Original Article

Keratometry in paediatric eyes with cataract in Indian population

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Abstract

Background: To compare the keratometric data of unilateral cataractous paediatric eyes with their corresponding non-cataractous fellow eyes.

Methods: In this clinic-based observational study eyes of 354 consecutive children who presented with unilateral or bilateral cataract were analysed. Other data collected included age at the time of surgery, gender, keratometry, axial length (AL) and laterality of cataract. Keratometric values were obtained under general anaesthesia using a handheld Nidek Auto Keratometer. AL was measured with an ultrasound A-scan using either the immersion or the contact technique (Ocuscan, Alcon).

Results: The average K value in the cataractous eyes was 44.97 ± 2.53 D (range: 37.38–55.13 D). The K values in different age groups were significantly different ($P < 0.001$). Irrespective of age, there was a significant difference between the K values of unilateral ($n = 34$ eyes: $K = 44.16 \pm 2.02$) and bilateral cataracts ($n = 320$ eyes: $K = 45.07 \pm 2.56$) ($P < 0.05$). In the age groups of 6–18 and 18–60 months, there was significant difference in K values of males and females ($P < 0.02$, $P < 0.008$). There was no significant difference in K values of unilateral cataractous eyes and their fellow eyes ($P = 0.096$). Age and AL demonstrated a significant linear relationship with K values: $K = 46.29 -$ (0.6 1 log of age in months) ($R^2 = 0.09$, $P < 0.001$) and $K = 53.78 -$ (0.451 AL) ($R^2 = 0.17$, $P < 0.001$).

Conclusions: The keratometric values of young children were steeper than those of older children. There was no significant difference in K values of the unilateral cataractous eyes as compared to the fellow eyes.

Keywords: Axial length, keratometry, paediatric cataract

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Submitted: 31-Mar-2021 **Accepted:** 18-Jun-2021 **Published:** 25-Oct-2021

INTRODUCTION

The eyeball grows rapidly in the neonatal period and in infancy.[1,2] This growth in the eyeball involves a remarkable change in the optical components of the eye, namely the cornea, the lens and the axial length (AL). However, changes in these three components are balanced with each

Access this article online	
Quick Response Code:	Website: www.jcsr.co.in
	DOI: 10.4103/jcsr.jcsr_23_21

How to cite this article: Vasavada AR, Sudhalkar A, Praveen MR, Shah SK, Vasavada VA. Keratometry in paediatric eyes with cataract in Indian population. J Clin Sci Res 2021;10:221-6.

other so that normal adult refraction is attained, resulting in emmetropia.[1-7] Several detailed reports have been published on the relationship between age,[2,7] birth weight,[2] AL,[4,6] refractive status[7] and clarity of the crystalline lens,[6] even in eyes that are otherwise normal.[2,6] New-borns have steep corneas and with-the-rule astigmatism, which tends to flatten with growth.[3]

In recent times, most physicians consider primary intraocular lens (IOL) implantation as a standard of care when children are undergoing cataract surgery after their first birthday.[5] Autokeratometers, however, are still not available in most medical centres, especially in non-paediatric ophthalmology units and in the developing world, where congenital cataract is a leading cause of childhood blindness. Several clinical conditions, such as the presence of corneal opacities or posttraumatic deformations, may preclude accurate keratometric measurement. Finally, it may be necessary to predict IOL power before narcosis. However, serious errors may occur in infants and small children, given the rapid changes in corneal curvature in the first few months of life. Keratometric values are important not only with respect to the refractive status of the eye in early life, but they also help in determining the accurate power of the IOL. The purpose of our study was to report the variations in keratometric data with respect to age, AL and the presence of cataract in Indian children who have otherwise normal eyes.

MATERIAL AND METHODS

We analysed 354 eyes of all children who had presented consecutively at our clinic for unilateral or bilateral cataract (in bilateral cataract both eyes were analysed) management between 2007 and 2010. We included microphthalmic eyes (corneal diameter ≤9 mm) and eyes with persistent foetal vasculature (PFV). We excluded eyes with traumatic cataract. We also excluded eyes if the keratometric value at the time of cataract surgery was not available. Other data collected included age at the time of surgery, gender, AL and laterality of cataract. All the patients were of Indian origin.[1,6] Keratometric values were obtained under general anaesthesia using a handheld Nidek Auto Keratometer, model KM-500 (Nidek, Gamagori, Japan). We attempted to obtain keratometric measurements without the use of an eyelid speculum. The automated readings were recorded in dioptres (D). A single, experienced examiner took three consecutive readings, and an average of these three readings was taken. AL was measured with an ultrasound A-scan using either the immersion or the contact technique (Ocuscan, Alcon). Two experienced examiners generated ten acceptable values of AL for each eye under anaesthesia and an average value was obtained from this.

