The role of the tear film in dysfunctional lens syndrome: a prospective review

O papel do filme lacrimal na síndrome da lente disfuncional: uma revisão prospectiva

Debora Fardim Mota[1], Jorge Selem Haddad[2], Karolinne Maia Rocha[3], George Oral Waring IV[4], Faride Waked Tanos[5], Renato Ambrosio Júnior[5]

[1] Instituto Oftalmológico Paulista, São Paulo, SP, Brazil.
[2] Department of Ophthalmology, Federal University of São Paulo, São Paulo, SP, Brazil
[2] Storm Eye Institute, Medical University of South Carolina, Charleston, SC, United States.
[3] Waring Vision Institute, Mount Pleasant, SC, United States.
[4] Instituto de Olhos Renato Ambrósio, Rio de Janeiro, RJ, Brazil.

How to cite:
Mota DF, Haddad JS, Rocha KM, Waring IV GO, Tanos FW, Ambrosio Júnior R. The role of the tear film in dysfunctional lens syndrome: a prospective review. Rev Bras Oftalmol. 2022;81:e0063.

doi:
https://doi.org/10.37039/1982.8551.20220063

Keywords:
Dry eye syndrome; Topography; Lens implantation, intraocular

Descritores:
Síndromes do olho seco; Topografia; Implante de lente intraocular

ABSTRACT

Dry eye disease comprises a spectrum of disorders that cause unstable tear film with an irregular surface. Preexisting dry eye disease poses challenges during cataract surgery in chronic inflammation since preoperative biometry measurements are highly dependent on a smooth and healthy tear film. Following the recent approval by the Conselho Federal de Medicina, lens replacement procedures have become legal in Brazil and are indicated for patients over 55 years of age who have presbyopia with moderate or high hyperopia. As a result, patients have higher expectations for accurate refractive outcomes and excellent quality of vision after intraocular lens implantation. This review aims to provide ophthalmologists with decisive criteria for approaching and treating patients with dry eye disease at various stages of dysfunctional lens syndrome.

RESUMO

A doença do olho seco compreende um espectro de distúrbios que causam instabilidade do filme lacrimal com superfície irregular. A doença do olho seco preexistente apresenta desafios durante a cirurgia de catarata na inflamação crônica, uma vez que as medições biométricas pré-operatórias são altamente dependentes de uma superfície lacrimal regular e saudável. Após a recente aprovação pelo Conselho Federal de Medicina, os procedimentos de substituição de lentes tornaram-se legais no Brasil e são indicados para pacientes com mais de 55 anos que apresentam presbiopia com hipermetropia moderada ou alta. Como resultado, os pacientes têm melhores expectativas de resultados refrativos precisos e excelente qualidade de visão após o implante de lentes intraoculares. Esta revisão de literatura visa fornecer aos oftalmologistas critérios decisivos para abordagem e tratamento de pacientes com doença do olho seco em vários estágios da síndrome disfuncional do cristalino.

Received on:
Jul 12,2022

Accepted on:
Sept 19, 2022

Corresponding author:
Debora Fardim Mota
Instituto Oftalmológico Paulista
Alameda Casa Branca, 35 – Bela Vista
Zip code: 01310-100 – São Paulo, SP, Brazil
Email: debora.fardim@hotmail.com

Institution:
Instituto Oftalmológico Paulista
Alameda Casa Branca, 35 – Bela Vista
Zip code: 01310-100 – São Paulo, SP, Brazil

Conflict of interest:
Dr. Ambrósio Júnior and Dr. Waring IV are consultants for OCULUS, Wetzlar, Germany. The other authors declare no conflict of interest.

Financial support:
the authors received no financial support for this work.

