Original Article

Internal Astigmatism Measurement; Testing a Theory

Hemn Baghban Jaldian [1], MS; Siavash Shangeh [1], BS; Saeed Rahmani [1], PhD; Parva Pourbagherkhah [*2], MS

1. Department of Optometry, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
2. Department of Optometry, School of Rehabilitation, Iran University of Medical Sciences, Tehran, Iran.

***Corresponding Author:** Parva Pourbagherkhah
E-mail: parvaprbkh@gmail.com

Abstract

Purpose: To determine refraction and corneal astigmatism using an ophthalmometer and to calculate the difference between the two to obtain the mean internal astigmatism.
Patients and Methods: This study included 45 patients. Inclusion criteria required participants to be 18 years or older with astigmatism. Manifest refraction was measured at least five times per eye using a Topcon RM-8900 autorefractometer and then confirmed by retinoscopy. Patients were subsequently examined with a Topcon Ophthalmometer and the results were recorded.
Results: The mean internal astigmatism values were approximately equal for the right (-0.5333 D) and left eyes (-0.5722 D). The mean amplitude of accommodation values were also similar for the right (9.2333 D) and left (9.0444 D) eyes. No correlation was found between internal astigmatism and amplitude of accommodation.
Conclusion: The mean internal astigmatism values obtained for the right and left eyes were consistent with Javal's hypothesis, supporting its validity. No significant difference in the distribution of internal astigmatism was observed between the two eyes. Additionally, no correlation was found between internal astigmatism and the amplitude of accommodation.

Keywords: Astigmatism; Refraction; Keratometry.

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Introduction

Astigmatism is a type of refractive error that occurs when parallel rays of light entering the unaccommodated eye do not focus on the retina [1]. Astigmatism is generally classified into keratometric, lenticular, and retinal types. It primarily originates from the cornea, while lenticular astigmatism results from uneven curvature and refractive irregularities within the crystalline lens [2]. Astigmatism can also be categorized as regular or irregular.

A statistical relationship exists between corneal and refractive astigmatism. This relationship was first established in 1890 by Javal, who used a keratometer for measuring objective refraction [3]. Javal observed that when the principal corneal meridians are aligned at 0 and 90 degrees-corresponding to with-the-rule and against-the-rule astigmatism, respectively-refractive astigmatism can be estimated by multiplying corneal astigmatism by 1.25 and then adding 0.50 diopters of against-the-rule astigmatism to account for internal astigmatism [3].

In theory, internal astigmatism is defined as the difference between refractive and corneal astigmatism [4,5]. Javal's rule is based on the premise that residual astigmatism is presumed to be permanent and against the rule. Grosvenor et al., [6] proposed a simplification of the Javal's rule. This facilitated rule was more consistent with their data than the original Javal's rule [6]. Keller et al., [7] examined the relationship between corneal astigmatism and total astigmatism by measuring corneal astigmatism with a computerized video keratoscope and concluded that the relationship between corneal and total astigmatism was independent of pupil size. The results of this study supported the facilitated Javal's rule proposed by Grosvenor et al., [6]. Dunne et al., [8] examined residual astigmatism by measuring the difference between ocular and total astigmatism (using cylinder analysis). The mean residual astigmatism was -0.46 × 98.2 ° for the right eye and -0.50 × 99.4 ° for the left eye. Several studies have examined the distribution of astigmatism between the posterior surfaces of the cornea [9-11]. These studies have obtained values of astigmatism for the posterior surface of the cornea in the range of 0.18-0.31 diopters.

It is understood that astigmatism of the posterior corneal surface has a contrasting effect compared to astigmatism of the anterior corneal surface. As a result, part of the compensation of corneal astigmatism by intraocular optic structures can be attributed to the posterior surface of the cornea. Some studies have suggested the possibility of an active feedback process that works to reduce the total astigmatism of the eye, especially horizontal and vertical astigmatism [12].

Since there is no specific clinical method for the direct acquisition of internal astigmatism and we cannot consider a fixed and equal amount for everyone, this study aimed to evaluate the mean internal astigmatism in a group of patients with astigmatism.

Patients and Methods

In this cross-sectional study, inclusion criteria for participants were to be 18 years of age or older with regular astigmatism and a best-corrected visual acuity of 20/50 or better. Exclusion criteria were history of previous eye surgery, pregnancy, trauma, corneal ulcer, corneal opacity, irregular astigmatism, keratoconus, dry eye or any type of eye disease. This study adhered to the principles of the Declaration of Helsinki and was approved by the institutional ethics committee. All patients gave written consent before entering the study. All participants underwent comprehensive

ophthalmic examinations. Uncorrected and corrected visual acuities were measured using an E-Snellen chart. Manifest refraction was assessed with at least five repeated readings per eye using a Topcon RM-8900 autorefractometer, followed by confirmation with a Beta 200 Heine retinoscope. The examination room lighting conditions were standardized for all patients, and they were positioned 6 meters away from the chart.

Keratometry measurements were conducted in a separate room using a Topcon Ophthalmometer. Measurements were performed first for the right eye and then for the left eye. Additional examinations included slit-lamp evaluation using a Topcon SL-D301 slit lamp, extraocular motility (EOM) assessment, the alternate prism cover test, near point of convergence (NPC), and near point of accommodation (NPA) measurements.

