Correlation Among Lens Opacities Classification System III Grading, Visual Function Index-14, Pentacam Nucleus Staging, and Objective Scatter Index for Cataract Assessment

AN-PENG PAN, QIN-MEI WANG, FANG HUANG, JIN-HAI HUANG, FANG-JUN BAO, AND A-YONG YU

CATARACTS ARE A MAJOR CAUSE OF BLINDNESS worldwide, affecting almost 18 million people. Fortunately, the visual impairment caused by cataract is reversible in the majority of patients after surgery. Thus the assessment, grading, and classification of cataract stage and the evaluation of cataract progression are vital, as they will help both eye care providers and patients to decide the optimal timing of cataract surgery.

Currently, both subjective and objective methods are used to assess cataracts. The Lens Opacities Classification System III (LOCS III) is a subjective grading system that has good reproducibility in cataract grading, and is widely used in clinical practice and research studies. The Visual Function Index-14 (VF-14) is a patient’s-perspective questionnaire. It subjectively quantifies the visual impairments caused by cataract and evaluates the need for cataract surgery. It is available in several languages, including Chinese, and is reliable, valid, and responsive to clinical changes.

One widely used objective method is Scheimpflug imaging, which assesses cataracts by analyzing lens density. Recently, another objective assessment of cataract that is based on recording and analyzing double-pass retinal images of a point source has been proposed. This method quantifies the combined effect of light scatter and optical aberrations in human eyes and provides parameters, including the objective scatter index and the modulation transfer function, that allow comprehensive assessment of the optical quality of the eyes.

To help clinicians select an appropriate way of assessing cataracts, we investigated the relationship among these 4 cataract assessment methods. Based on our data, we also provided evaluations on the merits of each one. These results will be especially useful for scheduling of potential surgical patients whose cataracts are in the early to moderate stages of development.

METHODS

THIS WAS A PROSPECTIVE, SINGLE-CENTER, CROSS-SECTIONAL STUDY. A TOTAL OF 36 SUBJECTS (60 EYES) WITH...
age-related cataract were recruited between November 4, 2013 and February 21, 2014 at The Eye Hospital of Wenzhou Medical University, Wenzhou, China. The average age was 65.8 ± 7.8 years, ranging from 42 to 80 years. A comprehensive eye examination was performed on each participant, including refraction, logMAR best-corrected visual acuity (BCVA), slit-lamp examination (SL115; Carl Zeiss, Oberkochen, Germany), fundus examination under dilation, and noncontact tonometry (TX-F; Canon, Tokyo, Japan). Inclusion criteria were age-related cataract patients without significant posterior subcapsular opacification or other ocular abnormalities. All subjects were free of any clinically detectable corneal disease such as keratoconus, corneal dystrophies, or corneal opacity, as assessed by detailed slit-lamp examinations. This study was approved by the Institutional Review Board of The Eye Hospital of Wenzhou Medical University and adhered to the tenets of the Declaration of Helsinki. Informed consent was obtained from all subjects.

- **LENS OPAECITIES CLASSIFICATION SYSTEM III LENS GRADING:** The opacity of each eye was assessed using the LOCS III standards under pupil dilation with 0.5% tropicamide and 0.5% phenylephrine hydrochloride eye drops (Zhuobian, Sinqi, China). A well-trained ophthalmologist graded every eye under slit-lamp examination by comparing nuclear opalescence, nuclear color, cortical cataract, and posterior subcapsular cataract to standard color photographic transparencies. The assigned score was graded to reflect the relative decimal position between 2 successive standards. Subjects with posterior subcapsular cataract were excluded, and only cortical and nuclear cataracts were evaluated. Nuclear opalescence (0.1–6.9) and cortical cataract (0.1–5.9) gradings were used to assess the independent effect of nuclear opalescence and cortical cataract on visual function.

- **VISUAL FUNCTION INDEX-14:** The Chinese Revision Visual Function Index-14 was used in this study. All subjects completed this questionnaire that was administered by the same trained interviewer. The subjects were asked whether, even with glasses, they had any difficulty in doing the 12 vision-dependent activities (2 of 14 were eliminated in the Chinese Revision Visual Function Index-14). The subjects then rated the amount of difficulty they had with the activity owing to their vision on the scale “a little,” “a moderate amount,” “a great deal,” or “unable to do.” The item was excluded if patients were not able to do the activity for any reasons other than their vision. The questionnaires were scored as recommended by the developers, with higher scores representing better visual functioning.

