ASTIGMATISM IN CANDIDATES OF CATARACT SURGERY AND ITS RELATIONSHIP WITH CORNEAL OPTICAL POWER, AXIAL LENGTH, SEX AND PATIENT AGE

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Abstract - *This study was conducted to define the prevalence and types of corneal astigmatism in relation with corneal optical power, axial length, sex and patient age. 641 cataract patients were included in a descriptive study. Complete eye examinations were performed. The data were analysed by standard procedures including analysis of variance, Chi square test and multiple linear regression models. With the rule, astigmatism was 55.6% in younger cases and against the rule astigmatism was 43.7% in older cases (P< 0.0001). Against the rule astigmatism was 55.8% in older males and 34.6% in older females (P< 0.0001). There was 0.023d decrease in kpol for each year increase in age 1 (P<0.0001). Axial length in males was 23.57 ± 1.46mm and females was 23.35 ± 1.76 mm (P< 0.05). For second degree model to show relationship between astigmatism and axial lenght R^2 was 0.019 and 0.03. By increasing axial lenght up to 26 mm corneal power decreased, but further increase in axial length led to corneal power increase. For each diopter increase in corneal power there was 0.1 diopter increase in net astigmatism (P<0.0001). In corneal powers less than 45.5 diopter there was no difference between direction of astigmatism, but in corneal powers more than 45.5 diopter with the rule astigmatism was dominated (P=0.01). Younger cases had more with the rule astigmatism and older cases had more against the rule astigmatism. Against the rule astigmatism was more common in older males than in older females. With the rule astigmatism ratio shifted to ATR astigmatism ratio with age but there was no change in against the rule astigmatism ratio with age. Males had 0.22 mm axial length more than females. There was significant relationship between axial length and net astigmatism. Abnormal size eyes had more astigmatism. Emmetropization mechanism of cornea did not work for eyes longer than 26 mm. Myopia was related to total astigmatism. Second degree model was more fitted to show relationship between astigmatism and axial length.*

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Key Words: Preoperative astigmatism, axial length , corneal optical power

INTRODUCTION

Despite its importance of Medical Sciences, astigmatism has not been studied in candates of cataract surgery in our country.

It has been demonstrated that the degree and direction of astigmatism are correlated to axial length and corneal optical power of the eye, as are patient age and sex (1-4). To recognize the situation in our center, we examined some preoperative measurements related to refraction in a sample of patients scheduled to undergo cataract surgery and analyzed the data to define the prevalence and types of astigmatism and its relationship with corneal optical power, axial length, sex and patient age.

MATERIALS AND METHODS

The study was performed from January to December 1997. 641 cases with normal intraocular pressure who had been scheduled for cataract surgery in Farabi Eye Hospital participated in the study regardless of age, sex and race. None of them had previous eye surgery, eye discases or any systemic disorder affecting eyes. Preoperative examinations included visual acuity measurement using E.chart, slit lamp examinations and applanation tonometry by Haag Streit devices, indirect fundoscopy by Topcon and keratometry by standard Javal keratometer.

A scan sonography was done by Kidek US 2500 to calculate IOL power and axial length measurement. The velocity of ultrasound was assumed to be 1550 m/s as has been used by Olsen (5).

All of the patients had normal IOP (14-16 mm/Hg) therefore we excluded it as a criterion. All the clinical and paraclinilcal data were obtained by ophthalmology assistants and a well-trained optometrist respectively, under close supervision of the author. Astigmatism was been defined as greater than 0.5 diopter difference between the highest and the lowest corneal meridian. With the rule astigmatism (WTR) was defined when the greatest corneal power lied between 30˚ of the vertical meridian, and against the rule astigmatism (ATR) when it was within 30 ˚ of the horizontal one, and the remainder were defined as oblique astigmatism.

For comparative purposes we chose the kpol advocated by Naeser (6) which takes into account both the direction and amount of astigmatism as a signle unit.   Kpol = M (Sin 2α - Cos 2α)

Kpol is the keratometric polar value of net astigmatism in diopter, where M is the difference between the highest and the lowest corneal meridian in diopter and α is the meridian of greatest corneal power. Using M (Si 2α) for the vertical component and M (Cos 2α) for the horizontal component. All meridians of greatest corneal power were included in the calculation of the polar value regardless of the amount of astigmation. By definition WTR astigmatism in this field exists when the greatest corneal power meridian lies between 45° and 135° which leads to positive value for kpol and ATR astigmatism when it lies at less than 45° or more than 135° which makes kpol value negative. In oblique astigmatism the greatest corneal merdian lies somewhere in between. When the greatest corneal meridian lies at 45° and 135°, kpol is zero (Fig. 1).

