -0.44 | 0.0001 | 0.07 | 0.544 | 0.14 | 0.24 |
| HOFFER – Q | -0.39 | 0.001 | -0.65 | 0.00001 | 0.10 | 0.403 | 0.35 | 0.002 |

Kekunnaya and associates studied the accuracy of IOL power calculation formulae in children less than 2 years of age. They compared the absolute prediction error with each of the formulae in 128 eyes of 84 children with mean age of 11.7± 6.2 months with axial length of 19.9± 1.7 mm and found that SRK-II was the least variable of the four formulae used – SRK-II, SRK-T, Hoffer-Q, Holladay, and gave the minimum absolute prediction error (2.27± 1.69D) while Hoffer-Q was the most variable with absolute prediction error of 4.61± 3.12. They have mentioned the range of absolute prediction error from 0-14.3 D. In their study the number of eyes with absolute prediction error within ±0.5D was 21.1% with SRK-II, 6.3% with SRK-T and 3.9% with Hoffer-Q. They found significant difference between absolute prediction error with SRK-II as compared to other formulae. They also studied the effect of age, axial length, mean keratometry
on the absolute prediction error with each of the formula. Age did not influence the absolute prediction error for any of the formulae. SRK-II was not affected by any factor of age, axial length, mean keratometry. Mean keratometry influenced absolute prediction error with SRK-T. Axial length influenced absolute prediction error with Holladay and Hoffer-Q. Similarly in our study we found significant difference in the absolute prediction error among the three formulae used (Friedman test – p value=0.0001). SRK-II gives minimum mean absolute prediction error (1.85±1.85), while it was comparable to SRK-T (2.09±2.73) and Hoffer-Q gave the maximum absolute prediction error (3.70±4.01). But the median absolute prediction error in our study was the least for SRK-T (1.3), while for SRK-II it was 1.5 and maximum for Hoffer-Q (2.375); while in their study it was around 2D for SRK-II and 3D for SRK-T and 4.25D for Hoffer-Q. The median as well as absolute prediction error were quite high in their study as compared to our results suggesting more accuracy and less measurement errors in our study. The range of prediction error in our study was from 0-11 for SRK-II, 0-16.5 for SRK-T, while it was maximum for Hoffer-Q, 0.375-21.5. This shows that SRK-II was the least variable, while Hoffer-Q was the most variable. The clinical accuracy of prediction error within ±0.5 D was 22% with SRK-T while it was 19% with SRK-II and 11% with Hoffer-Q. SRK-T was accurate to within ±1 D of predicted refractive outcome in 40% of cases which signifies the accuracy of SRK-T in predicting desired refraction in children with shorter eyes. The accuracy of SRK-II was 38% which is comparable to SRK-T. Hoffer-Q gave accurate results within ±1D in 26% cases, which proves it to be less reliable in children. Moreover the accuracy of IOL power calculation in children below 2 years was seen in greater percentage of eyes with all the three formulae in our study. Contrary to the study of Kekunnaya and associates, in our study age at surgery and axial length influenced absolute prediction error with each of the formulae.10 We found no correlation between absolute prediction error and mean keratometry. We also found a strong positive correlation between SRK-II, Hoffer-Q and IOL power calculated.

Ashworth et al in 2007 published a case review of 33 eyes of 25 children.11 It was a retrospective study including children with congenital cataract who underwent primary IOL implantation, with mean age of 18.09±16.22 weeks and with axial length of 18.52±1.8 mm. In this study SRK-T formula was used to calculate IOL power. The mean target refraction was 7.23±2.67 with the mean post operative refraction at 6 weeks was 7.07±3.23, (range=0.75 to 14 D). Similarly in our study SRK-T formula was used for IOL power implantation and the mean target refraction was 4.88±2.97. In our study the less hyperopic target refraction can be explained due to the age group chosen upto 2 years whereas it was upto 1 year in their study and also we wanted to study the effect of undercorrecting less on myopic shift. The mean postoperative early refraction in our study was 3.35±2.38 D (range=-2.5 to 9). The mean prediction error using SRK-T formula was -0.167±1.63D in their study with clinical accuracy within1D seen in 45% of eyes which is quiet comparable to accuracy within ±1D seen in 40% eyes using SRK-T formula in our study. They have also studied the influence of age, axial length, IOL power on accuracy of formula used, and found not much correlation whereas in our study the accuracy of IOL formula within ±0.5 D of absolute prediction error with each of the formula is influenced by age, axial length and also IOL power.

Vanderveen and associates reported that mean absolute prediction error in their study was lowest with SRK-T (1.4±1.1, median=1.3 D), while with SRK-II it was 2.4±1.8, median=2.1, and maximum prediction error was seen with Hoffer-Q (2.4±1.8, median=2.2).13 The mean absolute prediction error with all the formulae were lower in their study as compared to our study, although the median prediction error with SRK-T was also similar in our study (median=1.3D), while median prediction error with SRK-II was 1.5D and with Hoffer-Q it was 2.375 D in our study. This shows that the predictability of IOL power calculation with SRK-T was quiet reliable in our study too.

There are limitations of our study, the use of calculation formulae are based on the anatomic features of adult population, the structural variations in children also may alter the effective lens position, and therefore the lens power. Moreover the mean IOL power implanted was higher in our study which may also contribute to the measurement error. In some cases PMMA IOLs needed to be used and in a few cases the undercorrection needed to be modified due to unavailability of the required IOL power. The follow up period was short. This study was a retrospective study, so progressive axial length measurements could not be documented. We did not study the influence of age or axial length on myopic shift separately as our study already documented. We did not study the influence of age or axial length measurements in myopic shift separately as our study already included eyes with shorter axial lengths. There is scope of taking this study forward to evaluate and compare the long term refractive outcomes in these groups to come out with a gold standard of how accurate each IOL formula is for predicting the desired target.

Cite This Article as: Gupta R, Ganesh S, Singh C, Khurana A.K. Prediction Error After IOL implantation in Children with Axial Length Less Than 22 mm Below 2 Yrs of Age. Delhi J Ophthalmol 2016;26;250-5.

Acknowledgements: None

Date of Submission: 01/12/2015 Date of Acceptance: 28/12/2015

Conflict of interest: None declared

Source of Funding: Nil

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