The Effect of Posterior Corneal Astigmatism on Ocular Residual Astigmatism in Virgin Eyes

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ABSTRACT:

BACKGROUND:

Ocular astigmatism is the sum of corneal astigmatism and internal astigmatism. The component of ocular astigmatism that cannot be a attributed to the anterior corneal surface is referred to as ocular residual astigmatism.

OBJECTIVE:

To evaluate the difference between ocular residual astigmatism and total ocular residual astigmatism in normal virgin eyes with refractive errors.

PATIENTS AND METHODS:

Eighty four patients (135 virgin eyes) with refractive errors were enrolled consecutively in this study at the Lasik clinic in Ibn Al- Haitham Teaching Eye Hospital. Measurement of astigmatism was done by manifest refraction and corneal topography using Oculus Pentacam, and these measurements were used for calculating ocular residual astigmatism and total ocular residual astigmatism with comparison between them.

RESULTS:

The study showed a significant difference between the means of ocular residual astigmatism (-0.7416 ± 0.4341) and the total ocular residual astigmatism (-0.6223 ± 0.401) in with the rule astigmatism (P value < 0.001), and the means of ocular residual astigmatism (-0.8113 ± 0.38517) versus the means of total ocular residual astigmatism (-0.6658 ± 0.3844) in against the rule astigmatism (P value <0.001).

CONCLUSION:

The ocular residual astigmatism based on the total corneal topographic astigmatism corresponds better with manifest refractive cylinder than the ocular residual astigmatism based solely on anterior corneal topographic astigmatism .

KEY WORDS: Ocular residual astigmatism, Posterior corneal astigmatism.

INTRODUCTION:

The accurate measurement of corneal astigmatism has been a topic of many recent researches due to the increasing use of toric Intraocolur lens **(toric** IOLs) and femtosecond limbal relaxing incision (femtosecond LRI) techniques . These procedures get benefit from the invention of Scheimpflug Pentacam for imaging of the entire anterior chamber and the contribution of the posterior corneal surface to total corneal astigmatism . The alignment of the IOL and LRI with the steepest corneal meridian together with the selection of the appropriate power and degree of arc are precious factors in determining patient satisfaction.

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Nowadays, many patients have higher lifestyle expectations than in the past and they expect to reach spectacle independence.[1]

Ninety percent of the population has detectable astigmatism, and 25% of them have more than 1.0 D. An uncorrected astigmatic refractive error of 1.0 D will, on average, decrease visual acuity to the level of 6/9 or 6/12 depending on its orientation. Uncorrected astigmatism can cause blurring of vision, as well as, distortion, glare, asthenopia, headaches, and monocular Diplopia .[2]

The amount of astigmatism unable to be eliminated from the system is termed the ocular residual astigmatism (ORA). It is also known as intraocular astigmatism as it incorporates the astigmatic contribution from the internal optics of the eye as well as the interpretation of the image by the cerebral cortex.[3]

Ocular residual astigmatism (ORA) can be calculated from the vectorial difference between the refractive cylinder at the corneal plane and the corneal astigmatism and is expressed in diopters and axis.(4) For instance, a subjective refraction reveals 1.80 DC at a meridian of 109°, but the topography measures 2.80 DC @ 29°. It is easy to see that treating the refractive cylindrical component of 1.80 DC will not entirely eliminate the greater amount of corneal astigmatism. If the treatment is based on the refractive astigmatism alone, the entire ORA (to neutralize the astigmatic contribution by the internal optics and cerebral cortex perception) will be left as corneal astigmatism. The ORA can be taken into consideration when planning the treatment to ensure a more even distribution between the refractive and corneal astigmatism, and less likely overall astigmatism. Therefore, neither the corneal nor refractive astigmatic target is zero, if incorporating the corneal as well as refractive astigmatism in the surgical plan.(5)

The ocular residual astigmatism (ORA) magnitude and its standard deviation were used to assess how closely each measure of corneal astigmatism matched the manifest refractive cylinder and its variability.(6,7)

PATIENT AND METHODS:

STUDY DESIGN:

This study is a cross- sectional observational study and it was conducted at the Lasik outpatient clinic of Ibn Al-Haitham teaching eye hospital, Baghdad, Iraq in the period between April 2017 and December 2017.

STUDY SAMPLE:

The study included 84 consecutive patients (135 virgin healthy eyes) (male=40, female=44) with refractive errors. Exclusion criteria include: amblyopia, keratoconus, previous eye surgery or trauma, contact lens wear within two weeks, any ocular disease (like glaucoma, cataract, uveitis, keratitis) .

METHOD:

Full clinical history was taken and routine clinical examination of the patients' eyes with Haag-Streit BM 900® LED slit lamp was done to exclude any associated abnormalities of anterior or posterior segments of the eye. IOP measurements were done by Air-puff pneumotonometer.

