ABSTRACT

Aim: The assessment of repeatability and reproducibility of retinal straylight measurements with the C-Quant straylight meter (Oculus AG, Germany) and the effect of patient’s age on the instrument performance are tested with a series of experiments.

Methods: First, 20 eyes from 20 subjects (mean age 26.9 (SD 2.7) years, mean refractive error –1.34 (2.72) D) were examined with the C-Quant straylightmeter, taking 10 consecutive readings. Five subjects were also examined on five consecutive days to assess reproducibility. Additionally, repeated measures of straylight from 84 subjects of ages ranging from 19 to 86 years (mean (SD)): 42.4 (24.0) years) were retrospectively analysed to assess the effect of patient’s age on repeatability.

Results: The results failed to show significant differences between the readings taken within the same session (mean (0.07), p>0.05) or between sessions (mean (0.05), p>0.05). Variability of intrasession measurements was not significant for subjects of different age (p = 0.084).

Conclusion: It may be concluded that the C-Quant straylightmeter is repeatable and reliable for the assessment of retinal straylight in human eyes. Age of the patient does not decrease repeatability, even though they feel more insecure about their ability to perform the test.

Intracocular light scatter is light that has reflected, refracted, diffracted or experienced multiple combinations of all three from particles along the optical path of travel. There are five major sources that contribute to the total amount of ocular straylight: cornea, iris, sclera, retina and lens. It is assumed that for young healthy eyes, the total amount of straylight is 1/3 by the cornea, 1/3 by the lens and 1/3 by the iris, sclera and retina. Obviously, these ratios change with age, pigmentation and specific pathologies. Corneal light scatter is constant with age and it may change with corneal defects or after corneal refractive surgery. The iris and the sclera scatter light depend on the patient’s pigmentation (for example, brown eyes absorb more light and consequently produce less scatter than light eyes). Lens scatter increases with age, being greater in patients with cataracts. Finally, the retina produces light scatter to different locations being pigmentation-dependent.

A clinical application of straylight measurement is to diagnose patients with complaints caused by a high degree of light scattering in the eyes such as lens opacities or corneal turbidity after laser corneal surgery. Considering that scatter light causes contrast loss in the final retinal image, the estimation of this parameter becomes very important in cataract and refractive surgery procedures. Several clinical devices have been developed to evaluate straylight and glare (ie, nyktotest, mesotest and the straylight meter). A recent computer version of the straylight meter has been designed to improve the clinical measurement of the ocular straylight.

The C-Quant is a newly developed instrument to measure the retinal straylight using the “compensation comparison” method. In essence, this method presents exactly the same stimuli to the subject as the direct compensation method described in previous reports, and implemented in previous versions of the instrument. In contrast, in the compensation comparison method, two stimuli of the direct compensation method are presented to and compared by the subject simultaneously.

The aim of the present study is to assess the effect that repeated measurement of retinal straylight has in the final values, which would be the optimum number of measurements needed to obtain an optimum reliability, and also the possible influence of the age of the patient on the repeatability of the measures is explored due to the psychometric character of the test.

METHODS

The present study involves three different experiments in order to determine first the variability of retinal straylight values with repeated measurements within one session, second the intersession variation and third if the subject’s age has an impact on this repeatability. All the procedures followed the tenets of the Declaration of Helsinki and were approved by the Ethics Committee of the University of Valencia. Although both eyes could be used, since straylight is not symmetrical between eyes, only one eye was examined on each subject.

Intrasession repeatability

Twenty eyes from 20 young adults (mean age 26.9 (SD 2.7) years, mean refractive error –1.34 (2.72) D) were examined using the C-Quant stray-light meter (Oculus Optikgeräte GmbH, Wetzlar, Germany). Ten consecutive measurements were taken on each eye without any compensation of refractive error. All measurements obtained were considered reliable by the system, that is, the estimated standard deviation (ESD) and quality factor for the psychometric sampling (Q) were
lower than 0.08 and higher than 1.00, respectively. The C-
Quant relies on these two parameters to identify whether the
measurement can be considered reliable. The ESD, which the
system identifies as reliable when lower than 0.08, is based on a
single assumed shape for the psychometric function, which
depends itself on the critical modulation depth contrast and a
parameter describing the lapse rate. Both parameters and the
reasoning behind them have been described in detail elsewhere.21

Statistical analysis
Normality of data distribution was assessed with the
Kolmogorov–Smirnov test.

Repeated-measures analysis of variance (ANOVA) was
applied to determine the existence of significant differences
between the measurements obtained within the same session
and between sessions. ANOVA was used to determine the
impact of patient’s age in the variance of the repeated straylight
measures obtained.

