

Cylinder axis agreement: unexpected scenarios

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Research article

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Abstract

Background The purpose of this retrospective study was to evaluate cylinder axis agreement between manifest refraction (MR), cycloplegic refraction (CR), Allegro Oculyzer II and Allegro Topolyzer-Vario. **Methods** We included 82 patients (32 males and 50 females, 28.1 ± 8.7 years old), with 156 eyes scheduled for wavefront optimized laser refractive surgery, photorefractive keratectomy (PRK) in 50 eyes and laser- assisted in situ keratomileusis (LASIK) in 106 eyes, for correction of simple, myopic, hyperopic or mixed astigmatism. Cylinder axis was determined under manifest and cycloplegic refractions and using Allegro Oculyzer II and Allegro Topolyzer-Vario platforms. Cylinder axis agreement was assessed by Intra class Correlation coefficient, Pearson Correlation coefficient and by the method described by Bland and Altman. **Results** Intra class Correlation Coefficient and Pearson Correlation Coefficient showed statistically significant cylinder axis agreement between manifest refraction, cycloplegic refraction, Allegro Oculyzer II and Allegro Topolyzer-Vario ($p < 0.001^*$). Despite statistically significant cylinder axis agreement between the four measuring tools, 4 of 156 eyes (2.5%) showed unexpected discrepancy between Allegro Oculyzer II and Allegro Topolyzer-Vario cylinder axis. **Conclusions** Although cylinder axis shows statistically significant agreement between manifest refraction, cycloplegic refraction, Allegro Oculyzer II and Allegro Topolyzer-Vario, unexpected discrepancies occur.

Background

Laser refractive surgery, including photorefractive keratectomy (PRK) and laser- assisted in situ keratomileusis (LASIK), gained global establishment as a reliable and safe procedure for correction of refractive errors. ^(1,2)

Laser refractive surgery is undergoing great evolutions, including excimer laser current flying spot technology, enhanced intraoperative pupillary tracking mechanism and cyclorotation adjustment. ⁽³⁻⁵⁾ The WaveLight EX500 (Alcon Laboratories; Ft Worth, TX, USA), the recent excimer laser evolution, applies a 1,050 Hertz (Hz) multidimensional active tracking system with estimated 2 milliseconds (ms) latency and pupillary size tracking ability ranging from 1.5 mm to 8 mm. ⁽⁶⁾

The term "wavefront optimized" was introduced to describe aspherical ablation profiles attempting to eliminate or reduce spherical aberration associated with myopic laser refractive correction. ⁽⁷⁾

The majority of refractive surgeons rely on clinical refraction, manifest or cycloplegic, however this refractive data occasionally shows difference from topography, regarding cylinder axis. Some surgeons advocated clinical refractive data adjustment with topography, introducing the new term "topography-modified refraction". ⁽⁸⁾

Topography data can be obtained via Allegro Oculyzer II or Allegro Topolyzer-Vario.

The Oculyzer presents a Scheimpflug rotating camera, with a 360 degrees rotating light beam, scanning the cornea with high density of points from the corneal centre.

In contrast, the Topolyzer, is a placido-disk based system with a camera imaging reflections from the surface of the cornea. Since the Topolyzer camera is located at the centre of the topographer, a central scotoma is produced corresponding to the camera location, and hence a small area of central corneal data are extrapolated. ⁽⁹⁾

The aim of this study was to evaluate cylinder axis agreement between manifest refraction (MR), cycloplegic refraction (CR), Allegro Oculyzer II and Allegro Topolyzer-Vario.

Methods

All patients were recruited from the Department of Ophthalmology, Faculty of Medicine, Alexandria University (Alexandria, Egypt). Informed consent was obtained from all patients. This study was approved by the Ethics of Research Committee, Faculty of Medicine, University of Alexandria, Egypt.

Exclusion criteria were uncontrolled diabetes mellitus, collagen vascular diseases, pregnancy, severe xerophthalmia, corneal dystrophies, forme fruste keratoconus, and keratoconus.

Preoperative examination

All patients underwent manifest and cycloplegic refractions by a TOPCON RM-8900 Auto Refractometer (Topcon Medical Systems, Tokyo, Japan), measurements of the uncorrected visual acuity (UCVA) and best spectacle-corrected visual acuity (BSCVA).

