Comparison of Measurement of Pupil Sizes Among the Colvard Pupillometer, Procyon Pupillometer, and NIDEK OPD-Scan

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ABSTRACT

PURPOSE: To compare pupil sizes measured with the Colvard pupillometer, Procyon pupillometer, and NIDEK OPD-Scan.

METHODS: Pupil diameter was measured in 90 consecutive eyes from 55 patients under mesopic and scotopic light conditions with all three instruments.

RESULTS: The mean scotopic pupil diameter was 6.3 ± 0.98 mm with the Colvard pupillometer and 6.45 ± 1.01 mm with the Procyon pupillometer. The mean mesopic pupillometer was 5.58 ± 1.01 mm with the Procyon pupillometer and 6.26 ± 0.99 mm with the NIDEK OPD-Scan.

CONCLUSIONS: The mesopic pupil diameter measured with the NIDEK OPD-Scan is more consistent with the scotopic pupil diameter measured with the Procyon and Colvard pupillometers than the mesopic pupil diameter measured with the Procyon pupillometer. [J Refract Surg. 2006;22:S1027-S1030.]

The measurement of pupil diameter has become increasingly important in the field of refractive surgery. Larger scotopic pupil sizes may be partially responsible for the occurrence of postoperative symptoms such as halos, glare, and monocular diplopia.1,2 Refractive surgeons also need an accurate scotopic pupil measurement to determine appropriate treatment zones for excimer laser, corneal, and intraocular surgery.

Pupil size can be evaluated using various methods. The Colvard hand-held infrared pupillometer (Oasis Medical, Glendora, Calif) has been considered the gold standard for pupil measurement in refractive surgery, and the Procyon pupillometer (Procyon, London, United Kingdom) is considered one of the most accurate pupillometers.3,4

The purpose of this study was to compare pupil measurements taken with these two pupillometers, which were designed specifically to perform pupillometry, with pupil measurements taken with the NIDEK OPD-Scan (NIDEK Co Ltd, Gamagori, Japan), which is an autorefractor, topographer wavefront aberrometer that can perform pupil measurements.

MATERIALS AND METHODS

PATIENTS AND PUPILLOMETRY MEASUREMENTS

Measurements of pupil sizes were taken for 90 consecutive eyes from 55 patients who presented to the Optimax Laser Eye Treatment Specialists in London, United Kingdom. All patients were candidates undergoing screenings for primary or secondary refractive surgery. None of the patients included in the study had irregular pupils or had received any topical medication that could cause pupil mydriasis or miosis. All three measurements were carried out in the same room within 30 minutes of one another. The ambient room illumination...
was <1 lux for each measurement, determined using the Minolta chromameter (Minolta, Glen Cove, NY).

Measurements were performed with the NIDEK OPD-Scan first. Measurements were taken by different operators trained on the use of the OPD-Scan. The OPD-Scan records monocular pupil measurements under binocular conditions.

The OPD-Scan controls accommodation by providing a distance fixation target within the unit. The OPD-Scan does not account for hippus. According to the manufacturer, NIDEK Co Ltd, the OPD-Scan acquires the mesopic pupil measurement when aberrometry is being performed. To standardize nomenclature, we refer to the pupil size measurement generated by the OPD-Scan at this point as mesopic pupil size; however, the manufacturer’s designation of mesopic may not be correct for this particular instrument. The luminance emitted by the OPD-Scan at this point is 10 to 12 cd/m². Aberrometry measurements and mesopic pupillometry measurements are taken using infrared light, which does not affect pupil size. Ambient room illumination was <1 lux while the mesopic pupil measurements were obtained with the OPD-Scan. Subsequently, the OPD-Scan calculates one photopic pupil measurement, while the corneal topography measurements are being obtained. The luminance emitted by the OPD-Scan at this point is 100 to 150 cd/m². OPD-Scan measurements are recorded to ±0.01 mm.

