Assessment of Variation in Keratometry with the Axial Length and Refractive Status of the Eye - A Cross Sectional Observational Study in South Asian Population

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ABSTRACT

BACKGROUND

Refractive status of the eye depends on the balance between multiple factors such as corneal power, lens power, anterior chamber depth and axial length. Compensatory adjustments between the axial length and the keratometry of the cornea play an important role in emmetropisation. Capturing the biometric measurements of the eye is an important part of the preoperative work up of patients to calculate the intraocular lens (IOL) power, hence, the importance of better understanding of the interplay between the biometry parameters. Our aim was to assess the variation of keratometry with the refractive status and axial length of the eye.

METHODS

This is a cross sectional observational study of 299 eyes that were operated for cataract surgery from July 2018 to December 2018 at a tertiary care centre in South India. Axial length and central corneal curvature were measured and average was taken for analysis. Eyes with axial length ≤ 22 mm were grouped as hyperopic (Group 1), those with axial length between 22.0 mm and 24.0 mm were grouped as normal (Group 2) and eyes with axial length more than 24.0 mm were grouped as myopic (Group 3). The distribution of corneal curvature, AL / K ratio and IOL power across different ranges of axial length was assessed.

RESULTS

There was a statistically significant flattening of cornea with increase in axial length ($P < 0.001$). Distribution of axial length to corneal radius of curvature was also found to be statistically significant ($P < 0.001$) among the three groups.

CONCLUSIONS

With an increase in axial length there was a statistically significant progressive flattening of cornea. The AL / K ratio can be a better measure of the refractive status of an individual than axial length alone.

KEYWORDS

Axial Length, Keratometry, Myopia, Hyperopia, Axial Length to Corneal Radius of Curvature Ratio

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BACKGROUND

Refractive state of the eye is determined by the balance between multiple factors such as corneal power, lens power, anterior chamber depth and axial length.[1] Cornea is the principal refractive component of the eye and is significantly affected by any changes in ocular measurements and structural changes. Measurement of corneal parameters has a significant diagnostic potential in various diseases of the eye. During development and growth there is simultaneous change in eyeball size that is concomitant with the overall physical status which results in emmetropisation.[2,3]

Cataract surgery has evolved from a vision preserving procedure to a sophisticated refractive procedure that aims for a perfect visual outcome. Capturing the biometric measurements of the eye is an important part of the preoperative work up of patients to calculate the IOL power. Any error in measurement of the said parameters can result in post-operative refractive surprises and patient dissatisfaction. Therefore a good understanding of the interplay of these parameters is quintessential to an accurate preoperative biometry.

The axial length measurements that are taken from an ultrasound probe measures the distance from the corneal surface to the retinal pigment epithelium / Bruch's membrane. Cornea accounts for majority of the refractive power of the eye. The refractive power of the cornea depends on its curvature and the difference in refractive indices between cornea and air.[4] The compensatory adjustments between the axial length and the radius of curvature of the cornea plays an important role in emmetropisation. The axial length to corneal radius of curvature ratio was found to have a better correlation with refractive error than the axial length of the eye alone.

This study aims to establish the relationship between radius of corneal curvature and axial length and also the distribution of AL / K ratio across eyes with different refractive status. With the advent of premium IOLs and sophisticated refractive procedures this understanding is a prerequisite for any modern day cataract surgeon to cater to the expectations of patients.

METHODS

This is an observational cross-sectional study of 229 patients who presented to our centre, a tertiary care centre in South India, from July 2018 to December 2018 for cataract surgery. Adult patients aged 40 years or more with significant cataract and normal intraocular pressure were included in the study. Patients with any history of corneal infections, significant corneal opacity, active corneal pathologies, recent contact lens wear, and systemic diseases such as rheumatoid arthritis, ocular trauma or previous ocular surgeries were excluded from the study. Informed written consent was obtained from all patients.

Demographic details of the patients including age, gender and laterality of the cataract were recorded. Axial length and keratometric values were obtained from the preoperative biometry scans. The axial length measurements were taken with an applanation ultrasound probe by a single trained optometrist. Here, a drop of proparacaine was instilled in both eyes in supine position and the patient was asked to look into the red light on the probe of the sonography machine. The probe was gently placed on the patient's cornea with utmost care as to avoid pressure on the latter. The probe was placed vertical to the corneal surface to obtain the highest echo spike. A minimum of three readings were taken and the average was analysed.

Keratometry readings were captured with a Bausch and Lomb keratometer. The eye piece or the reticule was adjusted as per the examiner's refractive status in the keratometer. The patient was asked to be seated before the instrument with the forehead resting on the head rest comfortably and the chin resting on the chin rest. The mires were viewed through the eye piece after switching the instrument on, and the patient fixates on the reflection of his / her eye. With the help of the focusing knob the mires were focused clearly. To ensure the alignment of the optical axis of the instrument with the visual axis of the patient, the cross hair was placed at the centre of the focusing circle. After ensuring the accurate alignment, the knob was locked. The vertical drum superimposes the minus signs and the horizontal drum superimposes the plus signs. Keratometric measurements were taken, three each on steep and flat corneal meridians and the average keratometry for steep and flat corneal meridians were recorded. The average of both values was calculated to obtain the mean K. Radius of corneal curvature was calculated from the keratometry value with the help of a conversion chart. The axial length to radius of corneal curvature value was obtained from the above data.