Regression analysis and analysis of variance (ANOVA) were used for statistical analysis. To assess the adequacy of a normality assumption, we used the residuals to look at the histogram. For gender and laterality analysis, a *t*-test for independence was used based on the results of the *F*-test for equality of variance. For eyes with unilateral cataract, we compared the *K* values of the cataractous eye with those of the fellow eye using a paired *t*-test.

RESULTS

A total of 354 eyes were analysed, with a mean age being 19.25 ± 24.9 months (range: 1–96 months). The median age was 6.0 months. The average *K* value in cataractous eyes was 44.97 ± 2.53 D (range: 37.38–55.13 D) and the average AL was 20.90 ± 2.34 mm (range: 15.26–26.44 mm). Figure 1 shows the frequency distribution of *K* values. Table 1 lists descriptive statistics of *K* values in different age groups. The results of the ANOVA test revealed that the *K* values in different age groups were significantly different ($P < 0.001$). Irrespective of age, there was a significant difference between the *K* values of unilateral ($n = 34$ eyes: $K = 44.16 \pm 2.02$) and bilateral cataracts ($n = 320$ eyes: $K = 45.07 \pm 2.56$) ($P < 0.05$). Table 1 lists descriptive statistics of *K* values in different age groups with respect to males and females. There was no significant difference in *K* values between males and females in age group of up to 6 months and 60–96 months ($P = 0.5$, $P = 0.95$). However, in the age group of 6–18 and 18–60 months, there was significant difference in

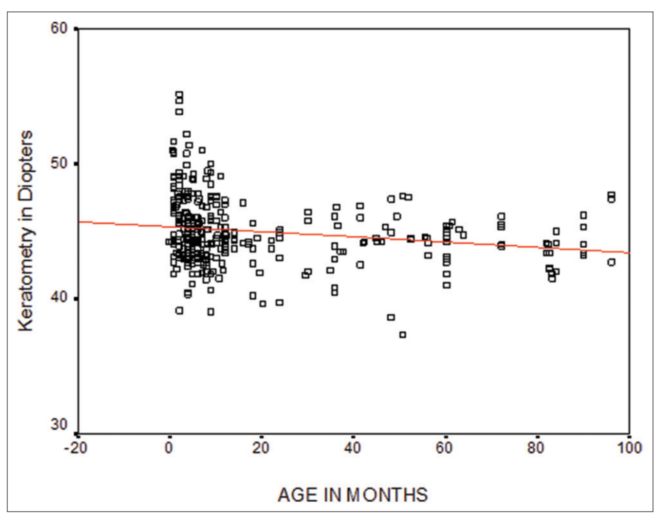

Figure 1: A scatter plot showing age versus keratometry values of all paediatric eyes with congenital cataract

Table 1: Descriptive statistics of keratometric values*

Age-group wise					
Age (months)	No. of eyes	Corneal curvature (Dioptres)	Median	95% CI	
				Lower bound	Upper bound
Upto 6	166	45.6±2.8	44.6	45.15	46.01
6–18	95	44.7±2.2	44.4	44.27	45.18
18–60	62	43.9±2.1	43.9	43.42	44.52
60–96	31	44.4±1.5	44.9	43.68	44.87
		F=3.70, P<0.001			
Age (months)	No. of eyes	Axial length (mm)	Median	Lower bound	Upper bound
Up to 6	166	18.09±1.54	18.13	18.09	17.85
6–18	95	19.57±1.55	19.50	19.57	19.26
18–60	62	22.05±1.32	21.61	22.05	21.55
60–96	31	22.35±1.97	21.94	22.35	21.85
		F=132.74, P<0.001			

Gender-wise				
Age (months)	Corneal curvature (Dioptres)		F	P-value
	Male	Female		
Upto 6	45.6±2.7	45.3±2.9	0.44	0.5
6–18	44.4±2.3	45.5±2.1	5.4	<0.02
18–60	43.5±2.1	45.4±1.5	7.4	<0.008
60–96	44.3±1.7	44.3±0.8	2.43	0.22

*Data are presented as mean±standard; CI=Confidence intervals

K values between males and females ($P < 0.02$, $P < 0.008$). Table 2 lists descriptive statistics of *K* values in different age groups with respect to unilateral and bilateral cataracts. There was no significant difference in *K* values between unilateral and bilateral cataracts in any age group ($P = 0.4$, $P = 0.46$, $P = 0.83$, $P = 0.37$).