Statistical analysis was performed with standard procedures including comparing mean data between two or more groups (analysis of variance), Chi square test and multiple linear regression models.

RESULTS

295 cases (46%) were females and 346 cases (54%) wer males. Mean age of females was 65 years (R = 3-94 years). Mean age of males was 62.9 years (R=4-98 years). (P=0.067).

The degree of astigmatism is shown in table 1. The difference between the mean degree of is astigmatism in males and females was 0.14 D. (P = 0.1). Distribution of astigmatic direction with respect to sex and age the mean degree of is shown in tables II and III and IV. The mean age was 61.27 years in cases with WTR astigmatism and 66.22 years in those with ATR astigmatism. The difference between the mean ages of the two groups was 4.94 years (P< 0.0001).

Relation between direction of astigmatism and age

There was a significant difference between cases of WTR astigmatism and ATR astigmatism with respect to age Younger cases had more WTR, and older cases had more ATR astigmatism. The difference between males and females with respect to direction of astigmatism was more significant in cases older than 65 years, in other words ATR astigmatism was more common in older males than older females P< 0.0001.

By controlling the sex factor with increasing the age there is a significant shift towards ATR astigmatism which coincides with decrease in K pol. (Fig 2).

With increasing each year in age the Kpol decreases by 0.023 D per year, approaching negative polar values or ATR astigmatism (P<0.0001).

K pol = 1.85 - 0.023 age - 0.35 sex
Sex = 1 (male and female) (P<0.0001).
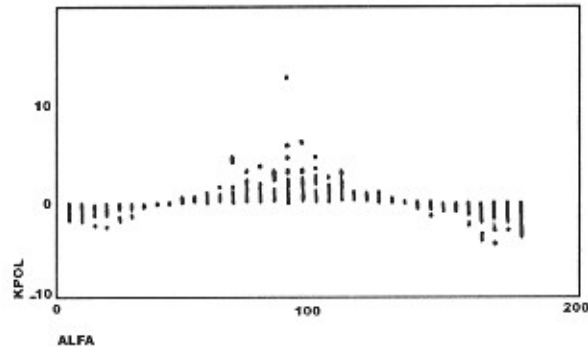

Fig. 1. Scatter plot of meridian of greatest power by Kpol.
Note that meridians between 45° and 135° Kpol take positive values. (above zero). At meridians less than 45° or greater than 135° Kpol takes negative values (below zero). At 45° & 135° Kpol is zero

Relation between axial length, gender and age

The mean eye axial length was 23.57 ± 1.46 mm and 23.35 ± 1.76 in males and females respectively, so that in the males, the axial length was 0.22 mm more than females (One-tail t-test, P=0.037).

Our study did not show any relation between age and axial length, which is against the results obtained by other investigators (1). Our findings may be due to our smaller sample size which shall be repeated in the future. (two tail t-test P=0.5).

Relation between net astigmatism, corneal power and axial length

Net astigmatism showed statistically significant relationship with corneal power, so that for each diopter increase in corneal power, we had 0.1 diopter increase in astigmatism (P< 0.0001). (astigmatism = -3.64 + 0.11 power).

There was a significant relationship between axial length and the degree of astigmatism regardless of direction P=0.0001. (net astigmatism = -1.42 + 0.11 DIA -0.16, female = 0 male = 1).

As shown in Fiure 3, when we move from the center of X axis (horizontal) which is the site of more spherical eyes towards both extremities, the ratio of abnormal size eyes (short < 22 mm or long > 24 mm) to normal size eyes increases. It means abnormal size

eyes have more astigmatism than normal size eyes. This concept has been confirmed also by previous studies (1).
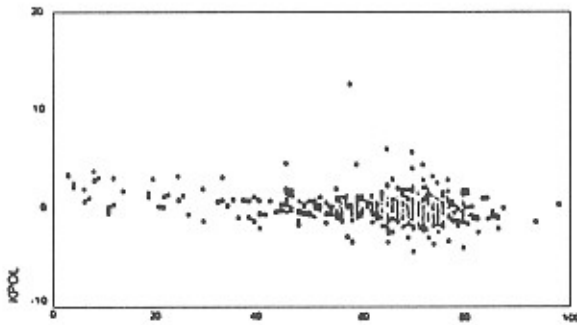
and females (confounding variables).

