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ORIGINAL ARTICLE

Straylight and Visual Quality on Early Nuclear and Posterior Subcapsular Cataracts

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ABSTRACT

Purpose: To measure log(*s*) and OSI parameters, both related to forward light scattering in the eye, in subjects with different kinds of early cataracts—nuclear or posterior subcapsular—and corrected visual acuity (CVA).

Methods: 34 eyes of 19 patients ranged between 50 and 75 years old with diagnosed nuclear (14 eyes) or posterior subcapsular cataract (20 eyes) were recruited. Only NO1, NO2, P1, and P2 opacity scores according to LOCS III were included. Observer examination included visual acuity, contrast threshold (Ct), and measurements performed by straylightmeter (straylight parameter log(*s*)) and double-pass instrument (objective scatter index (OSI)).

Results: OSI and log(*s*) were correlated with LOCSIII in nuclear opacities (p = 0.015 and 0.004, respectively) and in the whole data (p = 0.027 and 0.019, respectively) but did not for posterior subcapsular opacities alone. OSI was strongly correlated with log(*s*) in nuclear (r = 0.885 and $p < 0.001$) but not in posterior subcapsular cases (r = 0.382 and p = 0.097). Ct was correlated with log(*s*) for both cataract types (p = 0.043 for nuclear and p= 0.005 for posterior subcapsular cataract) but not with OSI (p = 0.093 for nuclear and p = 0.064 for posterior subcapsular cataract).

Conclusions: OSI and log(*s*) discriminate early stages of nuclear cataracts when taking LOCS III as reference, so these opacities could be graded by any of those parameters. LOCSIII does not represent the visual condition for posterior subcapsular cataract. Straylightmeter measurements express the loss in contrast sensitivity caused by nuclear and posterior subcapsular opacities. Studies of lens opacities must be separated according to the type of opacity present in eyes.

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Introduction

Vision is affected by cataracts in several ways. Patient complaints may include problems of blurred vision, color and contrast loss, halos around bright lights, difficulty with face recognition when they are dazzled, and poor night vision, among others. The nature of the effect varies with the morphological features of the opacity[1] and the density of opacities.

Although several works have found that increasing cataract severity is associated with a progressive decrease in both visual functions, contrast sensitivity (CS), and visual acuity (VA),[2,3] it has been reported that VA does not correlate with glare disability in patients with early cataracts when the three types of cataracts (nuclear, cortical, and posterior subcapsular) are evaluated.[4] Hence, a patient may have significant glare disability even with good VA.

Several approaches have been proposed to assess ocular scattering in lens with some opacity grade. Many of them use backward light scatter to evaluate the eye media. Some examples are the slitlamp, Scheimpflug slit-image photography,[5,6,7] lens opacity meter,[8,9,10] and the lens opacities classification system III (LOCS III).[11] Van den Berg made *in vitro* measurements of light scattering in human donor lenses showing that backward and forward scattering are governed by different processes.[12,13] This could explain the low correlations found between different measures of forward and backward scattering in patients with cataract, especially in posterior subcapsular and cortical opacities.[14]

On the other hand, some techniques have been developed for the estimation of forward scattering. C-Quant (Oculus Optikgeräte GmbH, Wetzlar-Dutenhofen, Germany) is a commercially available version of the straylightmeter developed by van den Berg. From this psychophysic method, the logarithm of the straylight parameter *s* (log(*s*)) is obtained, and it has been recommended for clinical use to assess the effect caused by ocular opacities.[15,16]

Besides, there are optical approaches for the estimation of forward scattering, which do not depend on subjective responses. They are based on double-pass (DP) technique and Hartmann-Shack (HS) wavefront sensor.[17,18] The OQAS II system (Visiometrics SL, Terrassa, Spain) is a commercially available device that uses the DP technique and provides the objective scattering index (OSI) for the estimation of intraocular forward scattering.

In this work, we measured log(*s*) and OSI parameters, both related to forward scattering, in groups with different kinds of cataract—nuclear and posterior subcapsular—and good corrected visual acuity (CVA) as in the case of early cataracts. Comparisons with routine clinical measurements such as CVA, LOCS III, and contrast threshold were made. While

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several works have been reported comparing these parameters in cataractous eyes,[2,3,19,20] the originality in this article is that OSI and log(s) give rise to novel relationships that were analyzed for the considered different cataract types.

