

Multi-modality imaging of a Highly Irregular Cornea: comparison of findings to a Novel LED Multicolor-Spot Reflection Topography

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Abstract

Background

This case report aims to evaluate safety, efficacy and feasibility of anterior corneal surface imaging by a novel multi-color Light-Emitting-Diode (LED) tear film-reflection topographer in comparison to several standard corneal imaging modalities in patient with severe ocular and corneal changes due to old acanthamoeba keratitis.

Case Description

An 18-year old female patient, infected approximately two years ago with acanthamoeba in her right (OD) eye, was subjected to a multitude of anterior-segment and ocular imaging diagnostic devices. The imaging modalities included Placido topography, Scheimpflug tomography, Anterior-Segment Optical Coherence Tomography (AS-OCT), ocular stray-light measurement quantifier, and the Cassini, a novel multi-spot, multi-color LED reflection topographer.

Clinical Relevance

The ease of use and comparable results offered by the Cassini, in comparison to established Placido topography and Scheimpflug tomography, as well as the increased sensitivity that the novel topographer may offer new clinical diagnostic significance. Scheimpflug-imaging derived pachymetry has limitations in cases of partially opaque corneas.

Accurate

This case report, based on a novel corneal topography imaging in comparison to a variety of corneal imaging modalities, verifies the clinical applicability of the new technology in the imaging of disturbed and highly asymmetric cornea.

Keywords: LED Cassini; multi-color LED topography; Acanthamoeba keratitis; Point-source topography; Pentacam HR; Placido topography; Scheimpflug topometry; Differential topography; Irregular corneal astigmatism; Stray light measurements; C-Quant; Anterior-Segment Optical Coherence Tomography

Introduction

The limitations of Placido-based topography have been identified in the past, particularly pertaining to imaging of radial, rather than only contour topographic changes [1]. Topography systems with color-coded LED reflection forward ray tracing have been proposed [2] as an alternative to Placido ring imaging [3]. The VU topographer (Vrije Universiteit Medical Center, Amsterdam, The Netherlands) [2] introduced a different approach, with a color-coded squares in a chess-pattern array projected on the cornea instead of the Placido rings [4]. The

algorithm for the surface reconstruction employed data from the pattern crossing points to eliminate source-image mismatch, enabling one-to-one match. In principle, this color-coded topographer was found to be more efficient in reconstructing the non-rotationally symmetric anterior corneal surface [5].

The Cassini (i-Optics, The Hague, The Netherlands) topography system is a novel topographer employing multi spot (up to 700), multicolor (red, yellow and green) Light Emitting Diode (LED) tear film-reflection-imaging, following the steps of the VU topographer. The difference is instead of a limited

number of color-coded squares, there are hundreds of LED spots on radial and contour arrangement imaged on the cornea. Image processing algorithm locates feature points in the reflection image and accounts for smearing and deformation in irregular corneas. The system has been recently introduced [6] and has received FDA approval for clinical use in corneal topography.

Due to the novelty, clinical validations of this novel topography system and its clinical implications have not yet been extensively investigated and reported. We have recently reported [7] clinical results of the Cassini in a case of forme fruste keratoconus (FFKC).

The scope of this manuscript is to examine the clinical feasibility of this newly-introduced corneal topographer in a case of a patient with old acanthamoeba infection. Very little has been documented in the last ten years in cases involving acanthamoeba keratitis - infected eyes, from the point-of-view by contemporary anterior segment imaging.

Case Report

We present the case of an 18-year old female subject, diagnosed with acanthamoeba keratitis [8] on her right (OD) eye, affected at approximately two years ago. Informed consent was obtained from the subject at the time of the first clinical visit. This study adhered to the tenets of the Declaration of Helsinki and was approved by the Ethics Committee of our Institution.

The non-affected left eye (OS) had best-corrected distance visual acuity (CDVA) 20/20 and manifest refraction -7.00 S-0.25 C x 180°. The affected OD eye had CDVA 20/50 when wearing the manifest refraction of -3.50 S -2.00 C x 18°.