- **LENS DENSITY MEASUREMENT:** The lens density of each participant was evaluated by the same examiner using a Scheimpflug imaging device (Pentacam HR; Oculus, Wetzlar, Germany) after pupil dilation with 0.5% tropicamide and 0.5% phenylephrine hydrochloride eye drops. Three successive measurements were performed in each eye using the 50-scan acquisition mode in a dark room. The acquisition with the best centrality of the 3 was selected and analyzed by the Pentacam Nucleus Staging software to evaluate lens density. The Pentacam Nucleus Staging gives the average lens density in 3 dimensions with a selected diameter of 4.0 mm. The software generated a nuclear cataract grade in 5 stages (Pentacam Nucleus Staging scores) based on the densities in the 3 dimensions.

- **OPTICAL QUALITY ANALYSIS OF LENS:** The optical quality of each subject’s eyes was measured using the Optical Quality Analysis System II (Visiometrics S.L., Tarrasa, Spain). The measurements were taken with an artificial pupil diameter of 4.0 mm, set by the instrument, which is the standard size used in clinical double-pass studies. Astigmatism ≥−0.75 diopter was corrected by using external ophthalmic cylindrical lenses. The measurements were made in a dark room to assure that the natural pupil diameter was larger than 4.0 mm, eliminating the need for further dilation that could cause a shift in refraction. Three successive measurements were obtained for each eye by the same examiner. The mean value was used for each parameter.

The main parameter provided by the Optical Quality Analysis System II to assess cataract was the objective scatter index. It is defined as the ratio of the intensity at an eccentric location in the double-pass image and the central area (the peak). The objective scatter index can quantify the magnitude of the intraocular scattering, the main source of which is the cataractous crystalline lens. An elevated value of objective scatter index represents more intraocular scatter, and therefore more disturbance in vision. The modulation transfer function, which represents the loss of contrast in the retinal image at various spatial frequencies, can be used to objectively evaluate the visual quality. The modulation transfer function cut-off is the highest spatial frequency that the eye can detect. Therefore, higher cut-off frequencies were associated with better optical quality. The Strehl ratio is the ratio between the area under the modulation transfer function curve of the measured optical system and the aberration-free system, with a higher value representing better optical quality.

- **STATISTICAL ANALYSIS:** All statistical analyses were performed using SPSS 16.0 (SPSS Inc, Chicago, Illinois, USA). All continuous variables were expressed as the means ± standard deviations. The normality of each variable was checked with the 1-sample Kolmogorov-Smirnov test. All variables were normally distributed except the Pentacam Nucleus Staging score. The relationship between each variable, including LOCS III grading (nuclear opalescence, cortical cataract), VF-14 score, objective scatter index, modulation transfer function cut-off, and
the Strehl ratio was analyzed by the Pearson correlation test. Spearman correlation tests were used for determining the relationship of Pentacam Nucleus Staging scores with other variables. Partial correlation tests were used to evaluate the relationships among average lens density, LOCS III grading (nuclear opalescence, cortical cataract), VF-14 score, objective scatter index, and BCVA while controlling for age. Independent sample t tests were used for comparing the means of each parameter between each group. The level of significance was $P < .05$.

## RESULTS

For all 60 eyes, the mean value of BCVA was $0.19 \pm 0.16$; LOCS III nuclear opalescence score, $3.28 \pm 0.49$ (range, 2.5–4.7); cortical cataract score, $2.70 \pm 1.12$ (range, 1.0–4.9); average lens density, $10.61 \pm 1.46$; and objective scatter index, $4.41 \pm 2.98$. There were 57 LOCS III grading nuclear opalescence scores (95.0%) that were less than 4.0 and 54 cortical cataract scores (90.0%) that were less than 4.0.