Methods

This prospective study included the analysis of 34 eyes of 19 patients ranged between 50 and 75 years old with diagnosed nuclear (14 eyes) or posterior subcapsular opacities (20 eyes). Every patient was informed of the aim of the study, a written informed consent was obtained, following the tenets of the Declaration of Helsinki, and the study was also approved by the bioethics commission of the Universidad Nacional de Tucumán.

The study consisted of a first part for the selection of observers performed by ophthalmologists and a second part conducted in the laboratory for the experiment.

Clinical evaluation

Three expertise ophthalmologists performed the patient selection stage, regarding an inclusion protocol previously established. They registered personal subject data and relevant clinical data as autorefraction, CVA, and LOCS III gradation (nuclear opalescence score and posterior subcapsular cataract score) through slit lamp examination. Specifically, this work included those eyes with CVA higher than or equal to 0.6 and with lens opacities graded either as nuclear or as posterior subcapsular. In order to analyze incipient cataracts with preserved visual acuity, only two consecutive levels of LOCS III were included both in nuclear (NO1 and NO2) and in posterior subcapsular cataract (P1 and P2). Patients with ocular diseases other than cataract and who had underwent ocular surgery were not included in the study.

Laboratory measurements

The second stage of the work was held at the visual optics laboratory of the Universidad Nacional de Tucumán (Argentina). The following three systems were employed for this work:

OQAS II system

The DP technique used by OQAS relies on the register of a retinal image after a double pass through the ocular media and retinal reflection of a point source[21] (laser diode of 780 nm). From the DP image, OQAS gives different parameters linked to the optical quality of the eye and one of them is the OSI previously mentioned. This is defined as the ratio between the integrated light in the periphery and the central peak of the DP image.[22] Although some drawbacks have been reported,[23] especially when near infrared light is used,[24] it has proved to be suitable for the estimation of scattering in those cases in which the amount of scattering is relatively high, such as in cataract patients.[22,25]

We performed five measurements of OSI in each eye, and the average was computed for the posterior analysis. Spherical errors were corrected automatically by the system, while astigmatism was corrected with cylindrical trial lenses. Measurements were carried out by setting the exit pupil at 4 mm. OQAS does not provide curves of typical values of OSI according to age, but we used published data in the posterior analysis.[26,27]

C-Quant system

Initially, the straylightmeter employed a direct compensation method[28] based on the principle of equivalent luminance (the luminance field having the same visual effect as the glare source at some angular distance) caused by a flickering glare source that the subject matches to the adjustable luminance of a test object that is flickering in counter-phase. Subsequently, the compensation comparison (CC) method was proposed[15] as a more reliable procedure specifically designed for the quantification of intraocular light scattering. The result of this method is the straylight parameter, $s(\theta)$, which is defined by the scattered angle θ and the point spread function (PSF) of the eye ($s(\theta) = \theta^2 \times \mathrm{PSF}(\theta)$).

The logarithm of the straylight parameter (log(s)) was measured five times in each eye and the average of the values obtained were used for the analysis. Spherical equivalent refraction were used in all measurements. C-Quant includes curves of typical values of log(s) regarding the age.

FVC-100 system

A relevant measurement of functional vision is contrast sensitivity whose reciprocal is contrast threshold (Ct). In this work, Ct was measured with a computerized system (FVC-100, Tecnovinc, Argentina),[29] using sinusoidal gratings of two cycles per degree (c.p.d.), considering that in cataract clinical trials the low spatial frequencies are the most informative.[30] The task for the observer is to answer whether the sinusoidal grating that is displayed in a screen is tilted to the right or to the left in a two alternative forced-choice configuration (2AFC). The system automatically computes the contrast of the next target according to responses of the subject.

Five measurements were also conducted with this system, and the average was obtained for the analysis. Both spherical and cylindrical refractive errors were fully corrected with trial lenses.