The Cassini (running on software version 1.2, updated September 2013) was employed to provide anterior cornea imaging. The system produces anterior elevation, tangential, axial curvature, and refractive power three-dimensional maps covering approximately a 7.5-mm diameter area. The report provides keratometry data (steep and flat K, simulated astigmatism), and computerized topographic and keratoconus indices. In addition, aberrations report is provided, according to the Zernike nomenclature. Four additional ocular imaging modalities were employed in this work. Placido imaging was provided by the Wave Light Allegro Topolyzer (Alcon Surgical, Ft Worth, and TX). The Topolyzer is a wide-cone corneal topographic Placido system with 22 concentric rings for the detection of up to 22,000 elevation points. Scheimpflug topometry was provided by the Wave Light Oculyzer II (Alcon Surgical, Ft Worth, TX), a Pentacam HR (high-resolution) camera providing corneal pachymetry and tomography imaging [9] was also included in this study.

The Fourier-domain Anterior-Segment Optical Coherence Tomography (AS-OCT) system RTVue-100 (Optovue Inc., Fremont, CA), running on analysis and report software version A6 (9,0,27) was employed in the study to provide cornea cross-

section, and corneal and epithelial thickness 3-dimensional mapping [10]. Finally, the C-Quant (Oculus Optikgeräte GmbH, Wetzlar, Germany), a system that measures stray-light scattering in the eye [11] was employed to provide quantitative data of scatter in relation to the identified corneal opacity.

Figure 1 presents OCT high-resolution meridian scan of the affected eye, corneal and epithelial pachymetry 3-dimensional maps. We observed the deep stromal scar, appearing as opacity associated with the residual stromal scarring, located in the near inferior-nasal area. Local corneal thinnest point and epithelial hyperplasia were also indicated in the same affected area. Central corneal thickness and minimum corneal thickness, as measured by the OCT were 381 and 318 μm respectively. A thinner epithelium (56 μm) over the thinnest, most ectatic region of the cornea also noted; overall, however, the epithelium was thick, in the vicinity of 70 - 74 μm, associated with large topographic variability (standard deviation of pachymetry) computed from the Scheimpflug system. The imaging successfully depicts the corneal opacity. The thinnest point also located inferior-nasally; however we note that the Scheimpflug imaging-derived central and minimum corneal thickness were 438 μm and 167 μm, a distinct disparity when compared to the OCT measurements (381 μm and 318 μm, as noted above). As it can be noticed in Figure 2a, the posterior surface was poorly identified at the lesion, a possible consequence of the corneal opacity. This is a clinical example of a cornea with considerable opacity that alters the 'normal' densitometry interpolation of the Scheimpflug algorithm and can possibly be associated with the reported cornea thickness results by the device.

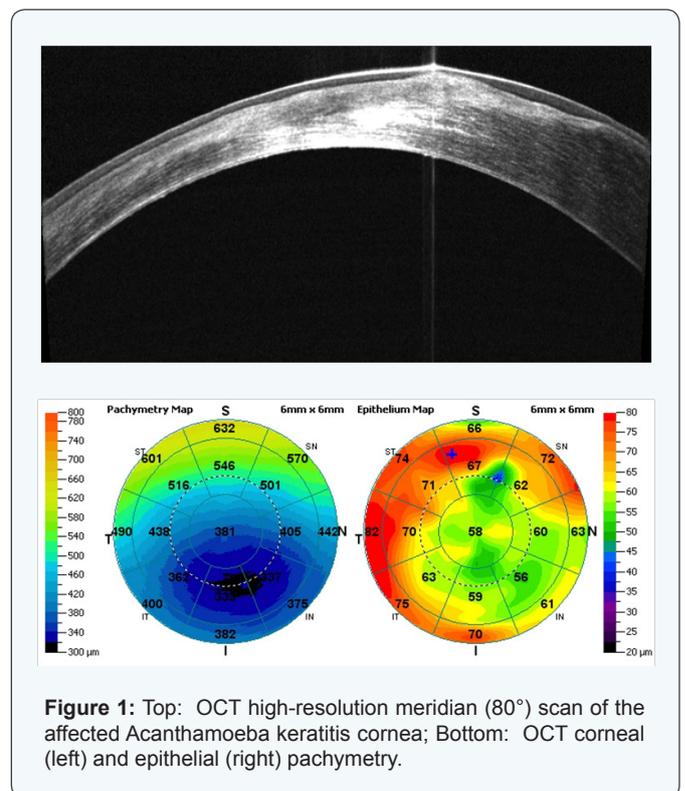


Figure 1: Top: OCT high-resolution meridian (80°) scan of the affected Acanthamoeba keratitis cornea; Bottom: OCT corneal (left) and epithelial (right) pachymetry.