INTRODUCTION

In 2017, the second Tear Film & Ocular Surface (TFOS) Dry Eye WorkShop (DEWS™) described dry eye disease (DED) as "a multifactorial disease of the ocular surface characterized by a loss of homeostasis of the tear film and accompanied by ocular symptoms."[1] Dry eye disease is classified as a group of illnesses that result in neurosensory abnormalities, tear film instability, and hyperosmolarity, which may contribute to chronic ocular surface dysfunction.[2] Preserving the proper functioning of the tear film poses a challenge during cataract surgery, especially in patients with preexisting DED. The tear film is also known to worsen following cataract surgery, leading to a higher rate of complications and compromised visual outcomes.[3-5] Several studies have shown that an unstable tear film can produce optical aberrations, which may reduce the accuracy and repeatability of these measurements.[6,7] One example is the changes in the corneal curvature and axial length – parameters that are essential for intraocular lens (IOL) power calculations.[8]

The dysfunctional lens syndrome (DLS) is characterized by progressive changes in the crystalline lens that impact the patient's accommodation and quality of vision. Due to its progressive or gradual nature, DLS is identified mainly through imaging methods and treated when early diagnosed. Recently, Haddad et al.[9] described the first and second stages of DLS as being characterized by loss of accommodation. A mild cataract is observed in the third stage, accompanied by loss of transparency of the lens, leading to a loss of visual quality. The fourth stage is characterized by a moderate decrease in contrast sensitivity and reduced visual acuity in the Snellen table (worse than 20/30). In the fifth and final stage, moderate cataract can be observed, with significant visual loss in the Snellen high-contrast acuity chart (vision equal to or worse than 20/50).

With the recognition of DLS and a recent approval by the Conselho Federal de Medicina (CFM), lens replacement procedures have been legalized in Brazil. Patients have higher expectations for accurate refractive outcomes and excellent quality of vision after IOL implantation. However, ocular biometry for IOL power calculations has become increasingly important to achieve preoperatively intended outcomes in clinical practice.[10]

In this literature review, we address the problems related to DED and its impact on the patients' visual quality, especially in conjunction with DLS. We discuss the diagnostic tools and terminology used to stage the disease and to assess DED. This review will provide ophthalmologists with decisive criteria to approach and treat patients with DED at various stages of DLS.

CONSIDERATIONS REGARDING THE MEASUREMENT OF THE OCULAR SURFACE AND CRYSTALLINE LENS

Topography and wavefront aberrometry

Several instruments have been developed to measure corneal surface data, including reflection-based, Scheimpflug-based, projection-based, slit-scanning-based, and Oct-based devices.[11] Intraocular lens can be calculated by simulated keratometry using a parameter that simulates the keratometry of the automated refractor. Corneal topographers rely on the reflection of thousands of points measured within 3-, 5-, and 7-mm zones, which provides significant data points to estimate corneal curvature.[12] Recently, topographers have developed and optimized functions that allow the analysis of the tear film; for example, the Placido disc projection technique (also known as the concentric ring method) can be used to evaluate the tear film.[13,14] In this technique, the anterior surface of the tear film reflects a target, and a camera collects the reflection for the analysis of the blink-free period.

Methods to qualify and quantify the ocular surface in DED have been incorporated in newer devices. Devices used to diagnose DED include the Antares topographer, LipiView interferometer, and the Keratograph 5M (OCULUS, Wetzlar, Germany).[13-15] Keratograph 5M topographer (a non-contact Placido ring-based corneal topographer) is equipped with an infrared illumination system for meibomian gland imaging. The device also incorporates fluoroscopy to measure noninvasive tear breakup time (NIT BUT). In addition, it provides the tear meniscus height along the lower lid margin and limbal redness evaluation.[15] Figure 1 shows a patient with moderate meibomian dysfunction. Figure 2 shows the infrared illumination system to capture the meibomian gland image in the same patient.