Table 2: Descriptive statistics of keratometry values* with respect to unilateral and bilateral cataract

Age group (months)	No. of eyes	Corneal curvature (Dioptres)	F	P
Up to 6				
Unilateral	9	44.8±2.4	0.73	0.4
Bilateral	157	45.6±2.8		
6–18				
Unilateral	8	44.1±2.2	0.56	0.46
Bilateral	87	44.7±2.2		
18–60				
Unilateral	12	43.8±1.9	0.04	0.83
Bilateral	50	43.9±2.2		
60–96				
Unilateral	5	43.7±1.0	0.81	0.37
Bilateral	26	44.4±1.6		

*Data are presented as mean±standard deviation

We also evaluated 34 subjects for the mean *K* values and AL of unilateral cataractous eyes and those of the fellow eyes with clear lenses. There was no significant difference in *K* values between the pairs (cataract vs. clear lens: 44.1 ± 2.02 vs. 44.6 ± 1.3, $P = 0.096$). However, the AL was longer in those of the fellow eyes with clear lenses when compared against cataractous eye attaining statistical significance (cataract vs. clear lens: 20.90 ± 2.3 vs. 21.79 ± 1.5, $P < 0.03$).

The results of the regression analysis using *K* as an independent variable are shown next. Regression analysis was attempted using a log of the patients' ages, and we found that age was a significant independent predictor. The negative coefficient shows that *K* values decline with a unit increase in the log of age by 0.612 units ($K = 46.29$ – [0.6 1 log of age in months] [$R^2 = 0.09$, $P < 0.001$]). Regression analysis was also attempted with AL, and we found that AL was also a significant independent predictor. The negative coefficient shows that *K* values decline with a unit increase in AL by 0.451 units ($K = 53.78$ – [0.451 AL] [$R^2 = 0.17$, $P < 0.001$]) Regression analysis was also attempted with both the logs of age and AL. We observed that although age was significant individually as an independent predictor, it was not significant when AL was also introduced in the model. Only AL was found to be statistically significant in the model where both the logs of age and AL were taken. The negative coefficient of AL shows that *K* values decline with a unit increase in AL by 0.433 units ($K = 53.59-$ [0.305 log of age in months] – [0.438 AL] [$R^2 = 0.173$; age, $P = 0.809$; AL, $P < 0.001$]). Age showed a significant linear relationship with *K* values (Figure 1). The hypotheses necessary for an accurate inference of normality assumptions were found to be more valid for a logarithmic value of age (Figure 2). Figure 3 shows a scatter plot of AL versus *K* values, suggesting a linear relationship between the two.

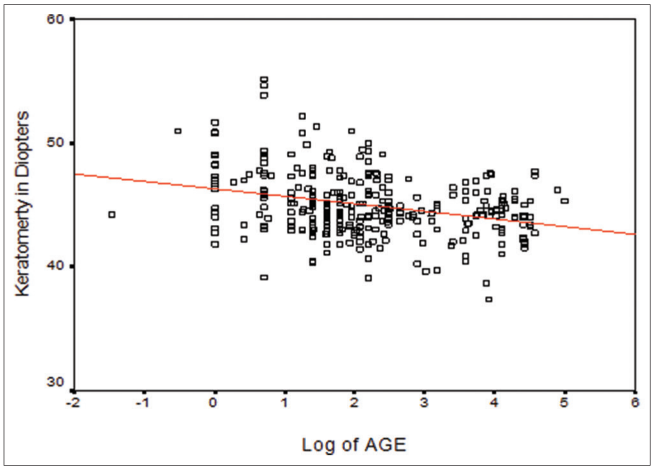

Figure 2: A scatter plot showing mean log of age versus keratometric values of all paediatric eyes with congenital cataract

