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Ocular residual astigmatism and topographic disparity vector indexes in normal healthy eyes

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ABSTRACT

Purpose: To define a range of normality for the vectorial parameters Ocular Residual Astigmatism (ORA) and topography disparity (TD) and to evaluate their relationship with visual, refractive, anterior and posterior corneal curvature, pachymetric and corneal volume data in normal healthy eyes.
Methods: This study comprised a total of 101 consecutive normal healthy eyes of 101 patients ranging in age from 15 to 64 years old. In all cases, a complete corneal analysis was performed using a Scheimpflug photography-based topography system (Pentacam system Oculus Optikgeräte GmbH). Anterior corneal topographic data were imported from the Pentacam system to the iASSORT software (ASSORT Pty. Ltd.), which allowed the calculation of the ocular residual astigmatism (ORA) and topography disparity (TD). Linear regression analysis was used for obtaining a linear expression relating ORA and posterior corneal astigmatism (PCA).
Results: Mean magnitude of ORA was 0.79 D (SD: 0.43), with a normality range from 0 to 1.63 D. 90 eyes (89.1%) showed against-the-rule ORA. A weak although statistically significant correlation was found between the magnitudes of posterior corneal astigmatism and ORA ($r = 0.34$, $p < 0.01$). Regression analysis showed the presence of a linear relationship between these two variables, although with a very limited predictability (R^2: 0.08). Mean magnitude of TD was 0.89 D (SD: 0.50), with a normality range from 0 to 1.87 D.
Conclusion: The magnitude of the vector parameters ORA and TD is lower than 1.9 D in the healthy human eye.

1. Introduction

The ocular residual astigmatism (ORA) is defined as the vectorial difference between the corneal and the refractive astigmatism calculated to the corneal plane [1,2]. This designation is based on the term residual astigmatism introduced by Duke-Elder 40 years ago [3]. The ORA is the result of the combination of the crystalline lens and posterior corneal surface astigmatisms with the perceptual physiology. This last term is referring to the perceptual preference for a specific object orientation that may contribute to the presence of differences between corneal topography astigmatism and manifest refractive cylinder [4]. The magnitude of the ORA has been shown to be abnormally high in some pathological conditions, such as keratoconus [5–7] or post-LASIK ectasia [8], or after keratorefractive surgery [1] and therefore it may be valid as an additional diagnostic parameter to be used in the clinical practice. However, in spite of the evaluation of the ORA in various limited samples by some authors [9,10], a range of normality has not been still defined for this parameter. Besides the ORA, a parameter that only considers the regular components of corneal and ocular astigmatism, another vector parameter has been recently developed to characterize the irregular component of corneal astigmatism, the topography disparity (TD), which is calculated as the vectorial difference between the regular astigmatism of the superior and inferior hemidivisions of the cornea. This vector parameter might be especially useful for the detection of corneal anomalies, such as keratoconus, in which infero-superior differences in corneal astigmatism are normally present [6], but it has not been still validated.

In addition, the analysis of the ORA has been suggested to be an indirect procedure of evaluating the contribution of the posterior corneal surface to the ocular astigmatism in patients with transparent crystalline lens and no lenticular pathology [6,8]. It should be

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considered that the contribution of the crystalline lens to the total astigmatism is limited in non-pathologic eyes [11]. According to this assumption, the presence of larger amounts of ORA in an eye might be due to significant amounts of astigmatism arising from the posterior corneal surface. However, the relationship between the magnitude of ORA and posterior corneal astigmatism has not been still evaluated.

The aim of the current study was to define a range of normality for the vectorial parameters ORA and TD and to evaluate their relationship with visual, refractive, anterior and posterior corneal curvature, pachymetric and corneal volume data in normal healthy eyes.

2. Materials and methods

2.1. Patients

This prospective study comprised a total of 101 consecutive normal healthy eyes of 101 patients ranging in age from 15 to 64 years old. All eyes were selected randomly from patients visiting our Ocular Surface and Cornea Unit in the Department of Ophthalmology of the Medimar International Hospital (Alicante, Spain), where this investigation was developed. Only one eye from each subject was randomly chosen for the study according to a random number sequence (dichotomic sequence, 0 and 1) in order to avoid the interference in the analysis of the correlation that often exists between the two eyes of the same person. Only healthy eyes with no active diseases were included in this prospective study. Patients with one pathological eye were excluded from the study as well as those subjects with previous ocular surgeries or ocular or visual sequelae after a past ocular pathological condition. All patients were informed previously about the study and signed an informed consent document in accordance with the Helsinki Declaration.