Apart from topography, wavefront aberrometry estimation is one of the most frequently used methods to evaluate the role of the tear film. Higher-order aberrations (HOAs) are refractive errors that are not corrected by sphere and cylinder corrections.[16] A wavefront sensor is a device that measures optical aberrations, such as coma and spherical aberrations (SA). The wavefront system scans the eye to obtain the layout of the aberration. Following this, the wave distortions are translated, and the individual acuity map of the patient is formed.[17] Total

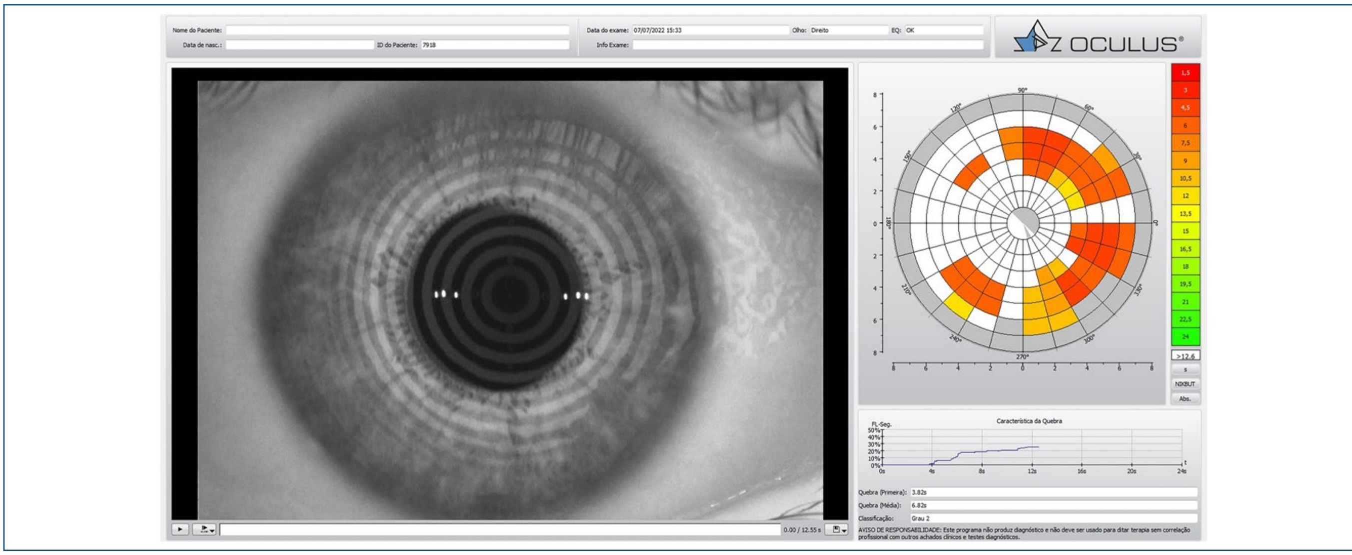

Figure 1. Testing with the OCULUS Keratograph 5M revealed a noninvasive tear film break-up time of 6.82 seconds. As a result, the patient was classified as a grade 2 in JENVIS Meibo Grading Scales.

