ARTICLE

New objective lens density quantification method using swept-source optical coherence tomography technology: Comparison with existing methods

Christophe Panthier, MD, MSc, Justine Burgos, OD, Helene Rouger, OD, Alain Saad, MD, Damien Gatinel, MD, PhD

Purpose: To assess a new objective cataract grading method based on lens densitometry on swept-source optical coherence tomography (SS-OCT) scans provided by the IOLMaster 700.

Settings: Rothschild Foundation, Paris, France.

Design: Prospective case series.

Methods: All patients consulting for cataract evaluation who provided their consent to participate in the study were included. A history of eye surgery, corneal or retinal disorders, and ocular dryness were exclusion criteria. The average lens densitometry was measured with SS-OCT scans using ImageJ software. The ocular scatter index (OSI) measured with a double-pass aberrometer (Optical Quality Analysis System), the Pentacam nucleus staging (hereafter referred to as nuclear staging) score, and mean nuclear staging were also measured and compared with the mean lens densitometry.

Results: One hundred ten eyes (51 with cataract and 59 controls) were included. The average lens densitometry measurements were repeatable ($P = .99$, analysis of variance). The repeatability limit was 2.50 pixel units. The average lens density was correlated with the OSI ($r^2 = 0.52$, $P < .01$), nuclear staging score ($r^2 = 0.75$, $P < .01$), and mean nuclear staging ($r^2 = 0.41$, $P < .01$). An average lens density greater than 82.9 pixel units was the cutoff threshold for cataract, with a sensitivity of 73.9% and a specificity of 91.2%.

Conclusions: The average lens density measured by SS-OCT was a repeatable and reliable objective cataract grading method. It was correlated with OSI measurement. If the average lens density was greater than 82.9 pixel units and the patient reported visual impairment, cataract surgery might be discussed.

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Cataract is the leading cause of blindness worldwide.[1] Quantitative measurements of lens density for assessing cataract might be required for documenting its progression and making a surgical decision. The main parameters used to define patient operability are subjective, such as the corrected distance visual acuity (CDVA) (usually a Snellen visual acuity worse than 0.3 logarithm of the minimum angle of resolution), difficulties in performing daily activities, and slitlamp examination to determine cataract density. Several clinical classifications are used to assess cataract density, including the Lens Opacification Classification System III (LOCS III).[2] Because of the limitations of these subjective methods, objective techniques have been developed to grade cataract severity and are especially interesting in early stages. Scheimpflug tomography (Pentacam, Oculus Optikgeräte GmbH) or double-pass aberrometry, using for example, the Optical Quality Analysis System (Visiometrics SL) device, have been shown to be repeatable and reliable objective methods to grade lens density.[3–10] In addition to optical biometry, the IOLMaster 700 intraocular lens (IOL) measuring device (Carl Zeiss Meditec AG) also provides swept-source optical coherence tomography (SS-OCT) imaging (B-scan) passing through the full thickness of the eye.

The aim of this study was to determine a new method for grading cataract severity using the average lens density measured on SS-OCT B-scans provided by the IOL measuring device and to compare it with previously validated objective measurements of lens opacity.

PATIENTS AND METHODS

Patient Selection

A prospective single-center cross-sectional study was performed at the Rothschild Foundation, Paris, France, between February and May 2016. The study was performed in accordance with the tenets of the Declaration of Helsinki, and written informed consent was

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From the Department of Ophthalmology (Panthier, Burgos, Rouger, Saad, Gatinel), Rothschild Foundation, and the Center of Expertise and Research in Optics for Clinicians (Saad, Gatinel), Paris, France; the Department of Ophthalmology (Saad), American University of Beirut, Beirut, Lebanon.

Corresponding author: Damien Gatinel, MD, Fondation Ophtalmologique Adolphe de Rothschild, 25 Rue Manin, 75019, Paris, France. E-mail: gatinel@gmail.com.

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obtained from all participants. This study was approved by the local ethics committee. Eligible patients were prospectively screened during cataract evaluation and refractive surgical evaluation visits, and those who gave their consent were consecutively included.

The population selected comprised patients diagnosed with cataract according to a slitlamp evaluation, loss of CDVA, presence of cataract symptoms (eg, glare, loss of vision), and LOCS III[2] assessed by the same surgeon (C.P.) (Table 1). Young patients with healthy eyes and a clear lens were included as normal controls. All patients were questioned using a standardized procedure and had a complete ocular examination, including CDVA, slitlamp biomicroscopy to rule out causes of ocular transparency loss other than cataract, and a dilated fundus examination. Patients with a corneal disorder (keratoconus, edema, dystrophy), retinal disorder, vision-threatening systemic disease (diabetes or uveitis), ocular dryness, or history of ocular surgery were excluded.

Cataract Grading

The type and grade of cataract were assessed by the same experienced ophthalmologist (C.P.) according to the LOCS III grading system.[2] All cataracts were classified and graded in 3 groups: cortical opacity, nuclear opacity, and posterior subcapsular opacity. The severity of each item was graded from 1 (early cataract) to 6 (mature cataract) for the nuclear opacity and from 1 to 5 for the cortical and posterior subcapsular opacities according to the LOCS III grading system. Control patients had a clear lens.