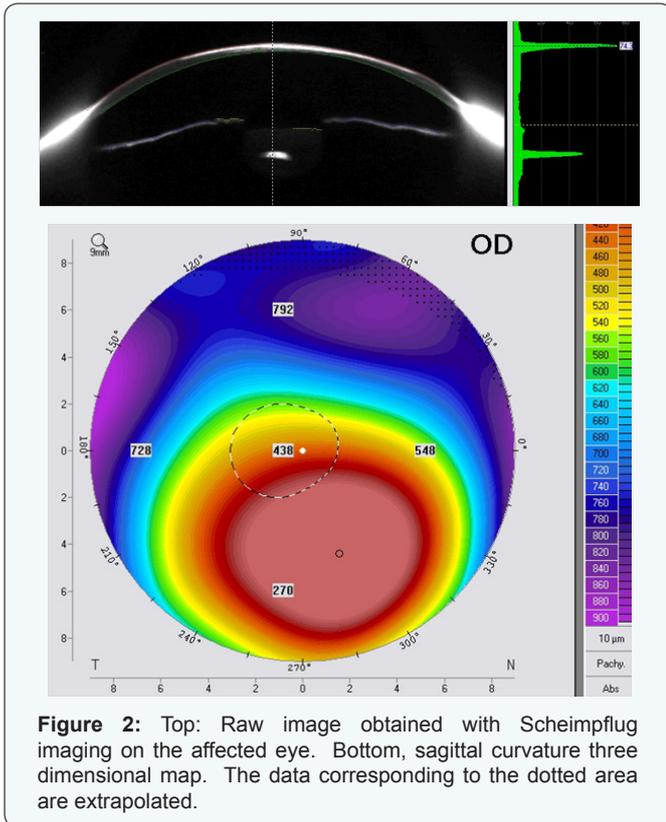


Figure 2: Top: Raw image obtained with Scheimpflug imaging on the affected eye. Bottom, sagittal curvature three dimensional map. The data corresponding to the dotted area are extrapolated.

Figure 3 presents stray-light measurement report by the C-Quant. The measurement, based on the compensation method, [12] reported a stray-light logarithm value of 1.43 ± 0.05 . When comparing this result to the average value of 0.80 ± 0.05 , obtained from a large number of healthy subjects of the same age (reference light curve in the upper graph), [13] it is clear that the measurement suggests that the affected eye has a substantially 'abnormal' ocular scatter.

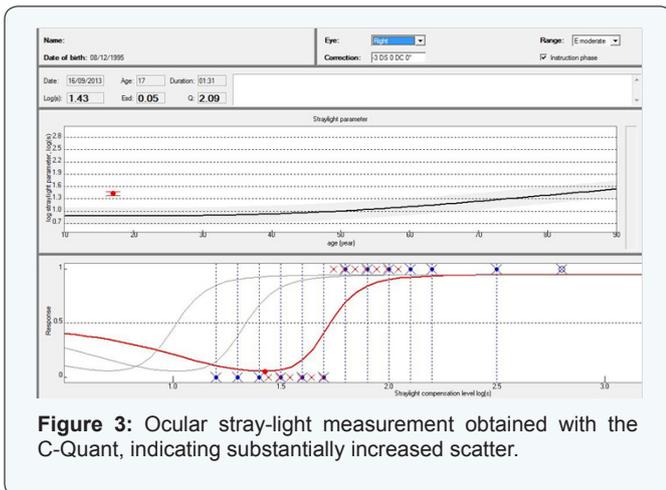


Figure 3: Ocular stray-light measurement obtained with the C-Quant, indicating substantially increased scatter.

Figure 4 presents Placido ring imaging raw data and the corresponding refractive map. We observed the highly distorted ring pattern along the vertical direction. The refractive map indicated very large variation of the cornea refraction, ranging from a localized 33.5 D inferiorly, to more than 48 D superiorly, and a distinct 'astigmatic' - like pattern in the mid-superior

cornea. Figure 5A presents Cassini imaging raw data imaging on the affected eye. Anterior surface axial curvature and refractive map (C) computerized with the above data are reported in Figures 5B and 5C, respectively.