Linear correlations were analyzed between the BCVA, LOCS III nuclear opalescence score, objective scatter index, average lens density, modulation transfer function cut-off, Pentacam Nucleus Staging score, and the Strehl ratio (Table 1). The LOCS III nuclear opalescence score was significantly correlated with BCVA, objective scatter index, and the average lens density ($P \leq .001$ each), and with the modulation transfer function cut-off ($P = .014$). The objective scatter index was significantly correlated with BCVA, modulation transfer function cut-off, and the Strehl ratio ($P < .001$ each), and with the average lens density ($P = .013$). The average lens density was significantly correlated with the BCVA and the Pentacam nuclear staging score ($P = .005$ and $P < .001$, respectively).

The value of the VF-14 score was the same for each subject regardless of the difference in other parameters for each eye. The vision in the better eye usually suggested the visual limitation to perform daily activities,

$^7,12$ Therefore, the parameters of the better eye for each subject were selected for analysis. For all 36 subjects, the VF-14 score correlated with the BCVA ($r = -0.645$, $P < .001$; Figure, Top left), average lens density ($r = -0.393$, $P = .018$; Figure, Top right), LOCS III nuclear opalescence ($r = -0.600$, $P < .001$; Figure, Middle left), and modulation transfer function cut-off ($r = 0.466$, $P = .004$; Figure, Middle right), and strongly correlated with objective scatter index ($r = -0.712$, $P < .001$; Figure, Bottom left).

To further explore the relationship between the objective scatter index and the other parameters, we divided the subjects and eyes into 2 groups, objective scatter index $<3.00$ and objective scatter index $\geq 3.00$ (Table 2).

<table>
<thead>
<tr>
<th>Comparisons</th>
<th>Correlation Coefficient</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOCS III NO score $\times$ BCVA$^a$</td>
<td>0.438</td>
<td>.001</td>
</tr>
<tr>
<td>LOCS III NO score $\times$ OSI</td>
<td>0.543</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>LOCS III NO score $\times$ ALD</td>
<td>0.621</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>LOCS III NO score $\times$ MTF cut-off</td>
<td>$-0.315$</td>
<td>.014</td>
</tr>
<tr>
<td>OSI $\times$ BCVA$^a$</td>
<td>0.779</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>OSI $\times$ MTF cut-off</td>
<td>$-0.690$</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>OSI $\times$ ALD</td>
<td>0.320</td>
<td>.013</td>
</tr>
<tr>
<td>OSI $\times$ SR</td>
<td>$-0.462$</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>ALD $\times$ BCVA$^a$</td>
<td>0.360</td>
<td>.005</td>
</tr>
<tr>
<td>ALD $\times$ PNS score</td>
<td>0.492</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

$^a$Partial correlation test was used while controlling for age.

Table 1: Correlations Among Best-Corrected Visual Acuity, Lens Opacities Classification System III Nuclear Opalescence Score, Objective Scatter Index, Modulation Transfer Function, Average Lens Density, Pentacam Nucleus Staging Score, and the Strehl Ratio for Cataract Assessment

To further explore the relationship between the objective scatter index, BCVA, average lens density, and LOCS III nuclear opalescence, the average values for eyes in the objective scatter index $<3.00$ group were significantly less than those for the objective scatter index $\geq 3.00$ group ($P < .001$ each). The LOCS III cortical cataract score was not significantly different for the 2 groups. For the VF-14, the score in the objective scatter index $<3.00$ group was significantly greater than for the objective scatter index $\geq 3.00$ group ($P = .002$).

## DISCUSSION

This study was mainly focused on early- to moderate-stage age-related cataract patients for whom the need for cataract surgery was difficult to assess clinically. The visual acuity of these patients could be relatively good, and therefore the problems associated with early to moderate cataract development could have been overlooked. In our study, 95.0% of the eyes were graded less than 4.0 in LOCS III grading of nuclear opalescence, and 90.0% were graded less than 4.0 in LOCS III grading of cortical cataract. Currently, there are 3 main points to evaluate the indications for cataract surgery, including the lens opacity (LOCS III, average lens density), visual quality (objective scatter index, modulation transfer function), and subjective complaints (VF-14). We used 4 different methods to assess the cataracts, and the efficiency of each method was evaluated.
We explored the relationships between the LOCS III and other methods. There was a positive linear correlation between the LOCS III nuclear opalescence score and average lens density ($r = 0.621$). The correlation was lower compared to the results reported by Pei and associates ($r = 0.965$), probably because of the different settings for

![Correlation Graphs](image-url)