2.2. Examination protocol

A comprehensive ophthalmologic examination was performed in all cases which included: LogMAR uncorrected distance visual acuity (UDVA), LogMAR corrected distance visual acuity (CDVA), manifest refraction (sphere and cylinder), slit-lamp biomicroscopy, Goldmann tonometry, fundus evaluation, ultrasonic pachymetry (DHG500 US Pachymeter, DHG Technology Inc, Exton, PA, USA), optical biometry (IOL-Master, Carl Zeiss Meditec) and corneal and anterior segment analysis by means of a Scheimpflug photography-based topography system, the Pentacam system version 1.14r01 (Oculus Optikgeräte GmbH, Germany). The Oculus Pentacam is a noninvasive system for measuring and characterizing the anterior segment using a rotating Scheimpflug camera [12,13]. The rotational measuring procedure generates Scheimpflug images in three dimensions, with the dot matrix fine-meshed in the center due to the rotation. It takes a maximum of 2 s to generate a complete image of the anterior eye segment. Any eye movement is detected by a second camera and corrected for in the process. The Pentacam calculates a three-dimensional model of the anterior eye segment from as many as 25,000 true elevation points. The Scheimpflug images taken during the examination are digitalized in the main unit and all image data are transferred to a computer and analyzed in detail. In the current study, the following Pentacam parameters were recorded and analyzed: anterior (K_a) and posterior average corneal radius (K_p) in the central 3-mm corneal area, anterior (ACA) and posterior corneal astigmatism (PCA) in the central 3-mm corneal area, and central corneal thickness (CCT). The patients wearing contact lenses for the correction of the refractive error were instructed in all cases to discontinue the use of contact lenses for at least 2 weeks before each examination for soft contact lenses and at least 4 weeks before each examination for rigid gas permeable contact lenses.

2.3. Calculation of the ocular residual astigmatism (ORA) and topographic disparity (TD)

ORA and TD were obtained using the iASSORT software (ASSORT Pty. Ltd., Cheltenham, Australia). This specialized software allows the clinician to perform astigmatic analyses on the topography and/or wavefront values provided by the diagnostic instrument into which the software has been installed. In this study, the

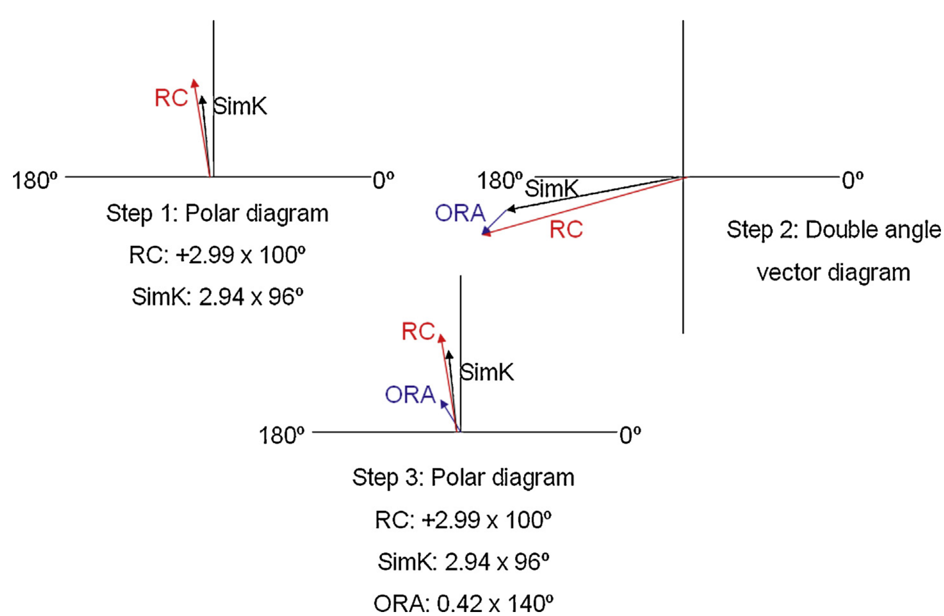

Fig. 1. Calculation of the Ocular Residual Astigmatism (ORA). Step 1 (up-left): polar diagram of refractive cylinder at the positive axis (calculated to the corneal plane) and corneal astigmatism from simulated keratometry. Step 2 (up-right): the double angle vector diagram showing a "doubling" of the angles without a change in the astigmatic magnitudes. Step 3 (down): polar diagram displaying the ORA as it would appear on the eye. *Abbreviations*: SimK, astigmatism from simulated keratometry obtained with the corneal topographer; RC, refractive or manifest astigmatism.