Correlational Analysis of Objective and Subjective Measures of Cataract Quantification

Béatrice Cochenet, MD, PhD; Sunni R. Patel, PhD; Florence Galliot, MD, PhD

ABSTRACT

PURPOSE: To evaluate whether correlations exist between objective and subjective measures of vision quality as a consequence of cataract and whether this may qualify the Objective Scatter Index as a supplementary means of cataract assessment.

METHODS: A prospective multicenter, cross-sectional study was conducted in 10 centers across France in patients undergoing cataract extraction surgery (lens opacity evaluated with the Lens Opacities Classification System III). A quality of life assessment using the Visual Function Index-14 (VF-14) (14 questions scored from 0 to 4) and measurement of visual acuity and evaluation of the Objective Scatter Index (HD Analyzer, Visiometrics SL, Terrassa, Spain) to assess the alteration of light scatter were used as measures in the study.

RESULTS: The study included 1,768 eyes of 1,768 patients (mean age: 72.5 years; range: 28 to 93 years). The average OSI score was 4.97 ± 3.13 (range: 0.4 to 20.5). There was good correlation between visual acuity and OSI ($r = -0.47, P < .001$) and between OSI and VF-14 ($r = -0.11, P < .001$).

CONCLUSIONS: The results presented in this study confirm that the Objective Scatter Index has sufficient correlations with visual acuity and VF-14 to supplement existing cataract diagnosis in a large population encompassing a broad spectrum of cataract presentations.


Visual acuity has long been regarded as the sole determinant for evaluating the visual function of patients presenting with cataracts. The loss of lenticular transparency primarily generates a loss of quality of vision that involves symptoms of varying severity, including haze, loss of contrast sensitivity, and glare. These are a result of light scattering and can be present with a little or no loss in measured visual acuity. Current cataract assessment is limited to the quantification of visual acuity and lifestyle impact.

The Visual Function Index-14 (VF-14) is a standardized and validated questionnaire that assesses the impairment of daily life functioning in patients with cataract. The quantitative study of light scattering through the ocular media has been in use since the advent of refractive surgery and is of particular interest for obtaining optimal quality of vision. It allows the functional assessment of visual impairment when visual acuity is retained, especially in cases of early cataracts. Excess light diffusion causes significant glare, thus affecting the daily life of the patient, such as driving and reading. The Objective Scatter Index (OSI) is based on the principle of “double-pass” aberrometry and quantifies this phenomenon. The double-pass technique has been reported as being useful to examine forward-scattered light, which causes degradation of retinal images in eyes with cataract.

Our previous work also investigated the associations and in particular the sensitivity and specificity of OSI alongside visual acuity and the VF-14 in the same sample of eyes, the results of which suggested that the OSI had excellent sensitivity and thus detection of cataract when compared to visual acuity and VF-14. Therefore, further analysis using a multicenter study was conducted to assess the value of integrating the concept of quality of vision in the definition and detection of cataract and to
identify correlations between existing measures such as visual acuity and quality of life with OSI.

**PATIENTS AND METHODS**

This was a prospective, multicenter (10-center) study, conducted from November 2011 to March 2014 on 1,768 patients. The study adhered to the tenets of the Declaration of Helsinki. Informed consent was obtained from all participants. The study was approved by the local institutional review board.

The inclusion criterion was any patient who was a candidate for cataract surgery (first eye). Exclusion criteria included any cause for alteration of light scattering through the ocular media such as a defect of the ocular surface (corneal opacity, corneal dystrophy, or tear breakup time [TBUT] < 10 sec), intraocular pressure greater than 20 mm Hg, optic nerve pathology (uncontrolled high intraocular pressure or optic neuropathy and progressive glaucoma), retinal pathology (age-related macular degeneration, retinal detachment, or macular dystrophy) or intraocular inflammation (uveitis or vitreous haze).