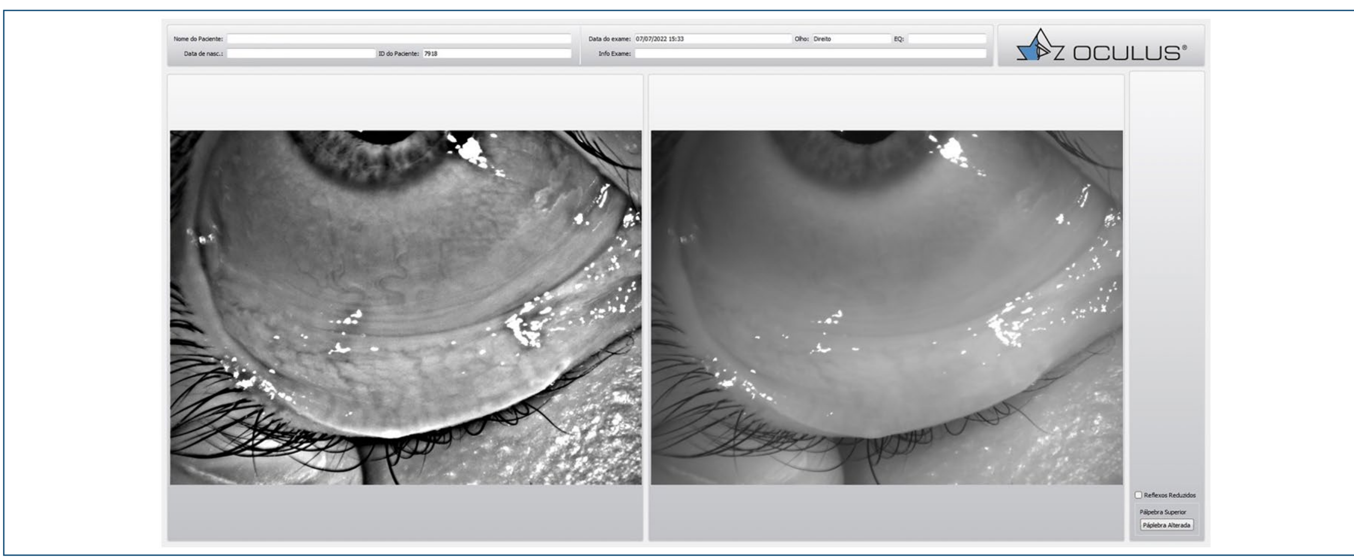

Figure 2. Meibography of the right lower lid reveals a grade of 2.0 and meibomian gland atrophy.

optical aberrations are most commonly measured by the Hartmann-Shack aberrometer[18] and ray racing aberrometer,[19] and corneal aberrations are typically measured based on topography.

Blinking is followed by a gradual increase in optical aberrations associated with the increasingly irregular tear film, which causes a progressive decline in the eye's optical quality.[7,20] In a prospective study, Montés-Micó et al.[20] reported that the optical quality of the human eye is dynamic and is affected by the tear film. Kasem et al.[21] showed a 1 to 5μm increase in peak central corneal thickness following treatment for DED. This was consistent with the findings of other studies that also reported a dramatic increase in peak central corneal thickness.[22]

Age-related HOA changes are one of the main reasons for presbyopia. In its relaxed state, the crystalline lens has a negative SA, which is counterbalanced by the positive value of the corneal surface.[23] This counterbalance is maintained until the age of 45, when the balance of aberration compensation seems to shift.[24] This shift is associated with increased ocular coma and a positive SA, which is attributed to the aging of the crystalline lens.[25] Untreated DED in combination with DLS increases the number of total ocular aberrations.

Objective scatter index and the point-spread function (PSF)

Aging and DED can lead to optical faults in the optical system, resulting in light dispersion. This phenomenon can be studied using two methods: forward scattering, which investigates light dispersed into the retina; and reverse scattering, which measures light scattered backward.[26] Double-pass retinal imaging (DPRI) can be used to analyze the point-spread function (PSF) directly from the retinal image[13,27] and can evaluate forward light scatter through the optical system. The objective scatter index (OSI) is another measure that quantifies forward light scatter as an objective value that can be monitored over time.[13,28] One way to objectively measure the OSI and quantify intraocular light scattering is by examining the double-pass (DP) wavefront (Optical Quality Analysis System, OQAS, HD Analyzer, Visiometrics, Terrasa, Spain). The DP system captures dynamic changes in the PSF over a period of 20 seconds and determines the mean OSI.[29] The impact of tear film instability on retinal image quality is functionally analyzed using changes in OSI values over time. In a prospective study, Gouvea et al.[30] divided the DED into three subgroups: the ladder pattern (a continuous increase of OSI over time), seesaw pattern (OSI fluctuation without improvement after blinking, and greater instability of the tear film and optical quality), and the plateau pattern (steady-state high OSI with minimal temporal changes). Figure 3 describes a patient with the seesaw pattern of DED.

Point-spread function and OSI are also valuable tools to evaluate and grade cataracts.[31] The HD Analyzer measures forward scatter by employing a DP technique as light passes through the ocular interfaces resulting from localized deviations of light and aberrations in light reflected from the retina.[32] The more significant the aberrations and intraocular scatter, the greater the spread of the PSF and the greater the OSI.

