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Correlation of major components of ocular astigmatism in myopic patients

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ABSTRACT:

Purpose: To investigate the correlation of major components of ocular astigmatism in myopic patients in an academic hospital.
Methods: This cross-sectional study was conducted on 376 eyes of 188 patients who were referred to Farabi Eye Hospital for refractive surgery. Preoperative examinations including refraction and corneal topography were performed for all candidates to measure refractive and corneal astigmatism. Ocular residual astigmatism was calculated using vector analysis. Pearson's correlation and ANOVA analysis were used to evaluate the strength of the association between different types of astigmatism. Both eyes were defined as cluster and the Generalized Estimating Equations (GEE) analysis were performed.
Results: Mean age of 119 women (63.3%) and 69 men (36.7%) was 27.8 ± 5.7 years. Mean refractive error based on spherical equivalent was −3.59 ± 1.95 D (range, −0.54 to −10.22 D). Mean refractive and corneal astigmatism was 1.97 ± 1.3 D and 1.85 ± 1.01 D, respectively. Mean amount of ORA was 0.65 ± 0.36 D. There was a significant correlation between ORA and refractive astigmatism(r = 0.23, p < 0.001), corneal and refractive astigmatism (r = 0.91, p < 0.001) and a weak correlation between ORA and corneal astigmatism (r = 0.13, p = 0.014). There was a significant correlation between J0 and J45 values of ORA and corneal astigmatism (p < 0.001).
Conclusion: There is a significant correlation between ORA and refractive astigmatism, refractive and corneal astigmatism and a weak correlation between ORA and corneal astigmatism in refractive surgery candidates. Identifying the type of astigmatism and preoperative measurement of ocular residual astigmatism is highly recommended prior to any refractive surgery, especially in cases with significant astigmatism.

1. Introduction

Astigmatism is a common optical disorder and exists in most human eyes in subtle amounts. Numerous studies have reported the prevalence of astigmatism in different ages [1–7], rural and urban populations [8–10] and ethnic groups [1–10]. Previous studies have reported the prevalence of astigmatism from 11.3% up to 70% in related studies [5,7,8]. Different factors have been suggested in the development of astigmatism including age, gender, ethnicity, genetic predisposition, eye lid pressure and unequal tension of extraocular muscles on the cornea [11,12].

Refractive or total astigmatism is comprised of anterior corneal and ocular residual astigmatism (ORA). Anterior corneal curvature is the main component of ocular astigmatism and causes the greatest optical effect; however, ORA is considered as the non-corneal component of total refractive astigmatism and is often caused by internal optics of the eye, especially the crystalline lens [12]. ORA cannot be measured independently and is calculated by the vectorial difference between the corneal and refractive astigmatism [13].

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Since, ORA is not calculated directly, it seems to have an special importance in patients undergoing refractive surgery. However, the relationship between ORA and other types of astigmatism is not clear [14]. Many studies have evaluated the correlation between refractive and corneal astigmatism and found that refractive astigmatism is mainly corneal in origin [15–17]. However, results regarding the contribution of ORA have been conflicting, with some studies finding a significant correlation between ORA and total astigmatism in normal astigmats [15] and others stating no significant relation between the two entities [18]. Astigmatism affects visual acuity and contrast sensitivity and compared to other refractive errors, is more difficult to treat. Additionally, with the advent of excimer laser techniques and the unpredictability of visual outcome after laser refractive surgeries in eyes with astigmatism [19] and lower efficiency of these surgeries in correcting astigmatism that is mainly due to internal optics of the eye [20], it is crucial to determine the pattern of astigmatism and its components preoperatively. The purpose of this study is to evaluate the correlation between refractive, corneal and ocular residual astigmatism in patients undergoing refractive surgery.

2. Patients and methods

This cross-sectional study was conducted on 376 eyes of 188 patients who referred to Farabi Eye Hospital for refractive surgery. The tenets of the Declaration of Helsinki were followed for all study procedures. Patients were included in this study if they were aged 20 years or older, had regular astigmatism of $\leq$6 D, and best-corrected visual acuity (BCVA) of 6/6 or better.

The exclusion criteria included any previous eye surgeries, trauma to the eye, corneal scar, corneal or lens opacity affecting the vision, irregular astigmatism and regular astigmatism of greater than 6 D, keratoconus, non-refractive eye disorders, dry eye and pregnancy.