Each patient underwent a comprehensive collection of data comprising the patient’s identity, date of birth, and ophthalmologic history. Examinations included a measure of uncorrected visual acuity and corrected distance visual acuity. A slit-lamp examination was conducted to evaluate corneal transparency, ocular status, and intraocular pressure. Fluorescein tear film TBUT test was also performed to detect any disorder of the ocular surface (TBUT < 10 sec).

**LENSES CLASSIFICATION SYSTEM (LOCS) III**

A dilated fundus examination was conducted by a certified operator in all patients to eliminate any retinal and vitreous pathology. Dilated assessment to accurately grade lenticular opacity according to the International LOCS IIIb was performed by the same two technicians certified for LOCS III grading.

Each cataract was classified as cortical cataract, nuclear cataract (NO+NC), or posterior cataract, and quantified by an index of 0 to 12 for nuclear cataracts (NO: 0 to 6; NC: 0 to 6) and from 0 to 6 for posterior and cortical cataracts (0 = no cataract; 6 = white cataract). The scores for cortical cataract, nuclear cataract, and posterior cataract were added to calculate the total LOCS III score. This system is based on a comparison between reference images representing different types of cataract.

**VF-14**

All participants completed the VF-14 questionnaire. In this study, a modified VF-14 was used to assess functional impairment in patients with cataract as amended by the members of the Society of the French Association of Implants and Refractive Surgery to match the habits of the French population. The VF-14 is a validated questionnaire that assesses the impairment of daily life functioning of patients and usual tasks (driving, watching television, completing paperwork, and playing golf and cards). It explores and assesses the difficulty in achieving 18 tasks from daily living (from simple discomfort to inability to perform the task). Each question is scored from 4 (no impact) to 0 (task cannot be performed). The total score is 100: a score below 84 is considered pathological. The participant rates his or her impairment. This questionnaire has also been used to quantify the functional impairment before corneal transplantation, in patients with age-related macular degeneration, and to assess the quality of vision in refractive surgery (before and after surgery).

**OSI**

The same two medical investigators examined 1,090 patients using the HD Analyzer (Visiometrics SL, Tarassa, Spain) to study light diffusion through the ocular media. The HD Analyzer is a double-pass ophthalmoscopic system that is able to measure the combined effect of higher order aberrations and the loss of ocular transparency by determining the quality of the retinal image. This system is based on the principle of so-called “double-pass” aberrometry. It uses a particularly sensitive sensor to directly analyze the image of the retinal reflection of a monochromatic 4-μm infrared beam (780-nm laser diode) transmitted through the ocular media, reflected on the fovea and then back through (double pass). It calculates the spatial distortion of the light spot projected crossing the ocular media. This beam can be projected in various vergences to perform a series of measurements corresponding to the image of a spot located at different distances. The system deduces the level of eye diffusion as the OSI and predicts the related contrast sensitivity (as modulation transfer function) and the theoretical maximum visual acuity for objects with 100%, 50%, and 9% contrast. The point spread function is the representation of the image projected on the retina from the point light source and is obtained from the average of six individual measurements.

A computer was used to collect the data. This examination, which is reproducible, objectively quantifies impaired ocular media transparency using the OSI. The resulting figure is proportional to the light diffusion rates. Normal values are less than 0.5 for a young person with healthy eyes, between 1.45 and 4 for an early-stage cataract, and greater than 4 for mature cataract. The OSI score may be abnormally increased in case of refractive errors (sphere or cylinder). Measure-
ments were performed with the best spherocylindrical correction to avoid such anomalies.

**Statistical Analyses**

SPSS software (version 2014; SPSS, Inc., Chicago, IL) was used for data analysis. Data were analyzed to determine the mean, standard deviation, and standard error of the various parameters cited above. Spearman rank correlation test was adopted for studying correlations and the level of statistical significance was set at a $P$ value of less than .05.

**RESULTS**

The mean age of patients was $72.5 \pm 18.2$ years (range: 28 to 93 years). The baseline data for the study sample are presented in **Table 1**.