Results

In the present study, 45 patients (90 eyes) were examined. Of these, 24 were male and 21 were female. Regarding spherical refractive errors, 58 eyes (64 %) were myopic, 24 eyes (26 %) were hyperopic, and 8 eyes (8 %) were emmetropic. Data regarding the astigmatism in the right eyes are presented in table 1, and data related to the left eyes are shown in table 2. Astigmatism values are reported in terms of minimum, maximum, mean, and standard deviation.

The mean internal astigmatism values were approximately equal for the right (mean: - 0.5333 D; range: - 0.75 to 2.25 D) and left eyes (mean: 0.5722 D; range: - 0.25 to 1.50 D) (Tables 1 and 2).

The mean value of amplitude of accommodation had a similar magnitude in both right (mean: 9.2333 D; range: 6.00 to 12.00 D) and left (mean: 9.0444 D; range: 6.00 to 12.00 D) eyes (Table 3). Analyzing data from tables 1, 2 and 3 gave no clues regarding the existence of a correlation between the values of internal astigmatism and amplitude of accommodation.

Table1: Information related to the right eyes' astigmatism

	Min	Max	Mean	Std. Deviation
Refractive Ast (OD)	- 1.50	.00	- 0.3389	0.36601
Corneal Ast (OD)	- 2.75	.00	- 0.8722	0.64979
Internal Ast (OD)	- 0.75	2.25	0.5333	0.62523

OD; right eye

Table 2: Information related to the left eyes' astigmatism

	Min	Max	Mean	Std. Deviation
Refractive Ast (OS)	- 1.50	.00	- 0.3667	0.42171
Corneal Ast (OS)	- 3.00	.00	- 0.9389	0.51167
Internal Ast (OS)	- 0.25	1.50	0.5722	0.46043

OS: left eye

Table 3: Information related to accommodation in the right and left eyes

	Min	Max	Mean	Std. Deviation
Amp of Acc (OD)	6.00	12.00	9.2333	1.55066
Amp of Acc (OS)	6.00	12.00	9.0444	1.48409

OD; right eye, OS: left eye, Acc: Accommodation

Discussion

The aim of the present study was to investigate and compare the amount of internal and corneal astigmatism using analysis of data collected from refraction and keratometry to find a relationship between the data.

Several points are understood from the results of tables 1, 2 and 3. The mean values of internal astigmatism for the right and left eyes were 0.53333 D and 0.5722 D, respectively. These values are close to the Javal's hypothesis and can be considered as a confirmation for it. The values of astigmatism in the right and left eyes were close and there was no evidence pointing to a difference in internal astigmatism of the right and left eyes.

The values of the amplitudes of accommodation of right and left eyes were 9,2333 D and 9,0444 D, respectively. It should be noted that no correlation was found between the degree of internal astigmatism and the amplitude of accommodation, and these two variables were considered independent of each other.

Numerous studies have concluded that corneal astigmatism is compensated by internal optics of the eye [5,8,13]. McKendrick and Brennan [14] proposed a small correlation between corneal astigmatism and refractive astigmatism using vector analysis, but Kelly et al., [12] emphasized the relationship between corneal and refractive astigmatism and their active compensatory state. Huynh et al., [15] investigated the relationship between corneal and refractive and lenticular astigmatism and their compensation during the refractive error consistent with the findings of some other studies [7,16,17]. They concluded that there was a linear relationship between corneal astigmatism and refractive astigmatism. Grosvenor and Ratnakaram [18] also reported a linear relationship between corneal astigmatism and refractive astigmatism in high powers of astigmatism, but did not mention lenticular astigmatism in their study. According to a study by Srivannaboon [19] study on refractive surgery volunteers, there was little correlation between corneal and internal astigmatism as well as refractive and internal astigmatism, while there was a significant correlation between corneal astigmatism and refractive astigmatism. He stated that there is no two-way relationship between corneal astigmatism and refractive astigmatism despite internal astigmatism [19]. The results of a study by Liu et al., [20] showed that, with age, changes to the cornea affect refractive astigmatism, while lens opacity plays a small role in altering total astigmatism.

The reason for different results in different studies can be due to the differences in astigmatism measurement with different devices, the manner of patient selection and referral of patients, as well as differences in age groups among patients entering the studies. Positive points in the present study included the inclusion of patients with different types of refractive errors (hyperopia, myopia, and

astigmatism). The small sample size and lack of age group diversity can be considered as the limitations of the present study.

Conclusion

The mean internal astigmatism values obtained for the right and left eyes were consistent with Javal's hypothesis, supporting its validity. No significant difference in the distribution of internal astigmatism was observed between the two eyes. Additionally, no correlation was found between internal astigmatism and the amplitude of accommodation.

Authors ORCIDs

Hemn Baghban Jaldian:
https://orcid.org/0000-0002-5136-3843
Parva Pourbagherkhah:
https://orcid.org/0000-0002-5417-3383

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Footnotes and Financial Disclosures

Conflict of interest:

The authors have no conflict of interest with the subject matter of the present manuscript.