3. Pre-operative examinations

Refractive astigmatism was determined by manifest refraction using Zywave aberrometry predicted phoropter refraction (PPR) (Bausch & Lomb, Rochester, NY, USA). Zywave's estimate of refractive error was then compared to subjective manifest refraction and confirmed with HEINE BETA 200 retinoscope (Herrsching, Germany) and Topcon RM8800 auto-refractometer (Tokyo, Japan). Repeatability and validity of Zywave's refractive error measurements have been confirmed [21].

Each patient's best visual acuity was measured by Snellen E-chart and corneal topography was performed using the OrbscanIIz (Bausch & Lomb, Rochester, NY, USA). Corneal astigmatism was calculated based on simulated keratometry (SimK) value, the difference in power between the steep and flat meridians, in 3 mm optical zone of the cornea. ORA was determined using vector analysis (Kaye and Patterson method) [22,23].

Patients were classified into the following groups: Mild, moderate and high myopia. Based on previous studies [7,24,25], high myopia was defined as a refractive error of more than –6.00 D, moderate myopia as a refractive error of −3.1 to −6.00 D and mild myopia as a refractive error of −0.51 to −3.00 D. In order to evaluate the correlation between the type of astigmatism and ORA, patients were divided into three groups: astigmatism $\leq$ 1.00 D, 1.00 < astigmatism $\leq$ 2.00 D, astigmatism > 2.00 D

4. Statistical analysis

In this study, Pearson correlation analysis and scatter plots were used for investigating the correlation between refractive, corneal and ocular residual astigmatism. The analysis of variance (ANOVA) was used to compare the mean power of astigmatism in different myopic groups.

Both eyes were defined as cluster and the Generalized Estimating Equations (GEE) analysis were performed. The data analysis was performed using SPSS software version 20. A p value of less than 0.05 was considered statistically significant.

5. Results

Of 188 patients (376 eyes), 119 (63.3%) were female. Mean age of patients was 27.8 ± 5.7 years (range, 20–52 years). Mean refractive error based on spherical equivalent was −3.59 ± 1.95 D (range, −0.54 to −10.22 D). Mean refractive and corneal astigmatism was 1.97 ± 1.3 D and 1.85 ± 1.01 D, respectively. Mean ocular residual astigmatism was 0.65 ± 0.36 D (Table 1).

A Pearson correlation coefficient was computed to assess the relationship between the amounts of ORA, refractive and corneal astigmatism. As demonstrated in Figs. 1 and 2, there was a significant but weak correlation between ORA and refractive astigmatism (r = 0.23, p < 0.001) and ORA and corneal astigmatism (r = 0.13, p = 0.014) and a strong correlation between corneal and refractive astigmatism (r = 0.91, p < 0.001) (Fig. 3).

Analysis of variance demonstrated a correlation between ORA and refractive astigmatism in different amounts of astigmatism (p = 0.01), but no correlation existed between ORA and corneal astigmatism in these subgroups (p = 0.70) (Table 2). There was no correlation between SE and amount of astigmatism, based on ANOVA results (p > 0.05).

Vector analysis demonstrated a statistically significant correlation between J0 value (Pearson correlation = −0.587, p < 0.001) and J45 value (Pearson correlation = −0.321, p < 0.001) of ORA and corneal astigmatism (Table 3).

Our analysis based on the axis of the principal meridians demonstrated that the correlation between J0 values of ORA and corneal astigmatism was mainly observed in patients with with-the-rule astigmatism (Pearson correlation = −0.421), while the correlation coefficient in patients who had against-the-rule astigmatism was 0.033. Similar results were observed regarding J45 values, with Pearson correlation of −0.373 in cases with with-the-rule astigmatism and correlation coefficient of 0.077 in patients with against-the-rule astigmatism.

6. Discussion

In this study, we found a significant correlation between ORA, refractive and corneal astigmatism and the strongest correlation existed between corneal and refractive astigmatism.

Many studies have emphasized on the correlation between corneal and refractive astigmatism. In 1996 Mckendrick reported a significant correlation between corneal and total refractive astigmatism using vector analysis [26]. Our results regarding the correlation between corneal and total refractive astigmatism were also compatible with the results of the studies done by Baldwin,

Table 1
Patients' characteristics

Total number = 376 eyes variable	Mean ± SD	Range
Age (y)	27.8 ± 5.70	20–52
Sphere MR. (D)	2.60 ± 2.02	−9.23 to 1.70
Refractive astigmatism	1.97 ± 1.30	0.05–6.45
Corneal astigmatism	1.85 ± 1.01	0.07–5.10
Residual astigmatism	0.65 ± 0.36	0.05–1.93
SE. MR (D)	−3.59 ± 1.95	−10.22 to −0.54

MR = manifest refraction, SE = spherical equivalent, D = dioptres.