**Table 1**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of eyes</td>
<td>1,768</td>
</tr>
<tr>
<td>Age, y</td>
<td>$72.5 \pm 18.2$ (28 to 93)</td>
</tr>
<tr>
<td>Visual acuity</td>
<td>$0.498 \pm 0.23$ (0 to 1)</td>
</tr>
<tr>
<td>LOCS III posterior</td>
<td>$3.07 \pm 1.46$ (0 to 5)</td>
</tr>
<tr>
<td>LOCS III nuclear</td>
<td>$6.63 \pm 3.04$ (0 to 12)</td>
</tr>
<tr>
<td>LOCS III cortical</td>
<td>$3.00 \pm 1.46$ (0 to 5)</td>
</tr>
<tr>
<td>Average OSI</td>
<td>$4.97 \pm 3.13$ (0.4 to 20.5)</td>
</tr>
<tr>
<td>Average VF-14 score</td>
<td>$75.01 \pm 18.21$ (0 to 100)</td>
</tr>
</tbody>
</table>

$SD = $ standard deviation; $LOCS = $ Lens Opacities Classification System; $OSI = $ Objective Scatter Index; $VF-14 = $ Visual Function Index-14

The mean OSI score was $5.57 \pm 2.8$ (range: 0.5 to 15.4) for cortical cataracts, $4.9 \pm 2.8$ (range: 0.6 to 17) for nuclear cataracts, and $6.5 \pm 3.9$ (range: 1.6 to 20.4) for posterior subcapsular cataracts. Using the LOCS III classification, the mean OSI score was $3.7 \pm 2.97$ (range: 0.4 to 16.2) for early-stage cataract (LOCS III 0 to 3), $4.8 \pm 2.99$ (range: 0.6 to 20.4) for mild cataracts (LOCS III 4 to 7), $6.25 \pm 2.85$ (range: 1.2 to 16) for moderate cataracts (LOCS III 8 to 12), and 10.2 (one case) for white cataracts (LOCS III 13 to 22) (**Figure 1**). The mean OSI scores for visual acuity were $6 \pm 3.22$ (range: 0.7 to 20.5) for 0.5 or worse, $3.5 \pm 2.32$ (range: 0 to 17.5) for better than 0.5, and $3.1 \pm 2.34$ (range: 0 to 17.5) for 0.7 or worse (**Figure 2**).

The mean VF-14 score was $78.7 \pm 16.34$ (range: 1.78 to 100) for early-stage cataract, $77 \pm 16.17$ (range: 0 to 100) for mild cataract, $75.5 \pm 17.78$ (range: 5.35 to 100) for moderate cataract, and $60.5 \pm 22.15$ (range: 92 to 100) for white cataract (**Figure 3**). The mean VF-14 score for visual acuity was $72.7 \pm 19.4$ (range: 0 to 100) for 0.5 or worse, $79 \pm 15.2$ (range: 17.85 to 100) for better than 0.5, and $80.9 \pm 13.7$ (range: 21.42 to 100) for 0.7 or worse (**Figure 4**).

**Correlations**

The Spearman rank test was used to test for correlations between all variables of the study (ie, visual acuity, cataract stage, OSI score, and VF-14 score) to demonstrate that the more severe the cataract, the higher the level of light scattering and impairment.

An average negative correlation was found between OSI score and visual acuity (**Figure A**, available in the online version of this article; $r = -0.467$, $P < .001$). A negative correlation was also observed between OSI...
and VF-14 scores (Figure B, available in the online version of this article; \( r = -0.11, P = .001 \)) and between visual acuity and VF-14 scores (Figure C, available in the online version of this article; \( r = -0.231, P < .001 \)). No correlation was found between age and VF-14 score \( (r = 0.04, P = .001) \).

All cataract subtypes were correlated to the OSI score: \( r = 0.182 \) \( (P < .001) \) for cortical cataracts, \( r = 0.213 \) \( (P < .001) \) for posterior capsular cataracts, and \( r = 0.238 \) \( (P < .001) \) for nuclear cataracts. An average correlation was obtained for the total LOCS III score (all cataract subtypes), with \( r = 0.373 \) \( (P = .001) \).