**FIGURE.** Correlations between the Visual Function Index-14 and other methods for cataract assessment. The data from the better eye in each subject were used. (Top left) Visual Function Index-14 score correlated with logMAR best corrected visual acuity ($r = -0.645, P < .001$); (Top right) Visual Function Index-14 score correlated with average lens density ($r = -0.393, P = .018$); (Middle left) Visual Function Index-14 score correlated with Lens Opacities Classification System III nuclear opalescence score ($r = -0.600, P < .001$); (Middle right) Visual Function Index-14 score correlated with modulation transfer function cut-off ($r = 0.466, P = .004$); (Bottom left) Visual Function Index-14 score correlated with objective scatter index ($r = -0.712, P < .001$).
this method. Pei’s study used the peak value of the lens density in eyes having a pure nuclear cataract with homogenous opacity. However, in the present study we used the average lens density calculated from 3 dimensions with the selected diameter of 4.0 mm by Pentacam Nucleus Staging software to assess both nuclear and cortical cataracts. Grewal and associates \(^1\) found that both the average lens density and the nuclear lens density were individually correlated with LOCS III nuclear opalescence (\(r = 0.774\) and \(r = 0.859\), respectively). They used ImageJ Software to calculate the lens density for the average lens density and for the lens nucleus in individual Scheimpflug images. The different methods for calculating lens density are the likely reason for the discrepancy between our study and Grewal’s. In the present study, the LOCS III nuclear opalescence score was also correlated with the BCVA, VF-14 score, and the objective scatter index. This indicated that the LOCS III nuclear opalescence grading used to assess nuclear cataract remains a convenient and effective method and agrees with other studies.\(^6,17\)

In LOCS III cortical cataract grading, the correlations with other parameters (BCVA, objective scatter index, and average lens density) were not significant. This may be attributable to the fact that most subjects recruited in this study were at early to moderate stages of cortical cataract development. In these patients the opacities were located mainly at the periphery, and the central 4.0-mm area of the cortex was relatively clear. The cortex is the main region used in other methods (BCVA, Pentacam Nucleus Staging lens density, and Optical Quality Analysis System II) to evaluate cataracts. For cortical cataract, the LOCS III cortical cataract grading was more sensitive for detecting early changes compared to the Optical Quality Analysis System II parameters and average lens density used in this study. The latter 2 methods only evaluated the central region of the cortex, not the peripheral opacity that is present in early cortical cataracts. The Pentacam Nucleus Staging software provides lens densitometry in 3 dimensions that can customize the area for evaluation. A study comparing the lens density of the cortex including periphery with the LOCS III cortical cataract grading would be desirable.

The VF-14 score demonstrated a strong correlation with BCVA for the better eye in our study. This is consistent with the results reported by Alonso and associates\(^6,18\) and Steinberg and associates.\(^12\) The visual functions and patient concerns evaluated by VF-14 were critical in determining the needs for cataract surgery and have been reported to be a strong indicator of visual outcome.\(^6,18\) Although conducting the VF-14 questionnaire is time consuming and may suffer from response bias owing to its subjective nature, it can be a major determinant of the needs of cataract surgery in some uncertain cases.\(^19\) Such a case includes early-stage cataracts with apparent visual disturbances while visual acuity remains good or moderate.

In this study, the objective scatter index provided by the Optical Quality Analysis System II correlated well with results of subjective methods: BCVA (\(r = 0.779\)) and VF-14 score (\(r = -0.712\)) from the patient’s perspective and LOCS III nuclear opalescence score (\(r = 0.543\)) from the clinician’s perspective. Lim and associates\(^20\) demonstrated that the objective scatter index was correlated with the LOCS III nuclear opalescence score (\(r = 0.772\)) and lens nuclear density (\(r = 0.764\)) when patients with only nuclear cataract were recruited and the peak lens density value of a single point in the lens nucleus was used. They also found the BCVA had a stronger correlation with the objective scatter index than with the nuclear lens density and LOCS III nuclear opalescence score. In the present study, we found similar results except for the correlation between the objective scatter index and average lens density (\(r = 0.320\)), which was weaker than that reported by Lim and associates. The discrepancy, again, can be explained by the different method settings of the 2 studies. In our study, both cortical and nuclear cataract subjects were recruited and the average lens density was calculated from 3 dimensions with the selected diameter of 4.0 mm by using the Pentacam Nucleus Staging software. With regard to the optical quality parameters provided by the Optical Quality Analysis System II, it is superior to the LOCS III and Pentacam Nucleus Staging densitometry because the latter 2 methods only evaluate the backscatter\(^11,21\) and fail to incorporate the forward scatter that directly reduces the contrast of the retinal image.\(^22\) This suggests that the objective scatter index, which quantifies the degree of scattering caused by crystalline lens opacities, was robust in evaluating the optical quality in cataract patients. The strong correlation of the objective scatter index with VF-14 score suggests that the Optical Quality Analysis