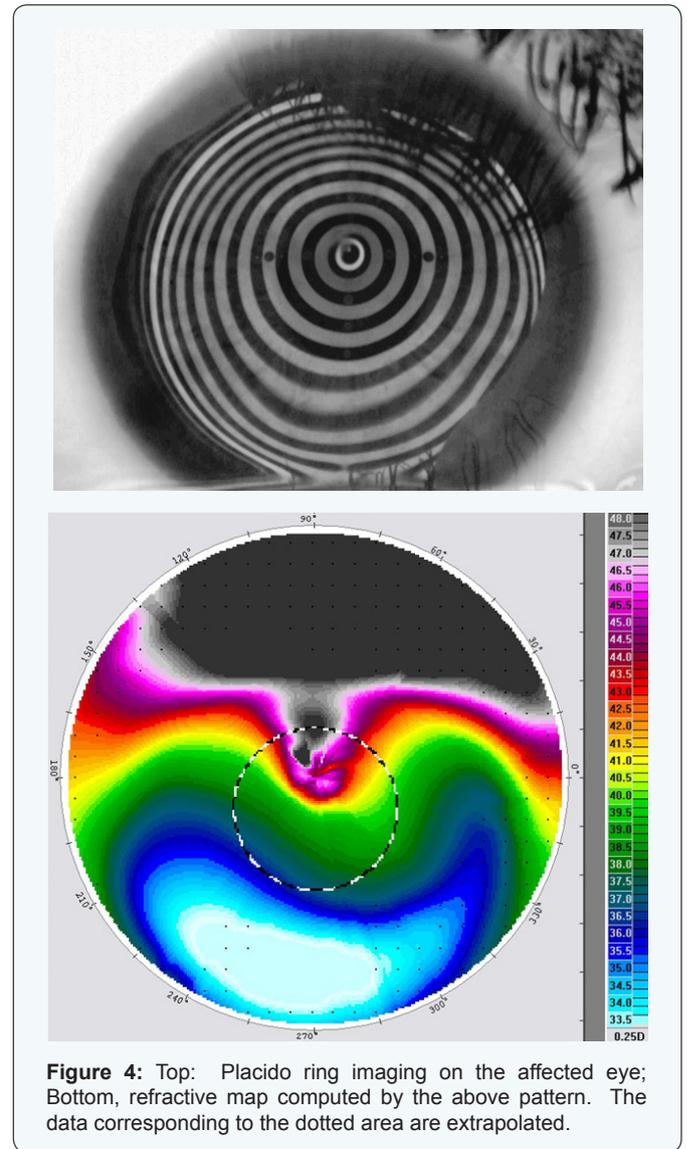


Figure 4: Top: Placido ring imaging on the affected eye; Bottom, refractive map computed by the above pattern. The data corresponding to the dotted area are extrapolated.

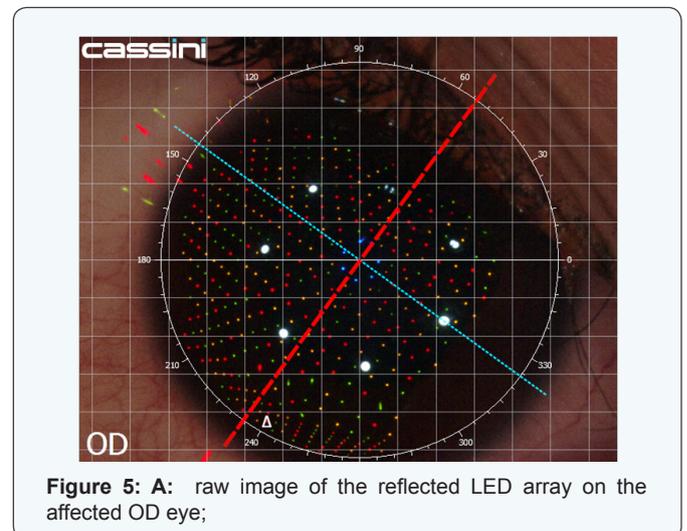


Figure 5: A: raw image of the reflected LED array on the affected OD eye;