Fig. 2. Relationship of Kpol with age.

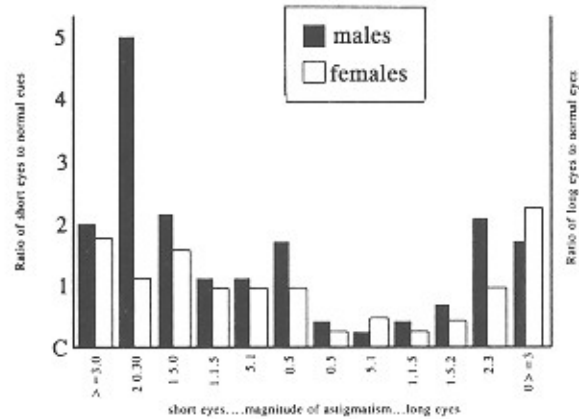Note : Kpol decreases with increasing age. (leads to negative values or ATR astigmatism)

Fig. 3. Relationship between axial length and astigmatism.

Note : as we move from the center of X axis to both extremes, astigmatism or the ratio of abnormal size eyes to normal size eyes increases.

Change of astigmatism by axial length could be shown by different models. In the first degree model, R^2 (correlation coefficient)was 0.019 and 0.03 and in the second degree model, R^2 was 0.037 and 0.049 for males and females, respectively.

As shown in Figure 4A and 4B, the second degree model is more suitable for demonstrating the relation net astigmatism and axial length which is consistent with the finding that the R^2 of the second degree model is greater than R^2 first degree model.

Relation between axial length and corneal power

As shown is Figure 5A and 5B by increasing A.P diameter up to about 26 mm, corneal power decreases, but further increase in diameter leads to increase in corneal power. Again second degree model is more fitted to show this relationship. R^2=0.2 and 0.016 for first degree model in males and females. R^2=0.3 and 0.18 for second degree model in males and females.

R^2 second degree model > R^2 first degree model

Relation between corneal power, age and sex

Corneal power relationships with age and sex were analyzed in two models. In a simple model, corneal power was related to both age and sex (P=0.0001) and (P = 0.031) respectively. But in a multiple model we could not find any relationship with age (P=0.11).

This finding may indicate that the above relation of corneal power with age is not a real one and could be due to difference in distribution of age between males

Table 1. Distribution of degree of net astigmatism among the cases.

Value	Frequency	Percent	Valid percent	Cum percent
0.0-0.5D	169	26.2	27.8	28.0
0.5-1	203	31.5	33.4	61.3
1-1.5	114	17.7	188	80.1
1.5-2	44	6.8	7.2	87.3
2-2.5	27	4.2	4.4	91.8
2.5-3	16	2.5	2.6	94.4
3-3.5	13	2.0	2.1	96.5
3.5-4	16	2.5	2.6	99.2
> 4	5	8	8	100
Missing	33	5.1	missing	

Table 2. Distribution of astigmatism direction with response to sex

Direction Sex	Oblique	ATR	WTR	Total
Female	57	94	144	295
	(19.3%)	(31.9%)	(48.8%)	(46.0%)
Male	65	151	130	346
	(18.8%)	(43.6%)	(37.6%)	(45.0%)
Total	122	245	274	641
	(19.0%)	(38.2%)	(42.7%)	(100%)

Chi sqaure   P = 0.0052

Note: WTR astigmatism is more common in females, ATR astigmatism is more common in the males.

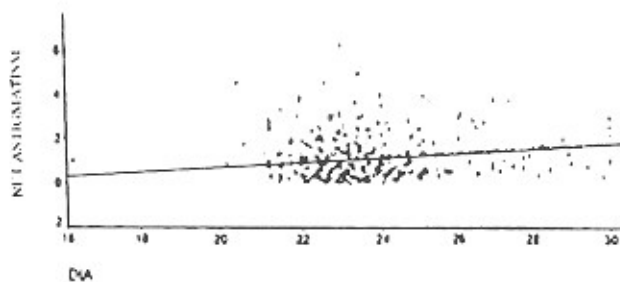Oblique astigmatism is the same in both sexes

Fig. 4A. Relationship between net astigmatism and axial length. (first degree model).

Note : The degree of net astigmatism increases with increasing axial length. The relationship can not be shown at neither extreme.