Visual acuity was measured by Snellen's chart. Both objective refraction, by TOMEY RC-5000 Auto Refkeratometer, and subjective refraction, by a trialframe , were done by the same person in the same room in the Lasik outpatient unit. The refractive data of this study were always presented in the negative cylinder form. Corneal topography has been done by OCULUS Pentacam, Germany , which uses a rotating Scheimpflug camera to measure the corneal thickness across the whole cornea and the anterior and posterior corneal surfaces.(8)

The simulated anterior and posterior corneal astigmatism were measured. For each measurement , the subjects were asked to fixate on the fixation target and to blink before starting the measurement. The internal quality check of the device was used to decide whether or not the measurement was acceptable. The measurements were accepted if the quality check indicated that the measurement was ''OK.'' and white in color. If not acceptable, repeated measurement was done until it was acceptable ,otherwise, it was omitted.

CALCULATION:

To calculate the total corneal astigmatism, the algorithm of vergence tracing was used. The vergence power (by the anterior corneal surface) at the plane of the posterior corneal surface in the flat meridian ($\mathbf{VP_{flat}}$) is (n_c) /[$(n_c$ / $\mathbf{P_{f,\,front}}$) - d].

The vergence power (by the anterior corneal surface) at the plane of the posterior corneal surface in the steep meridian ($\mathbf{VP_{steep}}$) is (n_c) /[$(n_c$ / $P_{s,\,front}$) - d].

Note that, N_c is the refractive index of the cornea (1.376) , **d** is the central corneal thickness, $\mathbf{P_{f,\,front}}$ is the power of flat meridian of anterior corneal surface and $P_{s,}$ front is the power of steep meridian of anterior corneal surface.Therefore, the astigmatism at the plane of posterior corneal surface ,caused by the anterior corneal surface, is [($\mathbf{VP}_{steep}$ – $\mathbf{VP}_{flat}$) - flat meridian of the anterior corneal surface]. The Total corneal astigmatism (PA), derived from pentacam measurement, was then obtained by vector summation of the astigmatism at the plane of posterior corneal surface , that is created by the anterior corneal surface, and the astigmatism from the posterior corneal surface.(9)

All vector calculations were performed by using the ASSORT® outcomes analysis (Alpins Statistical System for Ophthalmic Refractive Surgery Techniques). Features of the ASSORT Vector calculator include:

1.Calculation of the sum or difference of two astigmatisms.
2.Display of these astigmatisms on a polar diagram.
3.Display of the corresponding double angle vector diagram. These calculators allow astigmatism analysis of one eye only. [10]

Data Analysis:

Statistical analysis was performed using IBM SPSS statistics version 20. Categorical variables were presented as frequencies and percentages. Continuous variables were presented as (Mean± SD). Student t-test was used to compare means between two groups when study variable was normally distributed. Correlation coefficient (r) was used to assess relationship between two continuous variables. A P-value of ≤ 0.05 was considered to be statistically significant.

The results

Eighty four patients were included in this study (135 virgin healthy eyes), 40 of the them(47.6%) were males and 44 of them (52.4%) were females. The patients' ages were between 16 to 49 years with an average age of 27.15 years.

In our study ,68.61% of the eyes included, had with the rule Astigmatism (**WTR** : defined as 60° to 120°), 18.24% had against the rule astigmatism (**ATR**: 0° to 30° and 150° to 180°) and 13.13% had oblique astigmatism **(OA)**.

Table 1.1 shows mean differences of ocular residual astigmatism (ORA) and Total ocular residual astigmatism (Total ORA) in with the rule astigmatism (WTR), against the rule astigmatism (ATR) and oblique astigmatism (OA).

There were statistically significant differences between means of ORA and total ORA in with the rule and against the rule astigmatism. P value ≤ 0.05 was considered as statistically significant.

Table 1.1

Type of astigmatism	variable	N	Mean ± SD	t-test	P value*
WTR	ORA Total ORA	93 93	-0.7416 ± 0.4341 -0.6223 ± 0.401	-4.571	< 0.001
ATR	ORA Total ORA	24 24	-0.8113 ± 0.38517 -0.6658 ± 0.3844	- 4.135	< 0.001
OA	ORA Total ORA	18 18	-0.7756 ± 0.41908 -0.7561 ± 0.42872	-0.5	0.623

*p value ≤ 0.05 was significant.

Table 1.2 shows the correlation between posterior corneal astigmatism (PCA) and total ocular residual astigmatism (total ORA) for each type of astigmatism.

There was significant positive linear correlation between posterior corneal astigmatism (PCA) and total ocular residual astigmatism (total ORA) in with the rule astigmatism (WTR).