DISCUSSION

The first optical surface of the eye is not the corneal epithelium but the pre-corneal tear film. Tear fluid dynamics and tear volume can induce changes in HOAs, even in cases where the corneal shape is ideal. A smooth pre-corneal tear film yields more reliable and repeatable measurements than an irregular and highly dynamic tear film, such as the ones found in DED patients. Epitropoulos et al.[6] reported significantly more variability in average keratometry and anterior corneal astigmatism in hyperosmolar patients than in normal patients, with significant resulting differences in IOL power calculations.

As previously stated, HOA measurements are essential to evaluate the imaging quality of the ocular refractive system. In a parallel study, Montés-Micó et al.[33] showed that patients with DED exhibited faster degradation in the root mean square (RMS) aberration, with a minimum tear film aberration at 2.9±0.4 seconds after a blink. In contrast, healthy subjects had lower aberration values at

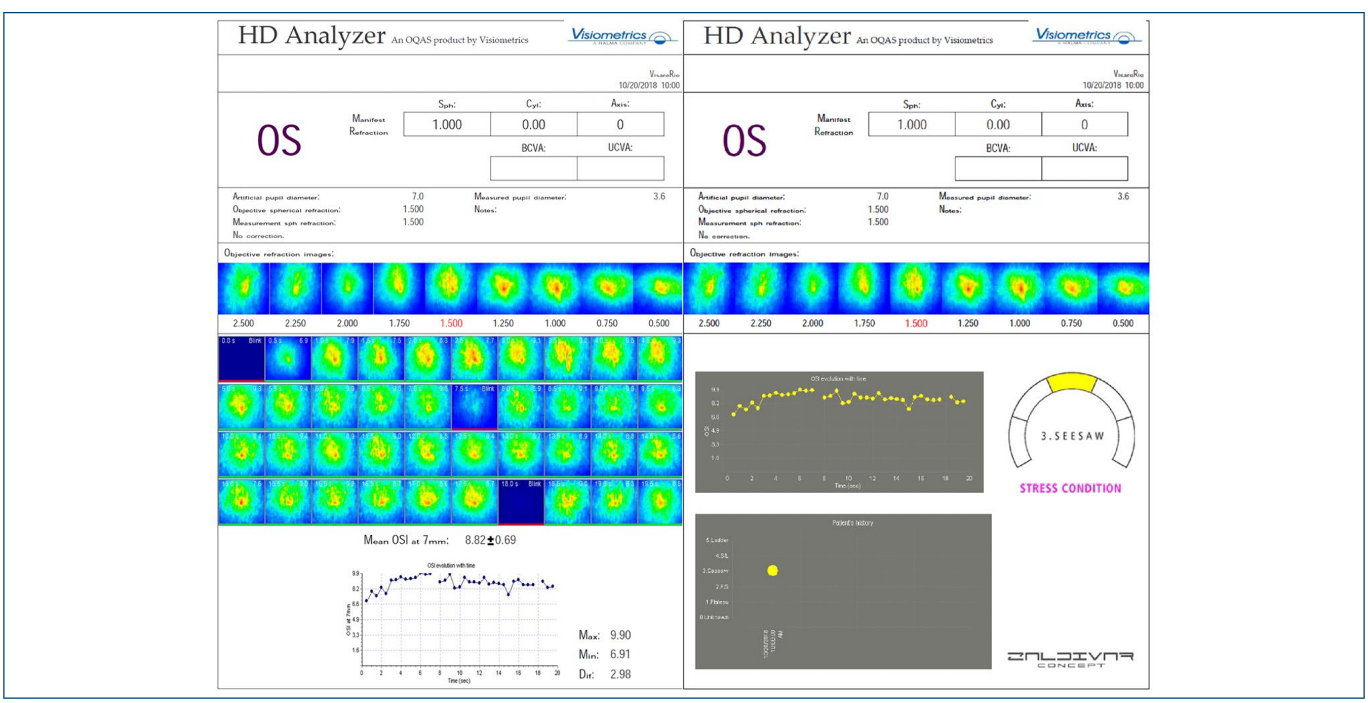

Figure 3. Dynamic changes of objective scatter index of an illustrative case in a dry eye patient showing a seesaw pattern repeatedly revealed fluctuation of objective scatter index.