The correlation for the VF-14 score was \( r = 0.163 \) \( (P = .01) \) for cortical cataracts, \( r = 0.301 \) \( (P = .01) \) for posterior subcapsular cataracts, and \( r = 0.208 \) \( (P = .001) \) for the total LOCS III score. No correlation was found between the VF-14 score and nuclear cataract \( (r = 0.068, P = .001) \).

Regarding the correlations between visual acuity and cataract subtype, the average correlation was \( r = 0.352 \) \( (P < .001) \) for nuclear cataract and \( r = 0.338 \) \( (P < .001) \) for total LOCS III score. Weak correlations were found for cortical cataract \( (r = 0.102, P = 0.01) \) and posterior subcapsular cataract \( (r = 0.253, P < .001) \).

**DISCUSSION**

In this study, both objective and subjective approaches to quantifying visual and functional outcomes as a consequence of cataract were investigated. The study design incorporated the HD Analyzer, providing an objective measurement of light scattering (OSI) alongside the conventional VF-14 questionnaire, which provided a subjective assessment.

The study aimed to find correlations between the OSI and subjective impairment reported by the patients in quality of vision. The VF-14 model was selected because it focuses on the very issues related to the impact of a potential cataract.

The HD Analyzer was recently evaluated by Hirnschall et al.\(^{12}\) to quantify light scattering in patients with posterior capsule opacification after cataract surgery. Furthermore, it has also been used in several studies to quantify light scattering in patients with cataract.\(^{13-15}\) Cabot et al. showed that the OSI was correlated with cataract severity within the three subtypes (nuclear cataract, \( r = 0.5, P < .0001 \); cortical cataract, \( r = 0.6, P < .0001 \); posterior subcapsular cataract, \( r = 0.3, P < .0001 \)).\(^{14}\) Our study also found correlations, albeit weaker. We observed statistically significant correlations between the OSI and the three types of cataract (cortical cataract, \( r = 0.18, P < .001 \); nuclear cataract, \( r = 0.24, P < .001 \); posterior subcapsular cataract, \( r = 0.21, P < .001 \); all types of cataract combined, \( r = 0.37, P < .001 \)). The weaker correlations may be due in part to the larger sample size and spectrum of cataract severity in this study. Furthermore, correlational analysis assumes a linear relationship between these variables, which we know is not the case where distribution error is also not normal. However, the results do show that the severity of cataract can affect the light scattering in the eye.

The mean OSI scores within the study population were 3.7 for early-stage cataract, 4.8 for mild cataract, 6.2 for moderate cataract, and 10.2 for white cataract. As previously shown in the literature, the OSI score therefore increases with cataract severity. Artal et al. demonstrated that an OSI score less than 1 corresponded to the absence of cataract, whereas a score of 2 correlated to early-stage cataract and a score of greater than...
2 to a moderate to mature cataract.\textsuperscript{15} We also showed that even an early-stage cataract can cause an alteration in ocular diffusion, thus leading to a deterioration in the patient’s quality of vision (OSI average of 3.7 in early-stage cataract).

We also observed a correlation between the OSI and visual acuity ($r = -0.47$, $P < .001$). This contradicts the findings by Pan et al.,\textsuperscript{16} who recorded positive correlations. This may be due to selection criteria or because early-to-moderate cataracts do not necessarily present with a significant deterioration in visual acuity, but this needs to be confirmed.

However, the more impaired the visual acuity, the higher was the OSI score (average OSI was 6 for visual acuity $\leq 0.5$ and 3.5 for visual acuity $> 0.5$). We also noted that patients with cataract whose visual acuity was preserved (visual acuity $\geq 0.7$) still presented with a deterioration of their quality of vision (mean OSI = 3.1). This may also affect differences found in correlations and patient populations.