Data analysis

Before starting measurements, we studied sample sizes needed to reach significant results. A sample size of 20 eyes for posterior subcapsular cataract group (PSC) and 14 eyes for nuclear cataract group (N), with five observations per eye, achieved 80% power to detect correlations between the different parameters measured in this work (Pearson correlation test with a significance level of 0.05). Because in only two correlation analyses (OSI versus LOCSIII and log(s) versus LOCSIII, both for SCP), the computed sample sizes resulted too big (approximately 100 eyes), it was considered that useful conclusions can be obtained with a smaller sample size. Sample size calculation was performed through an application available in the website of Clinical and Translational Sciences Institute of the University of California, San Francisco.[31,32]

Descriptive and inferential data analyses were performed using Minitab Statistical Software® 16.1.0 (Minitab Inc., State

College, PA). Data were shown as mean ± standard deviation (SD). The relationship between variables, including OSI, log(*s*), LOCS III grading score, CVA, and Ct, was analyzed by the Pearson correlation test. Independent sample *t*-test was used for comparing means between different groups. $p < 0.05$ was considered to be statistically significant.

Results

From the collected data, we computed the statistical parameters such as sample size *n* and mean values of age, CVA, OSI, log(*s*), and Ct for NO1, NO2, P1, and P2 groups, shown in Table 1.

Statistically significant differences were found in the CVA when eyes with nuclear and posterior subcapsular cataracts were compared ($p = 0.043$), possibly due to decreased visual acuity in the NO2 group (Table 1). The comparison of the mean log(*s*) reported no statistically significant differences between eyes with different cataract types ($p>0.05$) while in the case of mean OSI statistically significant differences were found ($p = 0.003$). No statistically significant differences were found in the Ct when different cataracts types were compared ($p = 0.342$).

The results of the Pearson correlation test are shown in Tables 2–4 summarizing the value of the *r* coefficient and the statistical significance *p*-values between the different parameters measured considering all data, nuclear, and posterior subcapsular, respectively. Some important considerations can be extracted from these tables:

When analyzing the correlation between both scattering parameters (OSI and log(*s*)) and the standard for cataract grading (LOCS III), it can be seen that the whole data (N+P) was statistically significant both for OSI versus LOCS III as for log(*s*) versus LOCS III. However, there are clear differences in the behavior for nuclear opacities compared with posterior subcapsular ones. Correlations for nuclear opacities were found to be statistically significant in both cases (OSI versus LOCS III and log(*s*) versus LOCS III), whereas there were no statistical evidence to correlate OSI and log(*s*) versus LOCS III in posterior subcapsular cases.

The relationship between OSI and log(*s*) appear to be strong in nuclear opacities resulting in high Pearson correlation coefficient ($r = 0.885$), as shown in Figure 1 (left). On the other hand, results for posterior subcapsular cataracts differ far from nuclear ones, which can be seen in Figure 1 (right) where posterior subcapsular cataracts appear to behave differently to nuclear cataracts. It is not only a weak correlation ($r = 0.382$) between them, but also there is not a statistical level of significance for that correlation. Again, all the data together were statistically significant, although showing a decreasing in Pearson correlation coefficient respect to the obtained for nuclear cataract data.

Table 2. Pearson correlation coefficients and their corresponding *p*-values for the whole data (N + P).

	r (*p*-value)			
	OSI	log(*s*)	CVA	LOCS III
log(*s*)	0.629* (<0.001)			
CVA	−0.636* (<0.001)	−0.464* (0.005)		
LOCS III	0.378* (0.027)	0.401* (0.019)	−0.373* (0.030)	
Ct	0.258 (0.141)	0.500* (0.003)	−0.313 (0.072)	0.403* (0.018)

*Correlation is significant at the 0.05 level.

Table 3. Pearson correlation coefficients and their corresponding *p*-values for the nuclear cataract data.

	r (*p*-value)			
	OSI	log(*s*)	CVA	LOCS III
log(*s*)	0.885* (<0.001)			
CVA	−0.337 (0.239)	−0.551* (0.041)		
LOCS III	0.632* (0.015)	0.721* (0.004)	−0.749* (0.002)	
Ct	0.466 (0.093)	0.548* (0.043)	−0.528 (0.053)	0.574* (0.032)

*Correlation is significant at the 0.05 level.

