Journal of Optometry (2017) xxx, xxx–xxx

Journal of Optometry

www.journalofoptometry.org

ORIGINAL ARTICLE

Agreement between total corneal astigmatism calculated by vector summation and total corneal astigmatism measured by ray tracing using Galilei double Scheimpflug analyzer

Sepehr Feizi*, **Siamak Delfazayebaher, Vahid Ownagh, Fatemeh Sadeghpour**

Ophthalmic Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Received 25 February 2017; accepted 28 May 2017

KEYWORDS
Total corneal astigmatism;
Ray tracing;
Vector summation

Abstract
Purpose: To evaluate the agreement between total corneal astigmatism calculated by vector summation of anterior and posterior corneal astigmatism (TCA_{Vec}) and total corneal astigmatism measured by ray tracing (TCA_{Ray}).
Methods: This study enrolled a total of 204 right eyes of 204 normal subjects. The eyes were measured using a Galilei double Scheimpflug analyzer. The measured parameters included simulated keratometric astigmatism using the keratometric index, anterior corneal astigmatism using the corneal refractive index, posterior corneal astigmatism, and TCA_{Ray}. TCA_{Vec} was derived by vector summation of the astigmatism on the anterior and posterior corneal surfaces. The magnitudes and axes of TCA_{Vec} and TCA_{Ray} were compared. The Pearson correlation coefficient and Bland–Altman plots were used to assess the relationship and agreement between TCA_{Vec} and TCA_{Ray}, respectively.
Results: The mean TCA_{Vec} and TCA_{Ray} magnitudes were 0.76 ± 0.57 D and 1.00 ± 0.78 D, respectively ($P < 0.001$). The mean axis orientations were $85.12 \pm 30.26^{\circ}$ and $89.67 \pm 36.76^{\circ}$, respectively ($P = 0.02$). Strong correlations were found between the TCA_{Vec} and TCA_{Ray} magnitudes ($r = 0.96$, $P < 0.001$). Moderate associations were observed between the TCA_{Vec} and TCA_{Ray} axes ($r = 0.75$, $P < 0.001$). Bland–Altman plots produced the 95% limits of agreement for the TCA_{Vec} and TCA_{Ray} magnitudes from −0.33 to 0.82 D. The 95% limits of agreement between the TCA_{Vec} and TCA_{Ray} axes was −43.0 to 52.1°.

* Corresponding author at: Ophthalmic Research Center, Labbafinejad Medical Center, Shahid Beheshti University of Medical Sciences, Tehran 16666, Iran.
E-mail address: sepehrfeizi@yahoo.com (S. Feizi).

http://dx.doi.org/10.1016/j.optom.2017.05.003

Please cite this article in press as: Feizi S, et al. Agreement between total corneal astigmatism calculated by vector summation and total corneal astigmatism measured by ray tracing using Galilei double Scheimpflug analyzer. *J Optom.* (2017), http://dx.doi.org/10.1016/j.optom.2017.05.003

Conclusion: The magnitudes and axes of astigmatisms measured by the vector summation and ray tracing methods cannot be used interchangeably. There was a systematic error between the TCA_{Vec} and TCA_{Ray} magnitudes.

PALABRAS CLAVE
Astigmatismo corneal total;
Trazado de rayos;
Suma de vectores

Concordancia entre el astigmatismo corneal total calculado mediante sumación vectorial, y el astigmatismo corneal total medido mediante trazado de rayos utilizando un analizador Galilei de doble cámara Scheimpflug