In this study we have considered AL less than 22 mm as hyperopic (group 1), between 22 mm and 24 mm as normal eyes (group 2) and those with axial length more than 24 mm were considered myopic (group 3). To study the distribution of data across various age groups we have grouped them to less than 50 years of age, 50 to 70 and more than 70 years of age.

Data was analysed using the SPSS software version 18. Qualitative data were presented as frequency and percentage. Quantitative data were documented as mean ± standard deviation. Independent sample t test and analysis of variance (ANOVA) were used to compare quantitative data between the groups. Pearson correlation was used to find out correlation between various quantitative data. A P value of < 0.001 was considered to be statistically significant.

RESULTS

The data of a total of 299 patients was studied, among them 86 (28.8 %) were males and 213 (71.2 %) were females. Six (2 %) patients were less than 50 years old, 177 (59.2 %) were between 50 and 70 years of age and 116 (38.8 %) were more than 70 years of age. Among the 299 eyes, 75 (25.1 %) were hyperopic with an axial length less than 22.0 mm and 209 (69.9 %) were normal eyes and 15 (5 %) were myopic with an axial length of more than 24.0 mm.

The mean age among male patients was 68.5 ± 7.36 and the mean age among females was 67.36 ± 9.51. There was no statistically significant difference (P = 0.29) between the mean age among the two genders.

The mean K among males was 42.30 ± 1.73 and the mean K among females was 43.30 ± 1.82. There was a statistically significant difference among the two genders with respect to the keratometry values (P < 0.001).

The mean axial length among males was 22.84 ± 0.85 and the mean axial length among females was 22.43 ± 0.96. This difference was not found to be statistically significant (P = 0.001).

The calculated mean IOL power among males was 22.61 ± 1.44 and among females was 23.06 ± 1.97 and this difference was also not statistically significant (P = 0.05).

The distribution of corneal curvature among different age groups was also analysed (Figure 1). Among those aged less than 50 years the mean K was 7.68 ± 0.45, in patients aged between 50 and 70 years of age the mean K was 7.83 ± 0.32 and in patients older than 70 years of age the mean K was 7.85 ± 0.29. There was no statistically significant difference in the mean K with age (P = 0.39).

The axial length distribution among the different age groups was also studied. In patients less than 50 years of age the mean axial length was 22.20 ± 1.19, in those aged between 50 and 70 years of age the mean axial length was 22.53 ± 0.98 and in patients older than 70 years of age the mean axial length was 22.59 ± 0.89. This difference in axial length among the different age group was also not statistically significant (P = 0.57).

The distribution of K among normal, myopic and hyperopic eyes was also studied. In hyperopic eyes the mean K was 7.62 ± 0.26, in normal eyes it was 7.89 ± 0.27 and in myopic eyes the mean K was 8.17 ± 0.42 (Table 1). This progressive flattening in corneal curvature among the three was noted to be statistically significant (P < 0.001). Post hoc comparison showed that the differences in K between hyperopic and normal, between normal and myopic and between hyperopic and myopic were found to be statistically significant (P < 0.001) (Table 2).

Axial Length	Mean K	P-Value
Hyperopic	7.62 ± 0.26	< 0.001*
Normal	7.89 ± 0.27	
Myopic	8.17 ± 0.42	

Table 1. Distribution of K among the Three Groups Based on Axial Length

*Statistically significant

Axial Length	Axial Length	Mean Difference	P-Value
Hyperopic	Normal	- .26	< 0.001*
	Myopic	- .55	< 0.001*
Normal	Hyperopic	0.26	< 0.001*
	Myopic	- .28	0.001*
Myopic	Hyperopic	0.55	< 0.001*
	Normal	0.28	0.001*

Table 2. Post Hoc Comparison of K between the Three Groups Based on Axial Length

*Statistically significant

Similarly, the distribution of the ratio of axial length to keratometry among the three groups was also studied. The mean AL / K in hyperopic group was 2.80 ± 0.09, in normal group was 2.89 ± 0.10 and in myopic eyes was 3.01 ± 0.14 (Table 3). This distribution was also statistically significant (P < 0.001). Post hoc comparison showed that the differences in AL / K between hyperopic and normal, between normal and myopic and between hyperopic and myopic were found to be statistically significant (P < 0.001) (Table 4).