a minimum of 6.1±0.5 seconds. Lu et al.[34] showed that a simple installation of eye drops before the examination was sufficient to reduce HOAs in the 3-and 5-mm zones. The optical aberration values of the eyes of patients with DED are 2.5X than those of patients with normal eyes, which are brought on by abnormalities in the tear film on the corneal surface.[35] However, DED does not affect the ocular biometry of axial length, and there is no significant difference in the repeatability of axial length measurements between DED and non-DED groups.[8]

When measured with a DP imaging system, irregularities in the air-tear film interface of the ocular surface caused ocular light to scatter, which deteriorates the quality of the retinal image.[36] The greater the aberrations and intraocular scatter, the greater the spread of the PSF and the greater the OSI. The DP imaging system can be an excellent tool to measure aberrations, not only from the ocular surface, but also from the crystalline lens. A dynamic study of the tear film may be crucial to preoperatively assess the ocular surface, even in asymptomatic patients. This can help optimize visual outcomes and improve surgical planning. When measuring the HOA of the crystalline lens, the DP imaging system shows good correlation between the OSI and the results of the clinical evaluation (such as those obtained using the Lens Opacities Classification System).[37,38]

Elevation-based topography generated by Scheimpflug-based devices (such as the Pentacam; OCULUS, Germany) has become the primary tool used in refractive surgery screening for DED and ectasia.[39] Scheimpflug imaging also allows ophthalmologists to grade lens densitometry and improve phacodynamics prediction.[40]

Refractive lens exchange is a reality in some countries. For example, in the USA, a patient must have 20/40 vision or worse and/or problems with their "activities of daily living" in order to qualify for cataract surgery. Following the recent approval by the CFM, lens replacement procedures have become legal in Brazil and are indicated for patients over 55 years old who have presbyopia with moderate or high hyperopia (>1.50D).

Regardless of the criteria by which some clinicians consider refractive lens exchange as a treatment for presbyopia, DED is an important factor to consider before performing cataract surgery. There are several ways to diagnose and treat DED. The TFOS DEWS II DED diagnostic battery was designed to identify the underlying cause of ocular discomfort so as to allow for more targeted treatment.[41] Before any refractive surgeries were performed, the American Society of Colon and Rectal Surgeons (ASCRS) Cornea Clinical Committee published a new consensus-based practical diagnostic ocular surface disease algorithm, which aids surgeons in diagnosing and treating visually significant ocular surface disease quickly.[42] Treating ocular surface disease is critical because it can lead to the following unfavorable outcomes: impaired vision, including refractive errors and induced HOAs; new or worsened ocular surface disease symptoms; and postoperative infections such as endophthalmitis.

CONCLUSIONS

The correct treatment and diagnosis of dry eye disease has been shown to improve biometry and disease symptoms. This underscores the importance of ocular surface disease preoperative screening, diagnosis, treatment, and management. Since preoperative biometry measurements are highly dependent on a smooth and healthy tear film, diagnosing and treating dry eye disease before cataract surgery can optimize the accuracy of biometry measurements. The concept of dysfunctional lens syndrome is now commonly recognized, and refractive lens exchange can be a definitive therapeutic solution for patients seeking visual improvement. As such, this review serves as a comprehensive reference for ophthalmologists to effectively treat patients with dry eye disease in conjunction with dysfunctional lens syndrome.