All eyes were subjected to corneal topography assessment by Allegro Topolyzer-Vario (WaveLight, Erlagen, Germany) and Scheimpflug tomography examination by Allegro Oculyzer II (WaveLight, Erlagen, Germany). Patients enrolled in the study had pre-operative pachymetry ≥ 460 microns (μm) for PRK and ≥ 500 μm for LASIK. PRK subjects were required to retain an average post-operative residual corneal bed ≥ 380 μm . LASIK subjects were required to retain an average post-operative residual corneal bed ≥ 300 μm .

Operative and postoperative data

All patients underwent wavefront optimized laser refractive surgery, PRK in 50 eyes and LASIK in 106 eyes, for correction of simple, myopic, hyperopic or mixed astigmatism, applying WaveLight EX500 (Alcon Laboratories; Ft Worth, TX, USA). All surgeries were performed by a single surgeon, the author. A superior hinge was applied in LASIK cases using Moria Evolution 3 Microkeratome (Moria, Antony, France) with a programmed planned flap thickness of 110 μm and a diameter of 8 mm. In PRK, the corneal epithelium was removed in a diameter of 8 mm in a centripetal fashion using a blunt hockey blade. UCVA and manifest refraction were evaluated at 1 month post-operatively. Postoperative refraction was assessed by a TOPCON RM-8900 Auto Refractometer (Topcon Medical Systems, Tokyo, Japan).

Statistical analysis of the data

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp). Intra class Correlation coefficient (ICC) and Pearson Correlation coefficient were used to assess agreement. A p value less than 0.05 was considered statistically significant. Cylinder axis agreement was also studied using the method described by Bland and Altman. This method also computed 95% limits of agreement (LoA=mean difference +/- 1.96SD).

Results

The present study was conducted on 82 patients 32 (39 %) males and 50 (61 %) females and involved 156 eyes scheduled for wavefront optimized laser refractive surgery, PRK in 50 eyes and LASIK in 106 eyes, for correction of simple, myopic, hyperopic or mixed astigmatism. The age of the studied patients ranged from 18 to 49 years (28.1 ± 8.7 years). (Table 1)

Intra class Correlation Coefficient and Pearson Correlation Coefficient showed statistically significant cylinder axis agreement between manifest refraction (MR), cycloplegic refraction (CR), Allegro Oculyzer II and Allegro Topolyzer-Vario ($p < 0.001^*$). (Tables 2, 3) (Figure 1).

Despite statistically significant cylinder axis agreement between the four measuring tools, 4 of 156 eyes (2.5 %) showed unexpected discrepancy between Allegro Oculyzer II and Allegro Topolyzer-Vario cylinder axis. (Figure 2). In these cases, the cylinder axis applied for laser treatment was the mean of the four measurements. 1 month postoperatively, these cases showed 0 cylinder with UCVA 1.

Discussion

The Alcon/WaveLight refractive surgery laser platform comprises the EX500 excimer laser, and a series of diagnostic networked devices that constitute the Refractive Suite® (including Allegro Placido Topolyzer-Vario and Allegro Scheimpflug Oculyzer II).⁽¹⁰⁾

This Refractive Suite applies ethernet networking, allowing diagnostic data import from networked screening devices into the laser planning software, including topography data from Allegro Placido Topolyzer-Vario and topometric data from Allegro Scheimpflug Oculyzer II.⁽¹¹⁾ Multiple studies reported the application of topography-guided treatment with such platforms, whether in normal or irregular corneas.⁽¹²⁻¹⁹⁾

The Oculyzer presents a Scheimpflug rotating camera, with a 360 degrees rotating light beam, scanning the cornea with high density of points from the corneal centre. Therefore, it should be the first choice when planning laser treatment in corneas with central irregularities or aberrations. However, it can be affected by ocular movement or corneal haze or cloudiness.⁽⁹⁾

In contrast, the Topolyzer, is a placido-disk based system with a camera imaging reflections from the surface of the cornea. Since the Topolyzer camera is located

at the centre of the topographer, a central scotoma is produced corresponding to the camera location, and hence a small area of central corneal data are extrapolated.

Therefore, it should be the first choice when planning laser treatment in corneas with more peripheral irregularities or aberrations. However, it lacks the provision of full surface information, with lower accuracy in cases of central corneal aberrations. ⁽⁹⁾

A recent study by Cummings et al showed that both the Oculyzer and Topolyzer provide reliable and comparable results in pre-operative myopes and in subjects with mixed astigmatism. ⁽⁹⁾ This coincides with the present study, where statistically significant agreement between Allegro Oculyzer II and Allegro Topolyzer-Vario was detected.