Table 4. Pearson correlation coefficients and their corresponding *p*-values for the posterior subcapsular cataract data.

	r (*p*-value)			
	OSI	log(*s*)	CVA	LOCS III
log(*s*)	0.382 (0.097)			
CVA	−0.886* (<0.001)	−0.308 (0.186)		
LOCS III	0.152 (0.523)	0.223 (0.345)	−0.015 (0.949)	
Ct	0.422 (0.064)	0.606* (0.005)	−0.341 (0.141)	0.341 (0.141)

*Correlation is significant at the 0.05 level.

It is also interesting to compare the results from visual functions with parameters associated to scattering. Regarding CVA, the most classical visual function in clinical practice, it was significantly related to LOCS III and log(*s*) but not with OSI and Ct for nuclear opacities. The only one correlation with CVA encountered for posterior subcapsular opacities was that of CVA versus OSI. The analysis between Ct and LOCS III kept the trend marked in the previous items in which correlations for nuclear cases were encountered but not for posterior subcapsular ones. However, statistical significance was found when relating Ct with log(*s*) both for nuclear and for posterior subcapsular opacities (Figure 2), evidencing that the greater the straylight toward the retina, the greater the difficulty to detect low contrast tests of low-to-intermediate spatial frequencies. Contrarily, there were no significant correlation between Ct and OSI, neither for nuclear opacities nor for subcapsular ones. Considering nuclear and posterior subcapsular cataract data together led to similar results to that of nuclear ones.

There were found important differences between nuclear and posterior subcapsular cataract when analyzing the correlation between log(*s*) and OSI (Figure 1), and there are other

Table 1. Mean and SD values of age, CVA, Ct, log(*s*), and OSI of groups: NO1, NO2, P1, P2.

	Age	CVA	Ct	log(*s*)	OSI
NO1 (*n* = 8)	70.0 ± 2.3	0.89 ± 0.08	0.006 ± 0.001	1.20 ± 0.14	1.49 ± 0.51
NO2 (*n* = 6)	68.3 ± 4.7	0.68 ± 0.15	0.010 ± 0.005	1.49 ± 0.14	2.82 ± 1.21
P1 (*n* = 13)	56.7 ± 5.5	0.93 ± 0.08	0.009 ± 0.005	1.13 ± 0.30	0.89 ± 0.60
P2 (*n* = 7)	55.3 ± 4.6	0.94 ± 0.15	0.015 ± 0.006	1.25 ± 0.15	1.09 ± 0.83

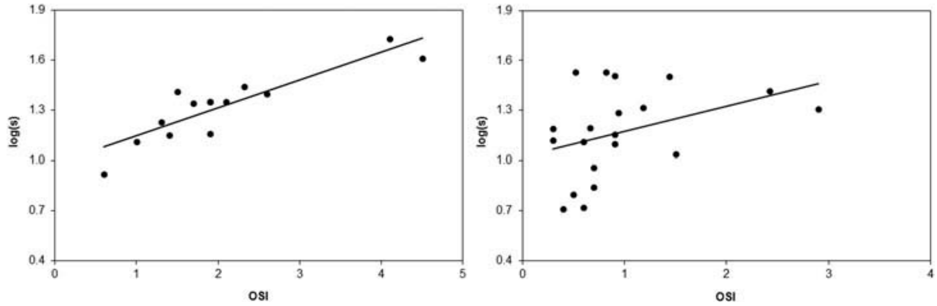

Figure 1. Correlations between log(s) and OSI for both groups assessed. (Left) log(s) correlated with OSI (r = 0.885, p < 0.001) for N cataracts; (right) log(s) did not correlate with OSI (r = 0.382, p = 0.097) for PSC cataracts.