REFERENCES

1. Craig JP, Nichols KK, Akpek EK, Caffery B, Dua HS, Joo CK, et al. TFOS DEWS II definition and classification report. Ocul Surf. 2017;15(3):276-83.
2. Sangwan VS, Gupta S, Das S. Cataract surgery in ocular surface diseases: clinical challenges and outcomes. Curr Opin Ophthalmol. 2018;29(1):81-7.
3. Donthineni PR, Das AV, Shanbhag SS, Basu S. Cataract surgery in dry eye disease: visual outcomes and complications. Front Med (Lausanne). 2020;7:575834.
4. Ting DS, Ghosh S. Acute corneal perforation 1 week following uncomplicated cataract surgery: the implication of undiagnosed dry eye disease and topical NSAIDs. Ther Adv Ophthalmol. 2019;11:2515841419869508.
5. Ram J, Gupta A, Brar G, Kaushik S, Gupta A. Outcomes of phacoemulsification in patients with dry eye. J Cataract Refract Surg. 2002;28(8):1386-9.
6. Epitropoulos AT, Matossian C, Berdy GJ, Malhotra RP, Potvin R. Effect of tear osmolarity on repeatability of keratometry for cataract surgery planning. J Cataract Refract Surg. Aug 2015;41(8):1672-7.
7. Montés-Micó R. Role of the tear film in the optical quality of the human eye. J Cataract Refract Surg. 2007;33(9):1631-5.
8. Hiraoka T, Asano H, Ogami T, Nakano S, Okamoto Y, Yamada Y, et al. Influence of dry eye disease on the measurement repeatability of corneal curvature radius and axial length in patients with cataract. J Clin Med. 2022;11(3).
9. Haddad JS, Rocha KM, Waring GO, Faria-Correia F, Ambrosio R. Dysfunctional lens syndrome: a prospective review. Revista Brasileira de Oftalmologia. 2021;80(5).
10. Olsen T. Calculation of intraocular lens power: a review. Acta Ophthalmol Scand. 2007;85(5):472-85.