Relation between axial length and direction of astigmatism

We could not find any relationship between axial length and direction of astigmatism. (Regression P = 0.91 Chi square comparing DIA > 23 mm DIA < 23 mm P=0.89).

Relation between corneal power and direction of astigmatism

The relationship between corneal power and direction of astigmatism is shown in table 5. Powers less than 45.5 diopter, there is not a significant difference between different direction groups, but with powers greater than 45.5 diopter WTR astigmatism dominated (Chi square P=0.01). We were not able to find any change in ATR astigmatism with increasing age. (95% CI = -0.0096 tp 0.0052) but the degree of WTR astigmatism showed 0.013 diopter decrease per year. (95% CI = -0.006 to 0.021).
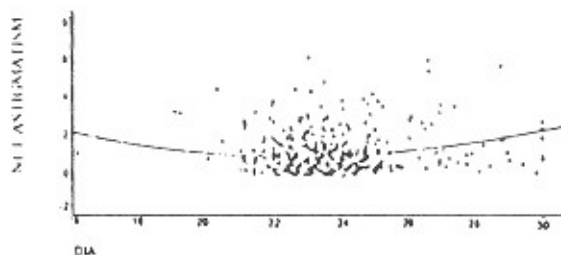

Fig. 4B. Relationship between net astigmatism and axial length (second degree model)

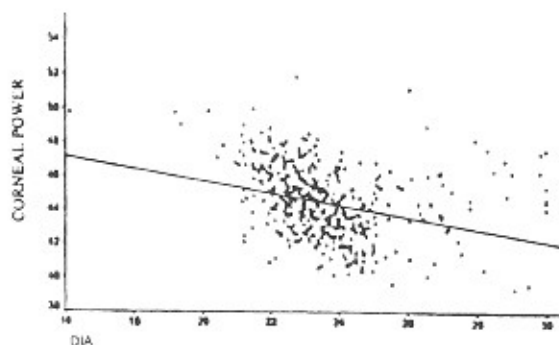Astigmatism increases in both extremes

Fig. 5A. Relationship between corneal power and axial length. (first degree model)

By increasing axial length up to 26 mm, corneal power decreases, this model is unable to show increase in corneal power by increasing the axial length more than 26mm.

Table 3. Distribution of astigmatic direction with respect to age.

Total		Oblique		ATR		WTR		Frequency
Rel	Ab	Rel	Ab	Rel	Ab	Relative	Absolute	age group
100%	153	17.6%	27	26.8%	41	55.6%	85	< 65 year
100%	286	14.3%	41	43.7%	125	42%	120	> 65 year
100%	439	15.5%	68	37.8%	166	46.7%	2.5	total

P = 0.0023
Note: In the younger cases WTR astigmatism, and ATR astigmatism is more common.
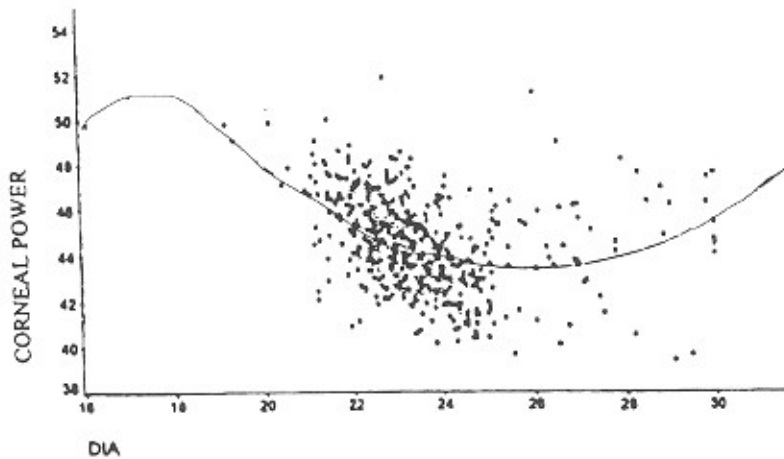
Fig. 5B. relationship between corneal power and axial length (second degree model).
Note : the corneal power decreases up to 26 mm axial length and increases by further increase in axial length

Table 4- Distribution of astigmatic direction with respect to age and sex

		Age < 65 year					Age > 65 year		
		Female		Male		Female		Male	
0	8	10.1%	5	5.4%	17	10.9%	14	85	
1	34	43.0%	31	33.3%	54	34.6%	92	55.8%	
2	37	46.8%	57	61.3%	85	54.5%	59	35.8%	
total	79	100%	93	100%	56	100%	165	100%	

o = oblique astigmatism   1 = ATR astigmatism   2= WTR astigmatism

Table 5- Relationship of corneal power and direction of astigmatism.