In a recent study by Kanellopoulos, clinical refractive data was modified with topographic data, considering cylinder axis and amount, introducing the new term "topography-modified refraction". This provided superior visual function regarding UCVA, residual refractive error, total high-order aberrations, coma aberration, and contrast sensitivity. He hypothesized that "topography-modified refraction" allows to bypass the bias induced by lenticular astigmatism, particularly active in young myopic patients. Such hypothesized lenticular astigmatism seems to be responsible for distortion of the objective cylinder axis and amount. ⁽⁸⁾ In the present study, 4 of 156 eyes (2.5 %) showed unexpected discrepancy between Allegro Oculyzer II and Allegro Topolyzer-Vario cylinder axis. In these cases, the cylinder axis applied for laser treatment was the mean of the four measurements. 1 month postoperatively, these cases showed 0 cylinder with UCVA 1.

"These findings may change the current clinical paradigm of the optimal subjective refraction utilized in laser vision correction." ⁽⁸⁾

Conclusions

Although cylinder axis shows statistically significant agreement between manifest refraction, cycloplegic refraction, Allegro Oculyzer II and Allegro Topolyzer-Vario, unexpected discrepancies occur.

Abbreviations

MR: manifest refraction

CR: cycloplegic refraction

PRK: photorefractive keratectomy

LASIK: laser- assisted in situ keratomileusis

Hz: Hertz

Ms: milliseconds

UCVA: uncorrected visual acuity

BSCVA: best spectacle-corrected visual acuity

µm: microns

ICC: Intra class Correlation coefficient

LoA: limits of agreement

Declarations

Ethics approval and consent to participate This study was approved by the Ethics of Research Committee (IRB 00007555, FWA 00015712), Faculty of Medicine, University of Alexandria, Egypt. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. Written informed consent to participate in the study was obtained from all individual participants included in the study.

Consent for publication Written informed consent to publish the results of the study and identifying images or other personal or clinical details of participants that compromise anonymity was obtained from all individual participants included in the study.

Availability of data and materials Datasets are available in additional supporting files.

Competing interests The author declares no conflict of interest.

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Authors' contributions Not applicable

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Tables

**Table (1): Distribution of the studied cases according to different parameters
(n = 156)**

	No. (%)
Age (years)	
Mean \pm SD	27.4 \pm 7.7
Median (Min. - Max.)	26 (18 - 49)
Refractive Surgery	
PRK	50 (32.1%)
LASIK	106 (67.9%)
Pachymetry (μm)	
Mean \pm SD	537.7 \pm 34
Median (Min. - Max.)	533 (487 - 639)
Keratometric K1 (D)	
Mean \pm SD	42.8 \pm 1.4
Median (Min. - Max.)	42.8 (39.6 - 46.3)
Keratometric K2 (D)	
Mean \pm SD	44.6 \pm 1.6
Median (Min. - Max.)	44.6 (41.5 - 50.6)
Sphere (D)	
Mean \pm SD	-2 \pm 3
Median (Min. - Max.)	-1.5 (-8 - 5.5)
Cylinder (D)	
Mean \pm SD	-1.9 \pm 1
Median (Min. - Max.)	-1.5 (-4.5 - -0.5)
Manifest Refraction cylinder axis	
Mean \pm SD	95 \pm 66.4
Median (Min. - Max.)	101.5 (3 - 192)
Cycloplegic Refraction cylinder axis	
Mean \pm SD	92.7 \pm 66.1
Median (Min. - Max.)	98.5 (1 - 194)
Allegro Oculyzer \square cylinder axis	
Mean \pm SD	94.8 \pm 68.5
Median (Min. - Max.)	107.5 (2 - 190)
Allegro Topolyzer-Vario cylinder axis	
Mean \pm SD	94.5 \pm 69.3
Median (Min. - Max.)	106 (0 - 185)
1 month sphere (D)	
Mean \pm SD	0 \pm 0.1
Median (Min. - Max.)	0 (-0.3 - 0.5)
1 month cylinder (D)	
Mean \pm SD	0 \pm 0.1
Median (Min. - Max.)	0 (-0.5 - 0)
1 month UCVA	
Mean \pm SD	1 \pm 0.1
Median (Min. - Max.)	1 (0.8 - 1)

Table (2): Intra class Correlation Coefficient for cylinder axis agreement

	ICC coefficient	95% C.I	p
MR axis vs.			
CR axis	0.996	0.995 - 0.997	<0.001*
Oculus axis	0.991	0.988 - 0.993	<0.001*
Topolyzer axis	0.989	0.985 - 0.992	<0.001*
CR axis vs.			
Oculus axis	0.990	0.986 - 0.993	<0.001*
Topolyzer axis	0.991	0.987 - 0.993	<0.001*
Oculus axis vs.			
Topolyzer axis	0.994	0.992 - 0.996	<0.001*

