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Original article

A steep peripheral ring in irregular cornea topography, real or an instrument error?

Alicia Galindo-Ferreiro [a,b,*]; Alberto Galvez-Ruiz [a]; Silvana A. Schellini [a,c]; Julio Galindo-Alonso [d,e]

Abstract

Purpose: To demonstrate that the steep peripheral ring (red zone) on corneal topography after myopic laser in situ keratomileusis (LASIK) could possibly due to instrument error and not always to a real increase in corneal curvature.
Methods: A spherical model for the corneal surface and modifying topography software was used to analyze the cause of an error due to instrument design. This study involved modification of the software of a commercially available topographer.
Results: A small modification of the topography image results in a red zone on the corneal topography color map.
Conclusion: Corneal modeling indicates that the red zone could be an artifact due to an instrument-induced error. The steep curvature changes after LASIK, signified by the red zone, could be also an error due to the plotting algorithms of the corneal topographer, besides a steep curvature change.

Keywords: Irregular corneal astigmatism, Red zone, Topography, Spherical aberration

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Introduction

Historically, the Placido disk was a device for the study of corneal curvature. Subsequently the corneascope was introduced that retained the image and quantified the corneal curvature albeit imperfectly.[1] Computerized surveyors were the first instruments that allowed greater reliability for the measurement of corneal curvature and are still widely used today. Over time, various topographic indices have been developed to facilitate the clinical applications of corneal topography.[2,3]

The corneal topographer exploits the principle that the anterior corneal surface is a convex mirror that reflects the image of a disk with alternate black-and-white circular bands. The reflected image is collected and stored in a computer in a number of common image formats. This image is then analyzed by software. First of all, the software measures the distance between the center of the image and each ring. This measurement is performed along the corneal meridians at angular intervals set by the manufacturer. The angle of each meridian and distance to the center of each ring in this meridian are the polar coordinates defining a point explored by the surveyor. The apparatus is designed in order to find the curvature at each point and not sagittal height, which would be more appropriate.[4]

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[a] King Khaled Eye Specialist Hospital, Al Urubah Branch Rd, Umm Al Hamam Al Gharbi, Riyadh 12329, Saudi Arabia
[b] Department of Ophthalmology, Complejo Asistencial Palencia, Donantes de sangre s/n, 34005 Palencia, Spain
[c] Department of Ophthalmology Faculdade de Medicina de Botucatu – UNESP, São Paulo CEP 18618-970, Brazil
[d] Galindo Clinic, Francisco Zarandona St 10, 47003 Valladolid, Spain
[e] Rio Hortega University Hospital, Dulzaina St 2, 47012 Valladolid, Spain

* Corresponding author at: Al Arouba street, 12329 Riyadh, Saudi Arabia. Tel.: +34 639839208.
e-mail addresses: ali_galindo@yahoo.es (A. Galindo-Ferreiro), algarui@yahoo.com (A. Galvez-Ruiz), sschellini@gmail.com (S.A. Schellini), julgalin@gmail.com (J. Galindo-Alonso).

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Once all the measurements are completed, a table is stored on the hard disk in a text file. The next step, based on resulting measurements, is to apply the algorithm designed by the manufacturer to calculate the radius of curvature in each of the measured points. At the end of the process the data are known for each ring and each angular coordinate. Additionally the data are available for the distance from the center of the image (image center is plotted on the visual axis because it is assumed that the topography is centered and properly focused) and the corneal radius of curvature as the corneal meridian passing through that point. This set of corneal radii is plotted on the computer screen as a color map.