Total ATR		WTR		Frequency		
Relative	Absolute	Relative	Absolute	Relative	Absolute	corneal power
100%	59	49.2%	29	50.8%	30	< 42.5D
100%	261	51%	133	49%	128	42.5-45.5D
100%	119	34.5%	41	65.5%	78	> 45.5D
100%	439	46.2%	203	53.8%	236	total

Note : C.P > 45.5 D is associated with meaningful increase in the proportion of WTR astigmatism.

DISCUSSION

A small degree WTR astigmatism is common in early life (3) although it may change in different sex and age groups. In our cases, WTR astigmatism was more common in females and younger age and ATR astigmatism in males and older ones. WTR astigmatism decreases with age and shifts to ATR astigmatism, but there is no change in ATR astigmatism with age. Our findings are compatible with the data obtained in the other studies (3,7), although they have shown that these changes take place more slowly in females than in males. In the present study in corneal powers less than 45.5 diopter we found no difference between the of

directions of astigmatism, but in corneal powers of more than 45.5 diopters, WTR astigmatism was dominant. In a previous study (8) females have been shown to have steeper corneas than males, but no relation between corneal astigmatism and sex has been detected yet.

For comparative purposes we chose k pol which takes into account both the amount of astigmatism and its direction (6). Our data showed that k pol decreases with age, means taking negative values and shifting to ATR astigmatism as in Figure 2. This concept has been noted also by Ninn-Pedersen (1), but ATR astigmatism has not shown any change with age. Our results showed that men have 0.22 mm axial length more than females.

The same results have been obtained by other authors too (9).

We found no relation between corneal power and age or sex, which is in contrast with dominancy of steeper corneal powers in females, and increase in corneal powers by age to compensate for decrease in axial length by age, to keep the patient emmetropia (8).

We were not able to show any relation between axial length and age, although it has been shown to decrease with age in both males and females (0.13 mm per year) (1). Our results may be due to smaller sample size. We found no relation between axial length and direction of astigmatism by using k pol (P=0.99). although Pedersen found that WTR astigmatism increases with increasing axial length (1). As shown in Figure 3, if we move far from normal size eyes towards abnormal size eyes, whether short or long, the amount of astigmatism increases, in other words abnormal size eyes have more astigmatism, the concept being consistent with the data obtained by Pedersen (1).

We might be able to say that k pol values whether positive or negative are more dependent on the direction rather than amount of astigmatism, but their absolute values depend on both direction and amount of astigmatism. It is interesting to note that some authors have suggested that the shape of cornea depends on the size of the eyes (10). Jackson noted that hyperopic eyes shift towards ATR astigmatism with age whereas myopic eyes shift more to WTR astigmatism. Beause it is now known that the size of the eye is actively regulated (11) the shape of the cornea may also be actively regulated as suggested by pederson (1).

We found that each diopter increase in corneal power may lead to 0.1 diopter increase in net astigmatism which contrasts with Pedersen's idea (1). This finding is statistically significant but its clinical significance is to be determined.

In a previous study it was found that a 1 mm change in axial length corresponds to an average change of 0.4D in the optical power of the cornea (12). Pedersen also showed that a 1 mm change in axial length corresponds to a change of 0.37 diopter in corneal optical power with no change in males and females (1).

Our findings showed that by increasing axial length up to 26 mm, corneal power decreases. This finding may be explained by emmetropization mechanism suggested by Grosvenor (13) which keeps the corneal power compatible with axial length to maintain emmetropia. But further increase in axial length, leads to increases in corneal power.The last point may be due to the fact that high axial length eyes are out of control of emmetropization mechanism of the cornea, although this point needs more investigation. We found a more significant relationship between axial length and corneal

power with net astigmatism. This concept has also been also shown by Pedersen (1). That is why second degree model IOL calculation formulas are more predictive than first degree ones, especially for hyperopic and myopic eyes (5).

Considering significant relationship between axial length and corneal astigmatism, one can find a relationship between myopia and total astigmatism, by relating axial length to myopia and corneal astigmatism to total astigmatism. This concept as noted by Stephen et al (14) is important when we want to treat a patient with myopia and corneal astigmatism. This fact accounts for the reduction in total astigmatism achieved by treating only the spherical component of myopia as postulated by Loewenstein (15).

Acknowledgements

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