ICC: Intra class Correlation coefficient

*: Statistically significant at $p \leq 0.05$

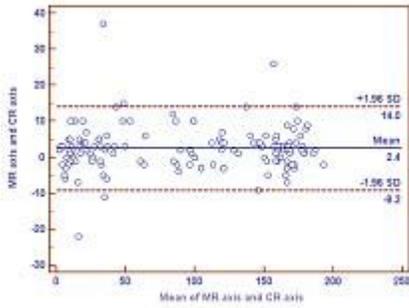
Table (3): Pearson Correlation coefficient for cylinder axis agreement

	Mean difference (SD)	95% limits of agreement	Pearson correlation Coefficient (r)*	p-value
MR axis - CR axis	2.37(2.92)	14.0 to -9.2	0.996	<0.001*
MR axis - Oculus axis	0.25(9.02)	17.9 to -17.4	0.992	<0.001*
MR axis - Topolyzer axis	0.55(9.94)	20.0 to -18.9	0.990	<0.001*
CR axis - Oculus axis	-2.12(9.50)	16.5 to -20.7	0.991	<0.001*
CR axis - Topolyzer axis	-1.81(9.33)	16.5 to -20.1	0.992	<0.001*
Oculus axis - Topolyzer axis	0.30(7.53)	15.1 to -14.5	0.994	<0.001*

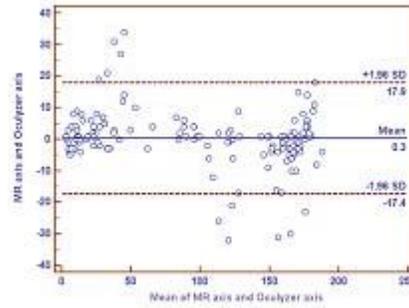
r: Pearson coefficient

*: Statistically significant at $p \leq 0.05$

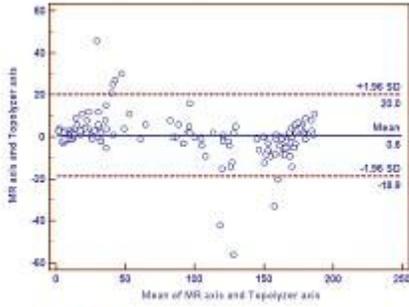
Figures



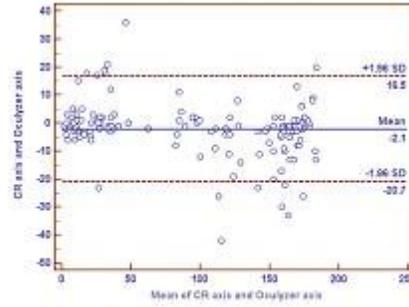
a: MR axis - CR axis



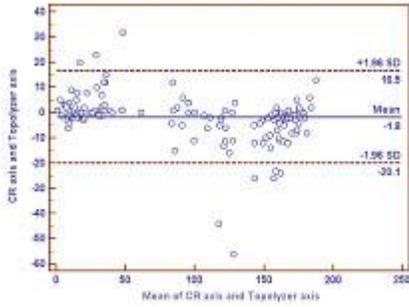
b: MR axis - Oculyzer axis



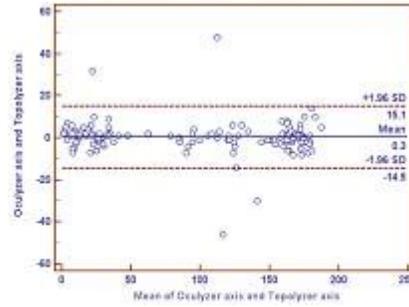
c: MR axis - Topolyzer axis



d: CR axis - Oculyzer axis



e: CR axis - Topolyzer axis



f: Oculyzer axis - Topolyzer axis

Figure 1

Bland–Altman plots of cylinder axis agreement between manifest refraction (MR), cycloplegic refraction (CR), Allegro Oculyzer II and Allegro Topolyzer-Vario. The bold horizontal line demonstrates the mean difference and the dotted lines above and below represent the 95% limits of agreement (LoA) interval.



Figure 2

Allegro Oculyzer II and Allegro Topolyzer-Vario cylinder axis disagreement in 4 studied cases (highlighted by the red circles).

Supplementary Files

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- [supplement1.xlsx](#)