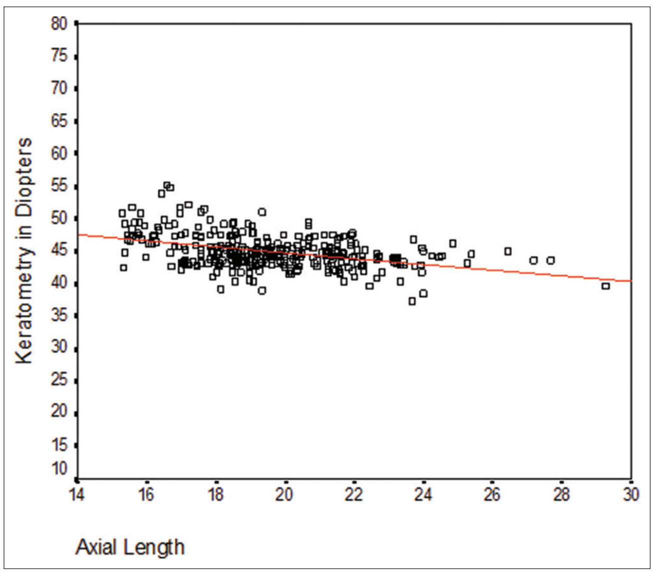

Figure 3: A scatter plot showing axial length versus keratometric values of all paediatric eyes with congenital cataract

DISCUSSION

The progress made in paediatric cataract surgery over the last 20 years allows cataract removal and primary IOL implantation very early in life, even before 1 year of age.[8-10] Achievement of the desired refractive outcome after primary IOL implantation is therefore as crucial as surgery itself to minimise anisometropia and ensure acceptable refraction on a long-term basis. However, IOL power calculation in infants below 1 year of age ranges from -4.06 to -3.86 and is prone to error.[11] The main reason for suboptimal results in IOL power calculation in infants include technical difficulties in measuring biometric parameters in small children, the use of formulas designed for adult patients, and incomplete knowledge of the development of the eye in the first few years of life. Several studies have been published on corneal development in infants. The older studies were pathologic ones on cadaveric eyes or were performed *in vivo* with obsolete techniques or a manual keratometer.[12-15] Other studies were limited by a small sample size or were designed with different purposes.[13-15] Flitcroft *et al*.[16] investigated keratometry in a paediatric population with congenital cataract, but the study was aimed at describing differences in corneal curvature before and after cataract surgery, and separate *K* values based on the patients' ages were not reported. More recent studies have focussed on refractive development in pre-term infants and keratometric readings for full-term infants are reported only for comparison purposes.[2,17] Moreover, the sample sizes used in these studies is usually small and not stratified by age. However, these studies include only normal subjects where age is not specifically relevant to cataract surgery. Direct comparisons between the results of these studies and our findings are difficult because of the previously mentioned methodological differences.

In this study, we report *K* values of cataractous paediatric eyes. We analysed biometric and keratometric values in a large population of full-term born children with uncomplicated congenital cataract. Most of the eyes in this series had keratometric measurements obtained using an automated handheld keratometer. While measuring corneal curvature, it was found that the Nidek automated keratometer was accurate, reliable and easy to use, and its results compared favourably with those obtained using the manual Zeiss keratometer (Carl Zeiss Vision, Jena, Germany).[18]

Consistent with the reports from previous studies, we found an expected pattern of corneal flattening with increasing age. It is well documented in the literature that infantile eyes have significantly steeper *K* values.[1,19] The results of our study suggest that paediatric cataractous eyes in the range of 0–6 months of age have significantly steeper *K* values when compared with older children. Keratometric values of younger children with cataract were steeper than those of older children.[6] Ehlers *et al*. obtained 47.50 D as a mean *K* value for mature infants and 43.69 D for children aged 2–4 years. They[20] concluded that corneal curvature reaches the adult range at about 3 years of age. It was noted that noted that the average *K* value of full-term infants was 45.2 D.[1] In Japan, Inagaki performed automated keratometry was performed on 11 mature neonates.[7] The authors[7] reported a mean ± standard deviation (SD) keratometric reading of 47.0 ± 1.2 D. The curvature decreased to a mean ± SD of 44.1 ± 1.7 D by the age of 3 months in 8 infants.[7] Asbell *et al*. noted that the mean corneal curvature of new-borns was 47.59 D. This mean value decreased to 46.30 D in the 6–12 months age group, dropped further to 45.56 D in the 12–18 months age group and further dropped to 42.69 D in the 54–90 months age group.[19] In a study[3] evaluated corneal topography in 200 infants using a special hand-held topographic instrument at a mean of 1.6 days after birth with follow-up in some infants again at 3 and 6 months. They reported a mean value of 48.5 D at birth, 44 D at 3 months and 43 D at 6 months.