Swept-source OCT of the lens was performed using the IOLMaster 700, and the 2-dimensional (2-D) image of the anterior segment was recorded for further analysis. Ocular scatter index (OSI) measurements using double-pass aberrometry, and Pentacam nucleus staging (hereafter referred to as nuclear staging) measurement using Scheimpflug tomography were performed independently during the same visit by a trained optometrist (J.B.).

Table 1. Baseline characteristics in the 2 groups.

Parameter	Cataract Group (n = 51)	Control Group (n = 59)
Age (y)		
Mean ± SD	68.9 ± 7.6	27.05 ± 2.9
Range	57, 85	21, 50
Spherical refractive error (D)		
Mean ± SD	−0.36 ± 2.35	−1.52 ± 2.18
Range	+5.00, −7.25	+2.50, −6.50
Cylindrical refractive error (D)		
Mean ± SD	−1.04 ± 0.69	−0.21 ± 0.36
Range	−3.25, 0.00	−1.25, 0.00
CDVA (logMAR)		
Mean ± SD	0.3359 ± 0.1423	0.0025 ± 0.014
Range	0.00, 1.00	0.00, 0.04
LOCS III grade		
Cortical	C1: 16; C2: 19; C3: 3; C4:0; C5:0	C0: 59
Nuclear	N1: 19; N2: 15; N3: 6; N4: 6; N5: 5; N6:0	N0: 59
Posterior	P1: 32; P2: 9; P3: 4; P4: 5; P5: 1	P0: 59

CDVA = corrected distance visual acuity; LOCS III = Lens Opacification Classification System III; logMAR = logarithm of the minimum angle of resolution

Swept-Source Optical Coherence Tomography Measurements Using the Intraocular Lens Measuring Device

The IOLMaster 700 device provides S5-OCT with a scan depth of 44.0 mm and a resolution in tissue of 22 μm. Lens thickness measurements were highly reproducible (within ±12 μm). Six radial B-scans were acquired from the vertex to the fovea 3 times for each meridian. The device then provided the horizontal B-scan that was displayed on the report as a 0 to180 degrees B-scan (Figure 1). Finally, a standard rectangular area was defined to delineate the lens (Figure 2).

Quantitative Analysis of Swept-Source Optical Coherence Tomography B-Scans Using Image Software

Linear densitometry was performed on the 2-D image data of the ultrasound lens images obtained with the SS-OCT of the IOL measuring device. The SS-OCT B-scans of the lens were exported to open-source ImageJ software.[A] The images were analyzed according to the method previously described by Grewal et al.[7] The lens area was selected with a high-precision level using the magic stick tool, which delineated lens boundaries and defined the region of interest (ROI). Then, the images were contrast-reversed. The ROI density was measured in pixel intensity units on a scale amplitude of 0 to 255 (Figure 3). It was assumed that higher pixel intensities (ie, denser ROIs) were associated with higher cataract densities. This method was repeated 3 times for each studied eye. Finally, the mean average lens density was calculated.

Double-Pass Measurements

During measurement with the double-pass system, patients were asked to fixate on the light test pattern forming a point-source image on their retina.[3,4] The spherical refractive error was corrected internally by an optometer that ranged from 8.0 to 6.0 diopters, whereas astigmatism was corrected with an external cylindrical lens placed in front of the eye. Then, an infrared light beam was focused on the retina and the reflected light passed through the diameter of the exit pupil, which was set at 4.0 mm. Camera-recorded double-pass images were then processed and analyzed on a computer. The first acquisition was performed to measure the best objective sphere and pupil size, whereas the second acquisition measured the OSI to quantify intraocular scattering magnitude. Higher OSIs were associated with higher intraocular scatterings. The OSI values range from 0 (no scatter) to a maximum of 25 (highly scattered system).[3,4] An OSI of 1 or higher indicates the presence of cataract.[3]

Scheimpflug Measurements

The Pentacam uses a blue light–emitting diode to image the anterior segment. The device captures 25 000 elevation datapoints (corresponding to 500 datapoints per slit image) in 2 seconds using the 50-scan acquisition mode. The datapoints are processed to generate a 3-dimensional (3-D) representation of the anterior eye and provide an image of the whole lens. The built-in nuclear staging software automatically analyzes lens densitometry on a 0 to 100 scale (0 = no cloudiness; 100 = completely opaque lens) using individual images and provides the mean and maximum lens density with a cataract grading score from 0 to 5. A nuclear staging score higher than 1 and a mean nuclear staging percentage higher than 11.0% (range 8.8% to 14.3%)[9,10] are the thresholds used for diagnosing cataract.

Repeatability of Lens Density Measurement and Statistical Analysis

The repeatability of lens density measurement using Scheimpflug imaging, double-pass system light scatter, and SS-OCT was