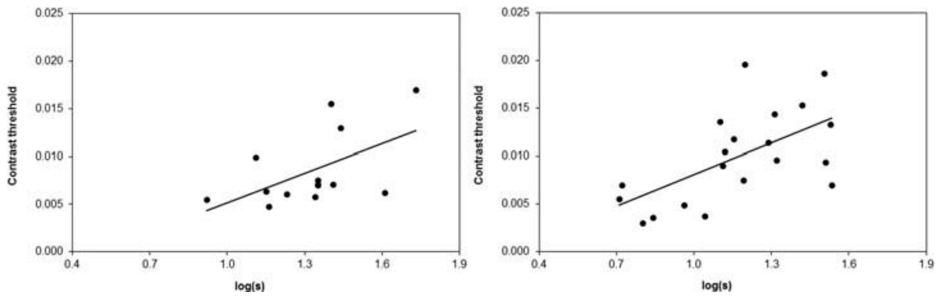

Figure 2. Correlations between contrast threshold and log(s) for both groups assessed. (Left) Contrast threshold correlated with log(s) (r = 0.548, p = 0.0430) for N cataracts; (right) Contrast threshold correlated with log(s) (r = 0.606, p = 0.005) for PSC cataracts.

differences that can be seen when presenting the datasets of OSI and log(s) with the normal values of both parameters as a function of age (Figures 3 and 4). It can be seen that all OSI and log(s) values for NO1 group are inside the region of typical values respect to age, and while some values of NO2 overlap into the normal region most of them overcome the limits of this region. Both OSI and log(s) values of NO2 group were statistically greater than values from NO1 group (p = 0.022 and p = 0.002, respectively). The distribution of dataset for posterior subcapsular cataracts is quite different. OSI values of both groups (P1 and P2) are distributed inside as well as outside the normal region (Figure 3), and log(s) behave in the same way (Figure 4). For the case of PSC cataracts, there were no statistical significance between both LOCS III classified groups, for OSI (p = 0.285) and for log(s) (p = 0.128).

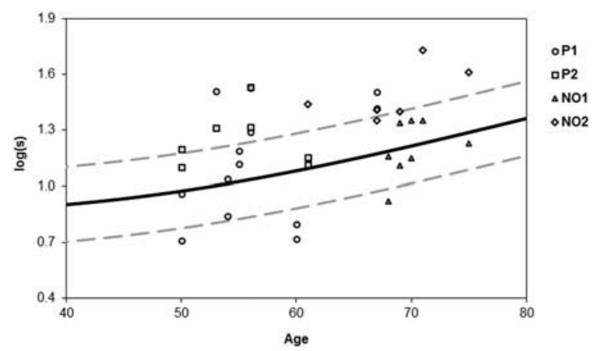

Figure 4. Log(s) values as a function of age for observers with nuclear opacities (NO1 and NO2) and posterior subcapsular opacities (P1 and P2). Typical log(s) values according to age are determined by the area between both dashed lines. Continuous line represents the age-normal curve.

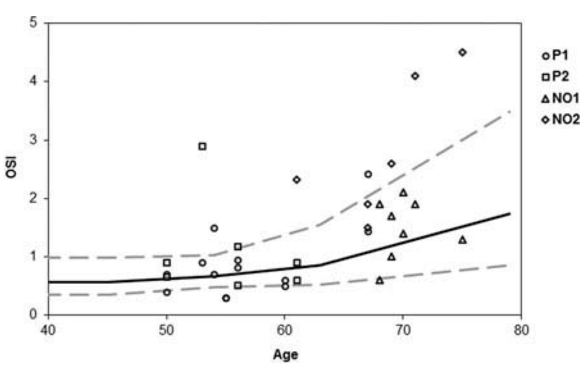

Figure 3. OSI values as a function of age for observers with nuclear opacities (NO1 and NO2) and posterior subcapsular opacities (P1 and P2). Typical OSI values according to age are determined by the area between both dashed lines. Continuous line represents the age-normal curve.

Discussion

In this study, we performed a set of measurements (CVA, Ct, log(s), and OSI) on eyes with early age-related cataracts classified using LOCS III nuclear opalescence score (NO1 and NO2) and LOCS III posterior subcapsular cataract score (P1 and P2). The most important results from this work are the differences found between the two types of cataracts when analyzing Tables 2–4.