Axial Length	AL / K	P-Value
Hyperopic	2.80 ± 0.09	< 0.001*
Normal	2.89 ± 0.10	
Myopic	3.01 ± 0.14	

Table 3. Distribution of AL / K among the Three Groups Based on Axial Length

*Statistically significant

Axial Length	Axial Length	Mean Difference	P-Value
Hyperopic	Normal	- .08	< 0.001*
	Myopic	- .21	< 0.001*
Normal	Hyperopic	0.08	< 0.001*
	Myopic	- .12	< 0.001*
Myopic	Hyperopic	0.21	< 0.001*
	Normal	0.12	< 0.001*

Table 4. Post Hoc Comparison of AL / K between the Three Groups Based on Axial Length

*Statistically significant

The IOL power distribution among the three groups based on axial length was analysed. The mean IOL power in hyperopic group was 24.62 ± 1.56, in normal eyes was 22.56 ± 1.36 and in myopic eyes was 19.60 ± 1.73, as depicted below (Table 5). Post hoc comparison showed that the differences in IOL power between hyperopic and normal, between normal and myopic and between hyperopic and myopic were found to be statistically significant (P < 0.001) (Table 6).

Axial Length	IOL Power	P-Value
Hyperopic	24.62 ± 1.56	< 0.001*
Normal	22.56 ± 1.36	
Myopic	19.60 ± 1.73	

Table 5. Distribution of IOL among the Three Groups Based on Axial Length

*Statistically significant

Axial Length	Axial Length	Mean Difference	P-Value
Hyperopic	Normal	2.05	< 0.001*
	Myopic	5.02	< 0.001*
Normal	Hyperopic	- 2.05	< 0.001*
	Myopic	2.96	< 0.001*
Myopic	Hyperopic	- 5.02	< 0.001*
	Normal	- 2.96	< 0.001*

Table 6. Post Hoc Comparison of IOL Power between The Three Groups Based on Axial Length

*Statistically significant

The correlation among K1 (corneal curvature along the steep meridian), K2 (corneal curvature along the flat meridian), axial length (AL), and IOL was also analysed and is depicted below (Table 7). Significant strong positive correlation was found between K1 and K2 whereas axial length had significant moderate negative correlation with K1, K2 and a significant strong negative correlation with IOL power.

	K1	K2	Axial Length (AL)	IOL Power
K1	1			
K2	0.804**	1		
Axial length (AL)	- 0.474**	- 0.518**	1	
IOL power	0.033	0.064	- 0.776**	1

Table 7. Correlation among K1, K2, AL and IOL Power

**Correlation is significant at the 0.01 level (2-tailed)

DISCUSSION

In this study we have analysed the geometrical parameters of hyperopic, normal and myopic eye. Here it has become obvious that the differences among the three groups were not just limited to the length of the eye ball. There was significant difference in corneal curvature among the three groups and the result was consistent with those studies conducted in populations in other parts of the world.

The cornea has an average radius of curvature of 7.84 mm when measured in an instrument calibrated for index of refraction 1.337. The mean radius of curvature in our study was 7.83 ± 0.32, which is consistent with previously published literature.[4] The changes in axial length have a paramount effect on the refractive status of the eye. The axial length and keratometry are interdependent rather than independent variables and their interaction plays a major role in the process of emmetropisation. Numerous studies conducted till date has proven the same and that the refractive status of the eye can be assessed based on the axial length-corneal radius of curvature ratio (AL / K).[1,4,5] It is a well-documented fact that myopes tend to have longer axial lengths and hyperopes have shorter axial length.[6,7] No statistically significant change was noted in axial length with age, this was also consistent with previously published literature.[8]

Analysis of the variation in corneal curvature among the three groups showed that there was a significant flattening of cornea among myopic eyes. The results were consistent with similar studies conducted in European countries.[9] The difference in the mean AL / K ratio among the three groups was also statistically significant, the ratio being higher in myopes and lower in hyperopes compared to emmetropic eyes. These results were consistent with the study done by Osuobeni.[10,11]

There was a statistically significant correlation of AL / K ratio with the refractive status of the eye and this was stronger than the correlation of axial length or keratometry variables alone. Therefore, it can be said that the AL / K ratio was a better index for categorising the refractive status than axial length or corneal curvature alone. This inverse relationship of axial length and corneal curvature supports the theory of emmetropisation by Grosvenor.[12] According to him an increase in the axial length tends cause myopia and the cornea tends to flatten to compensate for the induced myopia. This mechanism brings about a greater proportion of emmetropia than expected on the basis of chance alone. The inverse correlation between axial length and corneal radius of curvature demonstrates the ability of the eye to compensate for the physiologically driven axial length changes. Although male subjects showed a longer axial length than their female counterparts, the difference in mean AL between the two genders was not statistically significant. This is in contradiction to the claims by Osuobeni.[10] Similarly, gender related differences in the mean corneal radius of curvature and AL / K ratio was not statistically significant.

Our study was limited to adult population older than 40 years of age and it was observational and cross sectional. Prospective longitudinal studies would be more helpful in assessing the changes in these parameters.

CONCLUSIONS

In conclusion, there was significant flattening of the cornea along with an increase in axial length, with myopes having a tendency for flatter corneas and hyperopes for a steeper cornea. Also, there was a significant association between axial length-corneal radius of curvature and refractive state of the eye and this association was stronger than that with AL or K alone. Therefore, the AL / K ratio can be a better index for categorising the refractive status of an individual than axial length alone.

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