According to sample size calculations, for a critical p value of
0.05 used to denote statistical significance, a minimum sample
size of 20 subjects would be sufficient to detect statistical
significance for a change in light scattering of 0.10 log units
among sessions or between measurements taken within the
same session, based on an anticipated mean difference in the
change and an overall variability of 0.10 log units for an average
of 1.00 log units for the overall population and assuming a
statistical power of 0.99. To detect a difference of 0.05 in light
scatter, using the same sample size the statistical power would
be of 0.60. This implies that sample size for the intersession
repeatability is quite small for statistical power but sufficient to
offer a valid estimation of intersession variance through the
intersession SD, also when checked against intrasession SD values.

RESULTS

Intrasession repeatability

In order to obtain this, the stray-light values of 84 subjects were
retrospectively analysed. Subjects were between 19 and 86 years
of age (mean (SD) 42.4 (24.0) years) with no ocular condition
and between sessions. ANOVA was used to determine the
impact of age in the variance of the repeated straylight
measures obtained.

Table 2 shows the straylight values and SD throughout the five
sessions. Although some degree of variability
sessions. Analysis of variance (ANOVA) did not show
any statistically significant differences between the measure-
ments taken within the same session. Figure 1 however shows
that SD increases with the number of measurements, possibly
due to tiredness of the subject examined due to the subjective
character of the test and its duration (around 2 min); it also
shows little variation in SD throughout the 10 consecutive
readings. The mean SD was 0.07 log units.

Intersession repeatability

Additionally, five emmetropic subjects were measured three
times on each of five sessions. These measurements were taken
at the same time on five consecutive days in order to assess the
intersession repeatability of the measurements.

Effect of age of the patient on repeatability of measures

In order to obtain this, the stray-light values of 84 subjects were
retrospectively analysed. Subjects were between 19 and 86 years
of age (mean (SD) 42.4 (24.0) years) with no ocular condition
(median spherical equivalent: –1.12 (1.09) D). Some of those
subjects had previous cataract surgery, but since the aim of the
present study is to determine the impact of age in the
performance of the task involved in the psychometric determi-
nation of retinal straylight rather than the values themselves,
they were included in the analysis.

Three consecutive measurements of retinal straylight con-
sidered as “reliable” by the instrument were obtained from each
subject. The mean of those three was used for further statistical
analysis. As suggested by the manufacturer, no correction was
needed for the subjects examined to perform the compensation
comparison test.

Table 1 Mean logarithmic straylight value, log(s) and SD obtained from
10 measurements for each of the 20 patients within the same session

<table>
<thead>
<tr>
<th>Patient</th>
<th>Mean log(s)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.91</td>
<td>0.12</td>
</tr>
<tr>
<td>2</td>
<td>1.06</td>
<td>0.10</td>
</tr>
<tr>
<td>3</td>
<td>0.69</td>
<td>0.06</td>
</tr>
<tr>
<td>4</td>
<td>0.92</td>
<td>0.09</td>
</tr>
<tr>
<td>5</td>
<td>0.62</td>
<td>0.07</td>
</tr>
<tr>
<td>6</td>
<td>0.89</td>
<td>0.05</td>
</tr>
<tr>
<td>7</td>
<td>0.72</td>
<td>0.05</td>
</tr>
<tr>
<td>8</td>
<td>1.25</td>
<td>0.08</td>
</tr>
<tr>
<td>9</td>
<td>0.80</td>
<td>0.06</td>
</tr>
<tr>
<td>10</td>
<td>0.99</td>
<td>0.08</td>
</tr>
<tr>
<td>11</td>
<td>0.99</td>
<td>0.09</td>
</tr>
<tr>
<td>12</td>
<td>0.81</td>
<td>0.07</td>
</tr>
<tr>
<td>13</td>
<td>1.05</td>
<td>0.07</td>
</tr>
<tr>
<td>14</td>
<td>1.14</td>
<td>0.05</td>
</tr>
<tr>
<td>15</td>
<td>0.91</td>
<td>0.05</td>
</tr>
<tr>
<td>16</td>
<td>1.09</td>
<td>0.09</td>
</tr>
<tr>
<td>17</td>
<td>1.00</td>
<td>0.04</td>
</tr>
<tr>
<td>18</td>
<td>0.92</td>
<td>0.07</td>
</tr>
<tr>
<td>19</td>
<td>1.05</td>
<td>0.13</td>
</tr>
<tr>
<td>20</td>
<td>0.76</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Table 2 Mean logarithm of the stray light value, log(s) and SD from the three measurements obtained on the five sessions taken on consecutive days