Eyes that have undergone myopic laser in situ keratomileusis (LASIK) often have a characteristic steep peripheral ring. This steep peripheral ring is commonly called a ''red ring'' or ''red zone'' that is present on postoperative instantaneous or tangential topography maps plotted with an adjustable or normalized scale using the Smolek–Klyce colors or international standard organization colors. The red ring occurs within the corneal region that has undergone surgery. The red ring was used by Vinciguerra to determine the cause of decentration and pseudodecentration after laser ablation.[5] Dupps and Roberts used corneal biomechanics to explain the postoperative red zone. Their biomechanical model is a series of meridional arches or lamellae arranged from limbus to limbus.[6] The destruction of these lamellae by excimer ablation elicits a shrinkage and corneal thickening around the ablated area.[6] Roberts provided additional evidence for this theory by measuring the peripheral corneal thickness with the Orbscan II (Bausch and Lomb Inc., Rochester, NY, USA) in the corneal region with the red zone.[7]

The use of diverse physical instruments is crucial in Opthalmology. These instruments should be properly calibrated, so that their responses are in agreement with the corresponding theories. But only practitioners are able to criticize and correct the results given by these instruments, which may be ambiguous or uncertain even when they are well and carefully calibrated.

In this study we evaluate whether the creation of this red zone may be an artifact of corneal topographers, as a result of the method used to reflect the Placido disk rings at the edge of the surgical site. The potential clinical implication of this investigation is that the red zone on postoperative corneal topography could also be an artifact of corneal topography plotting algorithms.

Methods

The EyeSys Windows WorkStation V.2 software topographer (EyeSys Systems Technologies, Houston, TX, USA) was used in this study. This topographer has four calibration balls with radii of 6.13, 7.10, 7.94 and 9.00 mm. We randomly chose the 7.10 mm radius ball, and placed it in front of the topographer similar to the device calibration method. However we performed a topography of the calibration ball, as if it were an eye. Once the videokeratograph was captured, we used an option in the topographer software to edit and modify two adjacent rings in the image.

Fig. 1 presents the reflection image of the placido rings on the ball, and an schematic draws indicate the region and process for the modification.

The details of the modification are explained in Fig. 1 down. A section of each of the two rings was deleted and a line was drawn connecting a free end of one of the rings with the other opposite free adjacent ring. The resulting topography is presented in Fig. 2 with the red zone.

Results

A corneal topography was performed on a perfectly spherical model simulating an artificial cornea and the image was modified through software to simulate a discontinuity in the corneal curvature. The software then processed the modified image to plot the topography map.

By processing the modified image, the result was an abnormal topography map in which the central corneal map appears normal, but the region that was modified shows a red zone indicating an apparently smaller radius (Fig. 2).

Discussion

Corneal topography based on Placido disk imaging is inaccurate, particularly for irregular corneas which show considerable variability in measurements.[8] Hence, topographies in irregular corneas should be interpreted with caution.[9] The data from the topographers plot the distance to the center of each ring to the anterio-posterior axis that passes through the center of the cornea but the numbers are only real in flat or 2D representation of the cornea because the curvature of the cornea results in oblique imaging of the peripheral rings and they seem closer together the further they are from the central cornea. Many topographers change the spacing between the rings to account for the increased slope of the cornea in the periphery.

The radius of curvature for each point that the software reads is attached to an error even for a normal cornea. Therefore, the accuracy of the measurements in corneal topography decreases as the distance from the center of the cornea increases.[3] This difference in accuracy between central and peripheral measures depends, among other factors, in the difference between corneal radii of both areas, so that, if a corneal topography is performed on a test sphere, we find the correct radius of curvature at any distance from the center.

A major cause of topographic distortion is the lack of correspondence between data on the corneal angles and data on the topographic image. Kronemyer reported that a point of reflection on the cornea and the corresponding point on the topography image require the same angular coordinate to ensure reliable data.[10] According to Kronemyer, this is only possible if a reflected point always passes perpendicularly through the optical axis, or stated differently, a point on a placido ring, the reflected point from the cornea and the image point are on a plane containing the optical axis.[10] However, in cases with astigmatism, correct alignment with the optical axis is only possible in the meridians with maximum and minimum curvature.

Based on Kronemyer's conclusions this would be even more important for an irregular cornea.[10] Merlin states that ''the radius is reliable . . . when curvature variations are variations of radius always centered on the keratoscope axis''.[11]

Additionally, it is imperative that the points on a meridian on the image have the same order as the Placido rings. For