Resumen
Objetivo: Evaluar la concordancia entre el astigmatismo corneal total calculado mediante suma de los vectores del astigmatismo corneal anterior y posterior (TCA_{Vec}), y el astigmatismo corneal total medido mediante trazado de rayos (TCA_{Ray}).
Métodos: Este estudio incluyó a un total de 204 ojos derechos de 204 sujetos normales. Los ojos se midieron utilizando un analizador Galilei de doble cámara Scheimpflug. Los parámetros medidos incluyeron el astigmatismo queratométrico simulado utilizando el índice queratométrico, el astigmatismo corneal anterior utilizando el índice refractivo corneal, el astigmatismo corneal posterior, y TCA_{Ray}. TCA_{Vec} se calculó mediante la suma de los vectores del astigmatismo en las superficies corneales anterior y posterior. Se compararon las magnitudes y ejes de TCA_{Vec} y TCA_{Ray}. Se utilizaron el coeficiente de correlación de Pearson y los diagramas de Bland-Altman para valorar la relación y concordancia entre TCA_{Vec} y TCA_{Ray}, respectivamente.
Resultados: Los valores medios de las magnitudes TCA_{Vec} y TCA_{Ray} fueron $0,76 \pm 0,57$ D y $1 \pm 0,78$ D, respectivamente ($P < 0,001$). Las orientaciones medias del eje fueron $85,12 \pm 30,26$ grados y $89,67 \pm 36,76$ grados, respectivamente ($P = 0,02$). Se encontraron fuertes correlaciones entre las magnitudes de TCA_{Vec} y TCA_{Ray} ($r = 0,96$, $P < 0,001$). Se observaron asociaciones moderadas entre los ejes de TCA_{Vec} y TCA_{Ray} ($r = 0,75$, $P < 0,001$). Los diagramas de Bland-Altman establecieron un 95% de límite de acuerdo para las magnitudes de TCA_{Vec} y TCA_{Ray} de -0,33 a 0,82 D. Los límites de acuerdo del 95% entre los ejes de TCA_{Vec} y TCA_{Ray} fueron de -43 a 52,1 grados.
Conclusión: Las magnitudes y ejes de los astigmatismos medidos mediante suma de vectores y trazado de rayos no pueden intercambiarse. Se produjo un error sistemático entre las magnitudes de TCA_{Vec} y TCA_{Ray}.

Introduction

Toric intraocular lenses (IOLs) have been developed to reduce corneal astigmatism following cataract surgery.[1] The accurate measurement of corneal astigmatism is of the utmost importance for the prevention of astigmatism over- or undercorrection by toric IOLs. Conventional keratometers estimate the corneal refractive power and astigmatism from anterior corneal measurements and a fictitious keratometric index without taking into account the posterior corneal power.[2] However, neglecting the effect of posterior corneal astigmatism on anterior corneal astigmatism can lead to unacceptable toric IOL power calculation results. Several studies report that incorporating posterior astigmatism into the toric IOL calculation improves refractive outcomes.[3–6] Recently, the development of new technologies, such as slit-scanning devices, Scheimpflug devices, and optical coherence tomography, has made the quantitative measurement of the posterior corneal curvature in a clinical setting possible.[7,8] The Galilei dual Scheimpflug system (Ziemer Ophthalmic System AG, Zurich, Switzerland) is a noninvasive diagnostic instrument designed for the analysis of the anterior eye segment characteristics with an excellent repeatability of corneal power measurements.[9,10] This system combines both technologies, including Placido imaging, which provides curvature data, and Scheimpflug imaging, which is optimal for precise elevation measurements. This enables the calculation of the total corneal astigmatism using ray tracing of the anterior and posterior corneal surfaces, taking into account the effect of corneal thickness on the corneal power.[4,6,11–14] Alternatively, total corneal astigmatism can be calculated from the astigmatism of each surface using vector analysis.[5,15–17] However, a confirmation of the agreement between these two total corneal astigmatisms is still lacking and the best method for achieving optimum astigmatic outcomes after toric IOL

Please cite this article in press as: Feizi S, et al. Agreement between total corneal astigmatism calculated by vector summation and total corneal astigmatism measured by ray tracing using Galilei double Scheimpflug analyzer. *J Optom.* (2017), http://dx.doi.org/10.1016/j.optom.2017.05.003