Regarding these early stages for nuclear cataract, our results showed that LOCS III nuclear opalescence score is associated with CVA, in agreement with results for nuclear cataract of Vilaseca, Maraini, and Pan.[25,33,34] OSI and log(s)

discriminated NO1 from NO2 regarding LOCS III as reference. Vilaseca et al.[25] also found statistical significance to discriminate groups with different LOCS III in terms of OSI, while de Waard[14] and coworkers concluded that straylight measurements may separate between grades of opacities that had been scaled with a different backscattered-based opacities grading device. A recently published work has found a modest but significant correlation between OSI and log(*s*) in healthy subjects,[35] and in this work a strong correlation (r = 0.885) was found between those parameters in nuclear cataracts. Previous works reported non-linear correlation between OSI and CVA[25] as well as linear correlation between both parameters[34,36,37] when nuclear cataracts were taken into account, while we did not find any correlation. All these works considered a wide range of LOCS III (from NO1 to NO5) and CVA (from 0.1 to 1), while in the present study we excluded patients with CVA worse than 0.6. Therefore, differences with previous studies might be explained by the narrow range allowed for this visual function.

Correlations in posterior subcapsular cataract were very different as compared with nuclear ones. More important findings were that even though LOCS III is a good way of grading posterior subcapsular opacities,[38] it does not represent the loss of visual functions in observers, since no correlations were found with the other parameters measured, neither with psychophysical parameters (CVA, log(*s*), and Ct) nor with physical ones (OSI). Previous studies[14,39–41] have already shown the major variability in grading PSC through backscattered light compared with N. Two parameters associated with intraocular light scattering (OSI and log(*s*)) were not correlated with each other when the group of PSC cataracts was evaluated. This may be due to the fact of working with early cataract, where the distribution of the opacities (nuclear cataracts are optically more regular than posterior subcapsular ones) might generate different results when measuring forward scatter with either straylightmeter or double-pass instrument, considering that OSI measures scattering for small angles while log(*s*) measures for large angles. These first conclusions about PSC cataracts could be better assessed using a bigger sample size so that the power of the test is increased and it allows to detect lower magnitude correlations. On the other hand, log(*s*) and Ct correlated significantly, meaning that the bigger the log(*s*) value the more significant the loss in contrast sensitivity. Both measurements of scattering were correlated with one from two visual functions: log(*s*) was correlated with Ct and OSI was correlated with CVA.

It is important to note that correlations that are significant in one group (either N or PSC) but not in the other are significant in the whole data. As opacities from N and PSC groups are different morphologically, it can not be argued that statistically significant correlations from the whole data are reliable because they rather express a result that may be determined by only one of both groups.

In Figures 3 and 4, it can be seen that NO1 cataracts are generally normal both for OQAS and for C-Quant, while NO2 cataracts are mostly outside the normal area. Regarding nuclear cataracts, correlations encountered between almost all parameters suggest that they could be graded either by any of these parameters, but a study considering a higher sample size (including NO3 to NO5 grades) should confirm this.

None of the conclusions obtained from the analysis of the nuclear cataracts group can be extended for the posterior subcapsular opacities group. Values from P1 and P2 fell both inside the typical log(*s*) area and outside it. OSI data for this type of cataract showed a similar behavior. It has been found that LOCS III is useful in determining opacity development, either for clinical practice or for surgeries by establishing phacoemulsification times and power[42–45] and even in the study of the prevalence of cataract in populations,[46] but it would be reasonable to evaluate continuously this method, especially in posterior subcapsular opacities as our results suggest.

An important finding of this study is that the data provided by new technologies to assess cataracts, as well as those obtained from traditional studies, should be analyzed considering the different types of cataracts. While in the case of nuclear cataracts there is an agreement between results of most tests under review, in the case of posterior subcapsular cataracts an in-depth analysis of all the information that is available about the opacity is necessary, especially that related to visual discomfort afflicting the patient and that related to forward scattering measures.

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Declaration of interests

Issolio and Colombo have a licensed patent and a pending patent regarding contrast sensitivity measurement system FVC-100 used in this work. Paz Filgueira and Sánchez have no conflict of interest with the companies of instruments used in this study. The authors alone are responsible for the content and writing of the article.

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