Many studies have demonstrated that the VF-14 score is altered in patients presenting with lens opacification and is improved after phacoemulsification and positioning of an implant in the posterior chamber.\textsuperscript{17,18} Chew et al.\textsuperscript{19} showed that all types of cataract significantly affected the VF-14 score. The correlations in this study for cortical cataract ($r = -0.16$, $P = .001$) and posterior subcapsular cataract ($r = -0.2$, $P = .001$) suggest that this is also the case, but not with nuclear cataracts ($r = -0.06$, $P = .001$).

Even early-stage cataract can have a significant impact on the quality of life because the mean VF-14 score was calculated as 78.6 and gradually decreased with increasing cataract severity (77 for mild cataracts, 75.5 for moderate cataracts, and 60.5 for white cataracts). However, we did not find any correlation between age and VF-14 score ($r = -0.04$, $P = .001$). This may be due to the fact that younger patients often report impairment for similarly affected visual acuities and this could be a consequence of the activities and lifestyle of younger patients compared to their older counterparts.

Moreover, we observed a correlation between the OSI and VF-14 scores ($r = -0.12$, $P < .001$) and between visual acuity and VF-14 score ($r = 0.26$, $P = .001$), which indicates that the lower the visual acuity and the higher the OSI, the lower the VF-14 score. Despite a preserved visual acuity ($\geq 0.7$), patients with cataract have impaired daily lives (mean VF-14: 80.9). Cataract is known to cause decreased visual acuity, so an average correlation between visual acuity and nuclear cataracts ($r = -0.35$, $P = .001$) and low correlation with cortical cataracts and posterior subcapsular cataracts ($r = -0.1$, $P = .01$ and $r = -0.24$, $P = .01$, respectively) is not a surprise. Indeed, Pan et al.\textsuperscript{16} and Artal et al.\textsuperscript{15} have shown stronger correlations. However, these studies were mainly focused on patients with early-to-moderate stage age-related cataract of small subsets. Furthermore, these investigators obtained correlations on groups based on OSI value cut-offs. In our study, the correlations were performed in a large population to best represent a general cataract population.

Another factor resulting in weaker correlations may be that light scatter can be affected by alterations in the tear film, corneal opacity, refractive surgery, intraocular inflammation, and retinal vitreoretinal disease. For example, Nanavaty et al.\textsuperscript{20} used the HD Analyzer to study ocular light diffusion in patients with uveitis. The cells observed in the anterior chamber correlated to the OSI ($r = 0.9$, $P = .007$), demonstrating the influence of ocular variables and light scatter.

It could be argued that a more objective measure of tear film should have been adopted over TBUT in this study. It was decided not to adopt the Schirmer test because its limitations, due to the test itself and to other reported variations,\textsuperscript{21} provides an indirect measure of the tear film quality. We believe that performing TBUT alongside dye staining and careful checking of the meibomian glands performed in all of the patients was adequate to eliminate ocular surface disease that would otherwise impair the OSI measurement and create a bias. However, this study does supplement previous findings and the results reported by our group on the sensitivity, specificity, and efficiency of the OSI in detecting cataract against visual acuity and the VF-14.

**CONCLUSION**

The OSI provides a means of objectively detecting and quantifying cataract severity by means of quantifying light scatter. Previous findings showing good sensitivity and efficiency, alongside some of the correlations discussed in this study, warrant further investigation in the use of the OSI for detection of cataract of varying severities against different cut-off points in visual acuity and the VF-14 in the general population.

**AUTHOR CONTRIBUTIONS**

Study concept and design (BC, FG); data collection (BC, FG); analysis and interpretation of data (BC, SRP, FG); writing the manuscript (BC, SRP, FG); administrative, technical, or material support (BC); supervision (BC)

**REFERENCES**


Figure A. Spearman rank correlation of Objective Scatter Index (OSI) and visual acuity (VA) for the total sample.

Figure B. Spearman rank correlation of Objective Scatter Index (OSI) and Visual Function Index-14 (VF-14).

Figure C. Spearman rank correlation of visual acuity (VA) and Visual Function Index-14 (VF-14) for the total sample.