### TABLE 2. Comparison of Cataract Assessment Parameters for Objective Scatter Index <3.00 and Objective Scatter Index $\geq$3.00

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>OSI &lt;3.00</th>
<th>OSI $\geq$3.00</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of eyes</td>
<td>25</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>OSI</td>
<td>1.77 ± 0.69</td>
<td>6.30 ± 2.51</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>BCVA</td>
<td>0.065 ± 0.053</td>
<td>0.286 ± 0.155</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Average lens density</td>
<td>9.86 ± 1.22</td>
<td>11.15 ± 1.39</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>LOCS III NO score</td>
<td>2.98 ± 0.34</td>
<td>3.49 ± 0.48</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>LOCS III C score</td>
<td>2.39 ± 1.11</td>
<td>2.91 ± 1.09</td>
<td>.144</td>
</tr>
<tr>
<td>Number of patients(^a)</td>
<td>18</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>OSI(^a)</td>
<td>1.68 ± 0.71</td>
<td>5.82 ± 2.13</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>VF-14 score(^a)</td>
<td>91.48 ± 9.36</td>
<td>76.81 ± 11.87</td>
<td>.002</td>
</tr>
</tbody>
</table>

BCVA = best-corrected visual acuity (logMAR); LOCS III C = Lens Opacities Classification System III cortical cataract; LOCS III NO = Lens Opacities Classification System III nuclear opalescence; VF-14 = Visual Function Index-14.

\(^a\)Data from the better eye of each patient was used.
System II can provide adequate information regarding visual function. Therefore, it can be used to objectively confirm the visual disturbance of patients with cataracts. It is important to quantitatively assess the light scatter caused by lens opacity in cataract patients, especially at early stages. It can confirm the subjective visual symptoms, help the clinician determine the need for the surgery, and rule out potential etiologies of visual impairment other than cataract after integrating all the information (BCVA, LOCS III score, etc).

In a previous study, Artal and associates proposed a new classification of cataract based on the objective scatter index. In that classification scheme, an objective scatter index below 1 was normal, an index value between 1 and 3 corresponded to early cataract, an index value between 3 and 7 corresponded to developed cataracts that indicate surgery, and an index value greater than 7 corresponded to severe cataracts. They found a relevant correlation between the objective scatter index classification and LOCS III nuclear grading (75% agreement for all subjects, 84% agreement for early cataract). Accordingly, in our study, the subjects were divided into 2 groups based on an objective scatter index value less than 3.00 and a value equal to or greater than 3.00, for whom surgery is indicated as suggested by Artal and associates. The difference between the 2 groups was significant with regard to BCVA, average lens density, LOCS III nuclear opalescence score, and VF-14 score. This suggests that the objective scatter index of 3.0 is a potentially promising cut-off, and could safely be integrated into the clinician’s consideration when evaluating the necessity and benefit of cataract surgery. Future studies with larger sample sizes and with visual outcome data are needed to further explore the reliability and validity of the objective scatter index cut-off value.

In conclusion, a combination of current methods should be used for cataract surgery planning, and the consistency of lens opacities and subjective complaints is vital in confirming the need for cataract surgery. LOCS III grading remains an economical and effective method to assess lens opacities, especially in early cortical cataracts that start at the periphery when the central cortex is still relatively clear. The objective scatter index can be a useful parameter to objectively analyze the correlation between ocular examination findings and patient concerns. Finally, objective scatter index scores ≥3.0 can be a possible objective cut-off for preoperative decision making.

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REFERENCES


Biosketch

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Biosketch

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