In several studies[6,21,22] it was noted that girls have steeper corneas than boys. In the current study, we also found similar results only in two age groups (6–18 and 18–60 months) while we did not find any difference in keratometric readings between the genders in 0–6 and 60–96 months. In our study, the variation of *K* values was also noted to be higher in female subjects when compared with males. Few authors[6,23] studied a large series of cataract patients whose ages ranged from <1 month to 18 years. One hundred and eighty-eight eyes were of children below 4 years. In a small sub-sample of 39 patients with unilateral cataract, the authors found steeper corneas in the cataractous eye than in the non-cataractous fellow eye. In the same sub-sample where readings from the fellow eye were available, the mean keratometry was not significantly greater in the cataractous eye than in the unaffected fellow eye.[6] In the present study, no significant differences were observed in eyes with unilateral versus bilateral cataract. Asbell *et al*.[19] also noted no significant difference between eyes with and without cataract. However, between birth and 6 months of age, the mean *K* values were 46.82 D in normal eyes as opposed to 48.01 D in cataractous eyes. Furthermore, the authors analysed a group of 11 eyes that had persistent hyperplastic primary vitreous, now commonly known as PFV. Of these 11 eyes, 6 had *K* readings higher than the average readings noted in the non-PFV eyes. Although these data are obtained from a small sample, it suggests that corneas of eyes with PFV are steeper than the corneas of normal eyes of age-matched patients. The authors did not include these 11 eyes for statistical analysis. Had these eyes been included, their reported *K* values might have reflected steeper corneas. We have not done a separate analysis for PFV eyes.

In the present study, in eyes with unilateral cataract, we observed that the fellow eye had a longer AL when compared with the cataractous eye with a significant difference between the two eyes. However, we did not find any difference in the keratometric readings. Trivedi and Wilson[6] reported a shorter AL in unilateral versus bilateral cases, but the difference was not significant below 60 months of age. According to them, while AL elongation continues beyond the 1st year of life, keratometry stabilises by 6 months of age. With increasing age, the mean decrease in *K* values might have reflected the compensatory changes in AL to keep the refractive power of the eye at a constant. As the mean decrease in corneal curvature cannot optically match the mean increase in AL in later years of life, changes in the lens may compensate for the same, if a constant ocular refraction is maintained. The duration of visual deprivation may influence biometric parameters, but unfortunately, information on the type and severity of cataract and age of onset was not available for our patients. We used the same ultrasound velocity for cataractous and healthy eyes. Although congenital cataract is usually not very hard, the faster ultrasound propagation through the cataractous lens may lead to some underestimation of the AL in the affected eye, minimising its difference with the healthy eye.

In this study, our study population was from a single ethnicity (Indian). We did not use samples of patients from different ethnic backgrounds. In various other studies, ethnicity has been cited as a factor that impacts *K* values. Thus, it may not be possible to extrapolate the results of our study into another study carried out on a study population with varied ethnicity. This study has certain limitations. It was cross-sectional and based on a retrospective review of clinical records. Moreover, due to the cross-sectional nature of the study, it was not possible to provide a conclusive statement on when *K* values stabilise. Since congenital cataract needs to be removed as soon as it is detected to provide the best possible visual outcomes, the preoperative *K* values cannot be studied in a longitudinal manner. Future studies of longitudinal changes in *K* values after cataract surgery are being planned. Further, we measured corneal curvature under anaesthesia, and the lack of fixation might have affected our results. However, due to poor cooperation among children, hand-held keratometry under anaesthesia is the most practical method that can be used to obtain *K* values.

This study provides reference keratometric values from a homogeneous series of infants and small children with uncomplicated, non-traumatic paediatric cataract. Exclusion of pre-term births and other pathological eye conditions allowed us to precisely identify the type of patients to whom our results may be generalised: term-born children with uncomplicated congenital cataract, without accompanying pathological eye conditions and aged up to 96 months. This age range was selected because manual keratometric measurements present technical difficulties primarily in this period. Despite these limitations, certain conclusions can be drawn. The *K* values of younger children were higher than those of older children. The *K* values of female subjects were significantly different from those of male subjects. Logarithmic transformation of age can explain 61% of the variation in *K* values. AL has a linear relationship with keratometry. The *K* values of eyes with cataract in monocular cases were no different from those of bilateral cataract. In eyes with unilateral cataract, the *K* values of cataractous eyes were not different from those of the non-cataractous fellow eyes.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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