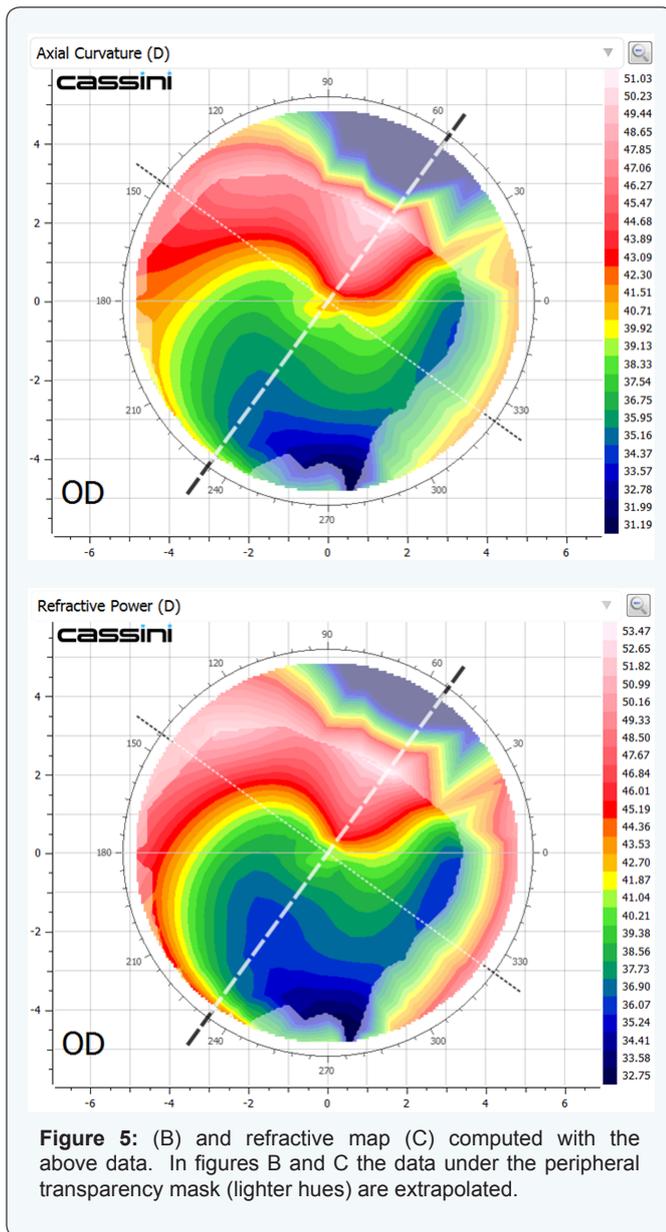


Figure 5: (B) and refractive map (C) computed with the above data. In figures B and C the data under the peripheral transparency mask (lighter hues) are extrapolated.

Discussion

Acanthamoeba keratitis is a rare disease in which amoebae invade the cornea [14-16]. The disease [17] as well as its sequelae is a common cause of corneal blindness in the United States, often a result of improper disinfection of contact lens use [17-19]. If it is not diagnosed early and not treated aggressively, infection by trophozoites [20] may result in extensive ocular damage, and enucleating may be required [21]. Even when cured, the disease may result in permanent irregular corneal surface and extensive central opacities, [22] thus rendering accurate imaging of the cornea is challenging. Subsequent corneal scarring may have severe impact on the anterior surface regularity, tear film regularity, as well as stromal density, as indicated by the OCT imaging, renders Placido and Scheimpflug imaging in this case challenging, as expected.

In this work we examined the clinical feasibility of the Cassini, the newly-introduced topographer in a case of Acanthamoeba keratitis in comparison to the established methods of clinical imaging, namely Placido topography, Scheimpflug topometry, and AS-OCT.

Thinnest cornea pachymetry, measured with Scheimpflug topometry (167 μ m) was in large disparity with the OCT-measured value (318 μ m). We believe this is a disadvantage of the Scheimpflug imaging principle, which assumes clear cornea interpolation of the posterior surface.

When correlating the novel Cassini to the established Placido topographer, it is clear from this case that the increased sensitivity, which includes both radial and contour differences, based on differential spot-imaging, enabled proper imaging of this highly irregular cornea. Particularly considering the extent of the abnormality presented in this case, and the fact that significant distortion was also present at the corneal center, the Placido device was not successful in imaging this case. The Scheimpflug topometry, on the other hand, was successful in imaging the anterior surface, but not the posterior.

Conclusion

The facility and comparable results offered by the novel Cassini topographer, in comparison to established Placido and Scheimpflug imaging, as well as the possibility of increased predictability that may be offered by the novel corneal imaging system in highly irregular corneas, may hold promise for wider clinical applications, such as screening of highly asymmetric and corneas with highly coinciding opacities.