Table 1.2

	Study variables	N	Mea-+SD	r	p-value
WTR	PCA	93	-0.5376±0.20426	0.286	0.005
	Total ORA	93	-0.6223±0.40100		
ATR	PCA	24	-0.2375±0.10959	0.016	0.940
	Total ORA	24	-0.6658±0.38440		
OA	PCA	18	-0.2722±0.16380	-0.466	0.051
	Total ORA	18	-0.7561±0.42872		

Correlation is significant at the 0.01 level.

DISCUSSION:

Obtaining an accurate measurement for the total astigmatic power of the cornea and its meridian is of ultimate importance—whether for selecting and orienting toric IOLs, determining the length and placement of limbal relaxing incisions, or the treatment of astigmatism using excimer laser.(11)

The posterior corneal astigmatism, the lenticular astigmatism and the astigmatism caused by visual cortex processing, all together contribute to the manifest refractive astigmatism and will be responsible for the ORA. So, by calculating the total corneal topographic astigmatism from anterior and posterior corneal topographic astigmatism vectorial summation, and then calculating the total ORA (vectorial difference between the total corneal topographic astigmatism and manifest refreaction), we can refine the value of ORA be exclusion of the effect of posterior corneal astigmatism.(11)

Unfortunately, few articles paid attention to posterior corneal astigmatism effect on the ocular residual astigmatism to compare our results with.

In this study, eighty four patients were included (135 virgin healthy eyes),where 40 of the them(47.6%) were males and 44 of them (52.4%) were females.

The patients' ages ranged from 16 to 49 years with an average age of 27.15 years, so, most patients included in this study are relatively young.

Compared to Noel Alpins et al 2015 study(11) , which included five hundred twenty-six virgin healthy eyes, and 60% of the patients were females with a range of age 20 to 57, our study is smaller in size. This can be explained, as there is limited time for our study (only 8 months), while the Noel Alpins et al study(11) lasted for more than two years. Besides that, our study included multiple exclusion criteria.

Note that, 68.61% of the eyes included in our study, had with the rule Astigmatism , 18.24% had against the rule astigmatism and 13.13% had oblique astigmatism **(OA)**. This is close to Noel Alpins et al 2015 study(11) , in which 71% of the eyes had with the rule astigmatism, 15% had against the rule astigmatism and 14% had oblique astigmatism. It is also close to JAU-DER HO et al 2008 study, in which 71.8% was with the rule astigmatism and 15% was against the rule astigmatism.

The refractions are performed at the spectacle plane and not at the corneal plane. So, refractive measurements must be vertexed to the corneal plane before they can be compared to those obtained by pentacam corneal topography.(12)

Refractions performed in the trial frame are at a nominal vertex distance of 13.75 mm. Within the trial frame, multiple lenses are aligned to produce a combined lens used in refraction. This combined lens has an effective vertex distance that frequently differs from the nominal value indicated on the vertex scale. This difference, along with the difficulty of maintaining precise frame alignment, causes the vertex distances measured with the trial frame to be unreliable, especially at higher refractive powers. A more accurate measurement can be obtained by performing the refraction by using a soft contact lens with a power near the spheroequivalent (SEQ) of the refractive error, but this was difficult to be done due to limitations in our locality. (12)

As the minus and plus cylinder notation for refraction represents a difference rather than an actual power in either meridian, they must be, at first, converted to the cross-cylinder notation before performing vertex calculations.

The spherocylindric refraction in this example is vertexed to the corneal plane as shown below:

The refraction is: -12 / +2 × 90

Cross cylinder form @ Spectacle : -12 × 180 and -10 × 90

Vertex 13.75mm

Vertex formula from spectacle plane (REF_s) to corneal plane (REFc) **(4):**

$$REFc = \frac{1000\ \times REF\ s}{1000 - REFs\ \times Vertex\ (mm)}$$

By substituting the values of the previous example:

$$REFc1 = \frac{1000\ \times (-12)}{1000 - (-12) \times 13.75} = -10.30$$

$$DREF\ c2 = \frac{1000 \times (-10)}{1000 - (-10) \times 13.75} = -8.79\ D$$

So, the Cross cylinder form@ cornea : -10.30 × 180 and -8.79 × 90

Vertex: 0 mm

Plus cylinder form: -10.30 / +1.51 × 90
Minus cylinder form: -8.79 / -1.51 × 180

In this study, in case of with the rule astigmatism, the manifest refraction was (-2.0323 ± 1.10165) and when vertexed to the corneal plane , it was (-1.8623 ± 0.99563). The manifest refraction of against the rule astigmatism was (-1.3854± 0.75534) , and when vertexed to the corneal plane, it was (-1.2129 ±0.64542). Finally, the manifest refraction of oblique astigmatism was (-1.6528 ± 0.60110) ,which on conversion into the corneal plane, it became (-1.4767 ± 0.56306). In case of with the rule astigmatism, the anterior topographic astigmatism was (- 2.2473 ± 0.99418) , the posterior corneal astigmatism was (-0.5376 ± 0.20426) and the total corneal topographic astigmatism was (- 1.8218 ± 0.86182). In case of against the rule astigmatism, the anterior topographic astigmatism was(- 0.8167 ± 0.45651) , the posterior corneal astigmatism was (- 0.2375 ± 0.10959) and the total corneal topographic astigmatism was (- 0.7683 ± 0.3956). Finally, in the case of Oblique astigmatism, the anterior topographic astigmatism was (-1.3222 ± 0.55578) , the posterior topographic astigmatism was (-0.2722 ± 0.1638) and the total corneal topographic astigmatism was (- 1.15 ± 0.45648).The results of Oblique astigmatism in this study are very close to Douglas D.Koch et al 2012 study [13] , in which the anterior topographic astigmatism was (-1.20 ± 0.79) , the posterior corneal astigmatism was (-0.3 ± 0.15) and the total corneal topographic astigmatism was (-1.07 ± 0.71). This can be explained, by the factors of difference in sample size, the involved age groups and the types of topographic devices used in both studies. However, the posterior corneal astigmatism of this study is close to the result of our study, in all types of astigmatism. The most important outcome variables in this study were the ocular residual astigmatism (ORA) and total ocular residual astigmatism (total ORA), which are the vectorial differences between the manifest astigmatism and the anterior corneal topographic astigmatism and total corneal topographic astigmatism, subsequently. In with the rule astigmatism, there was statistically significant difference between the means of the ORA (-0.7416 ± 0.43418) and total ORA (-0.6223 ± 0.401) with a paired t-test (-4.571) and P value (< 0.001). In against the rule astigmatism, there was also statistically significant difference between the means of the ORA (-0.8113 ± 0.38517) and the total ORA (-0.6658 ± 0.3844) with a paired t- test (-4.135) and P value(< 0.001).Finally, in oblique astigmatism, there was no statistically significant difference between the means of the ORA (- 0.7756 ± 0.41908) and the total ORA (- 0.7561 ± 0.42872) with a paired t-test (-0.5) and P value (0.623). Noel Alpins et al 2015 study [11] , has found that the ORA was (- 0.64 ± 0.32) and the total ORA was (-0.53 ± 0.30) with P value (< 0.001). This is very close to the result of with the rule astigmatism and against the rule astigmatism in our study. Stijn Klijn et al 2016 study [4] , compared the ORA and total ORA by using Pentacam and Cassini corneal topographers. With pentacam, the ORA was (-0.61± 0.28) and the total ORA was (-0.49 ± 0.27). While, with Cassini corneal topographer , the ORA was (-0.58 ± 0.29) and the total ORA was (- 0.45 ± 0.27). Although, the magnitude of means of ORA and total ORA are a bit different from the magnitude of the means of our study, but the difference between the ORA and total ORA means similar to difference between the ORA and total ORA (of with the rule and against the rule Astigmatism) of our study. Jau-Der Ho et al 2008 study [9], showed that the astigmatism of the posterior corneal surface resulted in an average 13.4% reduction of the astigmatism of the anterior corneal surface, which fits with the result of our study. The correlation test between posterior corneal astigmatism (PCA) and total ocular residual astigmatism (total ORA) for each type of astigmatism was done. There was a significant positive linear correlation between posterior corneal astigmatism (PCA) and total ocular residual astigmatism (total ORA) in with the rule astigmatism (WTR) ($r = 0.286$, P value = 0.005). This means, when the Posterior corneal astigmatism is larger (i.e. closer to zero, as it was in negative value), the total ORA is also larger (i.e. closer to zero), which is expected. But, unfortunately, we didn't find a research, who did this correlation relationship. So, a further research is recommended.

The study was limited by, Small sample size, inaccuracies in the measurement of vertex distances is a possible source of error and the refractive measurements were positioned along the pupil's center, While the corneal topography measurements were centered on the corneal apex, which may contribute to the mismatch between the manifest and topographic refraction.

CONCLUSION:

ORA based on the total corneal topographic astigmatism corresponds better with manifest refractive cylinder than, the ORA based solely on anterior corneal topographic astigmatism with omission of the posterior corneal astigmatism. We recommend, a routine calculation of ORA, prior to laser refractive surgery or cataract surgery with a toric IOL implantation or when using limbal relaxing incision, is very important. This would help to identify the high ORA, and advising the patient to reduce his expectations about the result of surgery. Using the total corneal topographic measurement ,based on both anterior and posterior corneal surfaces, is easier during surgical planning, because there is lower ORA and a lower possibility of adverse visual outcomes.Further studies with large cohort should be planned.

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