<table>
<thead>
<tr>
<th>Patient</th>
<th>Intersession SD</th>
<th>Session 1</th>
<th>Session 2</th>
<th>Session 3</th>
<th>Session 4</th>
<th>Session 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Log(s)</td>
<td>SD</td>
<td>Log(s)</td>
<td>SD</td>
<td>Log(s)</td>
</tr>
<tr>
<td>1</td>
<td>0.03</td>
<td>0.84</td>
<td>0.05</td>
<td>0.66</td>
<td>0.04</td>
<td>0.81</td>
</tr>
<tr>
<td>2</td>
<td>0.01</td>
<td>0.78</td>
<td>0.01</td>
<td>0.79</td>
<td>0.07</td>
<td>0.81</td>
</tr>
<tr>
<td>3</td>
<td>0.08</td>
<td>0.76</td>
<td>0.02</td>
<td>0.78</td>
<td>0.02</td>
<td>0.81</td>
</tr>
<tr>
<td>4</td>
<td>0.09</td>
<td>0.90</td>
<td>0.03</td>
<td>0.94</td>
<td>0.04</td>
<td>0.95</td>
</tr>
<tr>
<td>5</td>
<td>0.05</td>
<td>0.88</td>
<td>0.03</td>
<td>0.84</td>
<td>0.02</td>
<td>0.77</td>
</tr>
</tbody>
</table>
Effect of age of patient on repeatability

ANOVA showed, as expected, a significant increment of retinal straylight values with increasing age (p < 0.001) (fig 3). Repeatability was not significantly different for patients of different age (p = 0.094) (fig 4).

DISCUSSION

Direct compensation method for the determination of retinal straylight has been successfully used in a number of studies and has been widely reported in literature as a useful approach in the study of optical performance in cataract, corneal dystrophies or retinal disease, as well as the effects of ocular lubricants, laser refractive therapy or radial keratotomy. Recently, a modification to the original method has been made in order to make it more suitable for clinical use in a large scale. This new method was named the compensation comparison method, and has also been described in detail in the literature, resulting in a reliable instrument for the measurement of retinal straylight in clinical settings and successfully used in large-scale studies (see GLARE study: http://www.glare.be). However, all the studies reported to the authors’ knowledge have been performed taking no more than two repeated measurements on each of the subjects. The aim of the present study was to assess the effect that repeated measurement of retinal straylight had in the final values, and which would be the optimum number of measurements needed to obtain an optimum reliability.

When repeated measures are performed using a test in which a bright light flickers at different intensity levels, and we require a response from the patient, we would expect some kind of effect of multiple consecutive readings, that is, the last readings would be less reliable than the first readings due to the sustained psychometric effort that would make the task more difficult to perform. In a previous study describing and assessing the procedure used here, Franssen et al found an overall SD of repeated measures between 0.06 and 0.1 log units, which agrees with our findings of SD between 0.04 and 0.13 log units. This high repeatability suggests that the system is reliable and useful for detecting clinically significant stray light values.

The C-Quant relies on two parameters to identify whether the measurement can be considered reliable or another measurement should be taken. One of these parameters is the ESD, which the system identifies as reliable when lower than 0.08 and is based on a single assumed shape factor for the psychometric function, which itself depends on the critical modulation depth contrast and a parameter describing the lapse rate. Both parameters and the reasoning behind them have been described in detail elsewhere. In a recent publication assessing the reliability of the method, Coppens et al showed ESD to be efficient for detecting unreliable measurements. From the results presented here, it can be seen that measurements considered reliable by the instrument are very repeatable both intra- and intersession. Another issue that might affect the readings would be the ability of patients to perform the test. With increasing age, patients tend to feel more insecure about their ability to perform tests that require a direct response from them. During clinical determination of retinal straylight, it was noticed that many patients of considerable age would feel very worried during testing because they felt they did it wrong, were too slow or got confused about pressing the right button. One of the aims of the present study arose as a result of these observations. The results reported here show that the compensation comparison method is not affected by this, as long as the measurement obtained is considered as “reliable” by the instrument using the two parameters previously described, ESD and Q.
In summary, the C-Quant stray-light meter is a very intuitive, easy-to-use clinical tool that provides reliable, repeatable measurements of retinal straylight in human eyes irrespective of age. Contrary to possible initial impressions, more measurements do not increase the reliability of the values obtained, and a balance between number of measurements and time required for the patient to perform the test is crucial. From the results obtained in the present study, three valid consecutive measurements are sufficient to obtain a reliable value for retinal straylight (although two measurements would suffice). Furthermore, the repeatability of the measurements is not influenced by the age of the patient.

**Competing interests:** None.
Performance of the compensation comparison method for retinal straylight measurement: effect of patient’s age on repeatability

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