References

1. Rand RH, Howland HC, Applegate RA (1997) Mathematical model of a Placido disk keratometer and its implications for recovery of corneal topography. *Optom Vis Sci* 74(11): 926-930.
2. Vos FM, van der Heijde RGL, Spoelder HJW, van Stokkum IHM, Groen FCA (1997) A new instrument to measure the shape of the cornea based on pseudorandom color coding. *IEEE Trans Instrum Meas* 46: 794-797.
3. Snellenburg JJ, Braaf B, Hermans EA, van der Heijde RG, Sicam VA (2010) Forward ray tracing for image projection prediction and surface reconstruction in the evaluation of corneal topography systems. *Opt Express* 18: 19324-19338.
4. Sicam VA, Snellenburg JJ, van der Heijde RG, van Stokkum IH (2007) Pseudo forward ray-tracing: a new method for surface validation in cornea topography. *Optom Vis Sci* 84(9): 915-923.
5. Sicam VA, van der Heijde RG (2006) Topographer reconstruction of the nonrotation-symmetric anterior corneal surface features. *Optom Vis Sci* 83(12): 910-918.
6. Weikert MP, Koch DD, Wang D (2013) Evaluation of Corneal Topography Based on Color LED Technology. *ASCRS Symposium & Congress, San Francisco, CA*.
7. Kanellopoulos AJ, Asimellis G (2013) Forme Fruste Keratoconus Imaging and Validation via Novel Multi-spot Reflection Topography. *Case Rep Ophthalmol* 4(3): 199-209.
8. Knickelbein JE, Kovarik J, Dhaliwal DK, Chu CT (2013) Acanthamoeba

- keratitis: a clinicopathologic case report and review of the literature. *Hum Pathol* 44(5): 918-922.
9. Kanellopoulos AJ, Asimellis G (2013) Comparison of Placido disc and Scheimpflug image-derived topography-guided excimer laser surface normalization combined with higher fluence CXL: the Athens Protocol, in progressive keratoconus. *Clin Ophthalmol* 7: 1385-1396.
 10. Kanellopoulos AJ, Asimellis G (2013) In vivo three-dimensional epithelial imaging of corneal epithelium in normal eyes by anterior segment optical coherence tomography: a clinical reference study. *Cornea* 32(11): 1493-1498.
 11. van den Berg TJ, Franssen L, Kruijt B, Coppens JE (2013) History of ocular straylight measurement: A review. *Z Med Phys* 23(1): 6-20.
 12. Coppens JE, Franssen L, van den Berg TJ (2006) Reliability of the compensation comparison method for measuring retinal stray light studied using Monte-Carlo simulations. *J Biomed Opt* 11(5): 054010.
 13. Rozema JJ, van den Berg TJ, Tassignon MJ (2010) Retinal straylight as a function of age and ocular biometry in healthy eyes. *Invest Ophthalmol Vis Sci* 51(5): 2795-2799.
 14. Graffi S, Peretz A, Jabaly H, Naftali M (2013) Acanthamoeba keratitis. *Isr Med Assoc J* 15(4): 182-185.
 15. Lorenzo-Morales J, Martín-Navarro CM, López-Arencibia A, Arnalich-Montiel F, Piñero JE, et al. (2013) Acanthamoeba keratitis: an emerging disease gathering importance worldwide? *Trends Parasitol* 29(4): 181-187.
 16. Siddiqui R, Khan NA (2012) Biology and pathogenesis of Acanthamoeba. *Parasit Vectors* 5:6.
 17. Illingworth CD, Cook SD, Karabatsas CH, Easty DL (1995) Acanthamoeba keratitis: risk factors and outcome. *Br J Ophthalmol* 79(12): 1078-1082.
 18. de Aguiar AP, de Oliveira Silveira C, Todero Winck MA, Rott MB (2013) Susceptibility of Acanthamoeba to multipurpose lens-cleaning solutions. *Acta Parasitol* 58(3): 304-308.
 19. Pacella E, La Torre G, De Giusti M, Brillante C, Lombardi AM, et al. (2013) Results of case-control studies support the association between contact lens use and Acanthamoeba keratitis. *Clin Ophthalmol* 7: 991-994.
 20. Richo Z, Gatziofuz Z, Hafezi F (2013) Corneal Collagen Cross-Linking for the Treatment of Acanthamoeba Keratitis. *Cornea* [Epub ahead of print] PMID: 23974880.
 21. Hammersmith KM (2006) Diagnosis and management of Acanthamoeba keratitis. *Curr Opin Ophthalmol* 17: 327-331.
 22. Mathers WD (2004) Acanthamoeba: a difficult pathogen to evaluate and treat. *Cornea* 23(4): 325.