11. Rand RH, Howland HC, Applegate RA. Mathematical model of a Placido disk keratometer and its implications for recovery of corneal topography. Optom Vis Sci. 1997;74(11):926-30.
12. Taneja M. Commentary: Effect of dry eyes on the corneal diagnostic measurements. Indian J Ophthalmol. 2022;70(4):1157-8.
13. Herbaut A, Liang H, Denoyer A, Baudouin C, Labbé A. Tear film analysis and evaluation of optical quality: A review of the literature. J Fr Ophtalmol. 2019;42(2):e21-e35.
14. Lee JS, Jun I, Kim EK, Seo KY, Kim TI. Clinical accuracy of an advanced corneal topographer with tear-film analysis in functional and structural evaluation of dry eye disease. Semin Ophthalmol. 2020;35(2):134-40.
15. Tian L, Qu JH, Zhang XY, Sun XG. Repeatability and Reproducibility of Noninvasive Keratograph 5M Measurements in Patients with Dry Eye Disease. J Ophthalmol. 2016;2016:8013621.
16. Sabesan R, Yoon G. Visual performance after correcting higher order aberrations in keratoconic eyes. J Vis. 2009;9(5):1-10.
17. Roddier F, Roddier C. Wavefront reconstruction using iterative Fourier transforms. Appl Opt. 1991;30(11):1325-7.
18. Thibos LN. Principles of Hartmann-Shack aberrometry. J Refract Surg. 2000;16(5):S563-5.
19. Molebny VV, Panagopoulou SI, Molebny SV, Wakil YS, Pallikaris IG. Principles of ray tracing aberrometry. J Refract Surg. 2000;16(5):S572-5.
20. Montés-Micó R, Alió JL, Muñoz G, Pérez-Santonja JJ, Charman WN. Postblink changes in total and corneal ocular aberrations. Ophthalmology. 2004;111(4):758-67.
21. Kasem AM, Awara A, Shafik H, Shalaby O. Corneal topography and wavefront data changes in dry eye. Tanta Med J. 2021;49(1):31.
22. Meyer LM, Kronschläger M, Wegener AR. Scheimpflug photography detects alterations in corneal density and thickness in patients with dry eye disease. Ophthalmologe. 2014;111(10):914-9.
23. Smith G, Cox MJ, Calver R, Garner LF. The spherical aberration of the crystalline lens of the human eye. Vision Res. 2001;41(2):235-43.
24. Artal P, Berrio E, Guirao A, Piers P. Contribution of the cornea and internal surfaces to the change of ocular aberrations with age. J Opt Soc Am A Opt Image Sci Vis. 2002;19(1):137-43.
25. Alió JL, Schimchak P, Negri HP, Montés-Micó R. Crystalline lens optical dysfunction through aging. Ophthalmology. 2005;112(11):2022-9.
26. Garcin T, Grivet D, Thuret G, Gain P. Using Optical Quality Analysis System for predicting surgical parameters in age-related cataract patients. PLOS ONE. 2020;15(10):e0240350.
27. Koh S, Tung CI, Inoue Y, Jhanji V. Effects of tear film dynamics on quality of vision. Br J Ophthalmol. 2018;102(12):1615-20.
28. Hu AL, Qiao LY, Zhang Y, Cai XG, Li L, Wan XH. Reproducibility of optical quality parameters measured at objective and subjective best focuses in a double-pass system. Int J Ophthalmol. 2015;8(5):1043-50.
29. Yu AY, Lu T, Pan AP, Lin DR, Xu CC, Huang JH, et al. Assessment of tear film optical quality dynamics. Invest Ophthalmol Vis Sci. 2016;57(8):3821-7.
30. Gouvea L, Waring GO, Brundrett A, Crouse M, Rocha KM. Objective assessment of optical quality in dry eye disease using a double-pass imaging system. Clin Ophthalmol. 2019;13:1991-6.
31. Artal P, Benito A, Pérez GM, Alcón E, De Casas A, Pujol J, et al. An objective scatter index based on double-pass retinal images of a point source to classify cataracts. PlOS ONE. 2011;6(2):e16823.
32. Leonard AP, Gardner SD, Rocha KM, Zeldin ER, Tremblay DM, Waring GO. Double-pass retina point imaging for the evaluation of optical light scatter, retinal image quality, and staging of keratoconus. J Refract Surg. 2016;32(11):760-5.
33. Montés-Micó R, Alió JL, Charman WN. Dynamic changes in the tear film in dry eyes. Invest Ophthalmol Vis Sci. 2005;46(5):1615-9.
34. Lu N, Lin F, Huang Z, He Q, Han W. Changes of corneal wavefront aberrations in dry eye patients after treatment with artificial lubricant drops. J Ophthalmol. 2016;2016:1342056.
35. Montés-Micó R, Cáliz A, Alió JL. Wavefront analysis of higher order aberrations in dry eye patients. J Refract Surg. 2004;20(3):243-7.
36. Kobashi H, Kamiya K, Yanome K, Igarashi A, Shimizu K. Longitudinal assessment of optical quality and intraocular scattering using the double-pass instrument in normal eyes and eyes with short tear breakup time. PLOS ONE. 2013;8(12):e82427.
37. Vilaseca M, Romero MJ, Arjona M, Luque SO, Ondategui JC, Salvador A, et al. Grading nuclear, cortical and posterior subcapsular cataracts using an objective scatter index measured with a double-pass system. Br J Ophthalmol. 2012;96(9):1204-10.
38. Cabot F, Saad A, McAlinden C, Haddad NM, Grise-Dulac A, Gatinel D. Objective assessment of crystalline lens opacity level by measuring ocular light scattering with a double-pass system. Am J Ophthalmol. 2013;155(4):629-35.
39. Asena L, Altınörs DD, Cezairlioğlu Ş, Bölük SO. Effect of dry eye on Scheimpflug imaging of the cornea and elevation data. Can J Ophthalmol. 2017;52(3):313-7.
40. Faria-Correia F, Lopes BT, Ramos IC, Monteiro T, Franqueira N, Ambrósio R, Jr. Application of different Scheimpflug-based lens densitometry methods in phacodynamics prediction. Clin Ophthalmol. 2016;10:609-15.
41. Wolffsohn JS, Arita R, Chalmers R, Djalilian A, Dogru M, Dumbleton K, et al. TFOS DEWS II Diagnostic Methodology report. Ocul Surf. 2017;15(3):539-74.
42. Starr CE, Gupta PK, Farid M, Beckman KA, Chan CC, Yeu E, et al. An algorithm for the preoperative diagnosis and treatment of ocular surface disorders. J Cataract Refract Surg. 2019;45(5):669-84.