Measurements obtained with the Procyon pupillometer were calculated next. Measurements obtained with the Procyon pupillometer were taken by the same operator for all patients. For all Procyon measurements, the scotopic pupil size was measured first, followed by low mesopic pupil size. The Procyon is a digital infrared pupillometer that can measure pupil size monocularly or binocularly at three different illumination levels: scotopic (0.04 lux), low mesopic (0.4 lux), and high mesopic (4 lux). In this study, only binocular measurements were obtained with the Procyon pupillometer. Infrared light-emitting diodes illuminate the eyes with long-wave light that does not affect pupil size but is recognized by the charge-coupled device camera in the system.

Measurements are not affected by ambient illumination, because rubber cups encompass the patient’s orbit, preventing stray light from entering the eye. The Procyon pupillometer takes hippus into account. At each illuminance level, a sequence of 10 images is acquired within 2 seconds. Mean values are then reported as the pupil diameter. Measurements are recorded to ±0.01 mm.

The final measurement was performed using the Colvard hand-held infrared pupillometer. Measurements obtained with the Colvard pupillometer were taken by the same operator for all patients. This device calculates monocular measurements. Ambient light does not enter the eye being measured because of a rubber cup that encompasses the orbit to prevent stray light entry. The opposite eye is occluded during measurements. The Colvard pupillometer does not account for hippus. This device uses light amplification technology and is subjective. The examiner has to focus on the iris and pupil while the patient fixates on an infrared light-emitting diode, which emits a red light at very low levels. A millimeter ruler is superimposed as a reticle in the device. The reticle is calibrated in 1-mm increments. In this study, Colvard measurements were taken to the nearest 0.25 mm. Other studies have attempted to measure to the nearest 0.1 mm. The Colvard pupillometer performs only scotopic measurements.

**DATA ANALYSIS**

The data were analyzed using the Bland-Altman technique, which compares two methods of measurements by plotting their mean against their differences. Bland-Altman plots were also used for the comparison of agreement in pupil size between different pupillometers. Using the Bland-Altman method, the average pupil size measured with the two instruments is plotted on the x axis, and the difference between the two measurements is plotted on the y axis. The closer the mean difference is to zero, the better the agreement. The limits of agreement are the mean ±2 standard deviations (SD).

**RESULTS**

Ninety eyes in 55 patients (23 men and 32 women) who presented at a refractive surgery center were evaluated for this study. Mean patient age for the entire cohort was 38 ± 12.6 years (range: 19 to 63 years). The mean pupil diameter obtained with each instrument is shown in Table 1. The mean scotopic pupil size with
the Colvard pupillometer showed better agreement with the mean mesopic pupil size as measured with the OPD-Scan than it did with the mean mesopic pupil size as measured with the Procyon (Table 1). Comparison of measurements of pupil size with each instrument plotted against each other show the tightest group of points between the Procyon scotopic pupil sizes and the OPD-Scan mesopic pupil size (Fig 1). Values comparing the scotopic pupil size with the Colvard pupillometer with the scotopic pupil size with the Procyon pupillometer and the scotopic pupil size with Colvard pupillometer with the mesopic pupil size with the OPD-Scan were also similar.

With the exception of the Procyon pupillometer on low mesopic setting versus the OPD-Scan, all of the mean differences were near zero, and all of the limits of agreement were within ±1 mm (Table 2). Almost all of the points on all of the graphs were within the limits of agreement (Fig 2). The best agreement was between the mesopic pupil size with the OPD-Scan and the Procyon pupillometer on a scotopic setting and the worst agreement was between the mesopic pupil size on the OPD-Scan and the Procyon pupillometer on a low mesopic setting.

**DISCUSSION**

Measurement of pupil size is important in corneal refractive surgery, cataract surgery, and implantable corrective lens surgery. Pupil size must be considered by refractive surgeons in planning their treatment. It is likely that binocular measurement of pupil diameter under low mesopic conditions approaches the realistic situation of daily night driving more than monocular measurement.7

Currently one of the most widely used instruments to measure pupil size in refractive surgery centers is the Colvard pupillometer. The popularity of the Colvard pupillometer is likely due to its cost-effectiveness, portability, and ease of use. However, it has a number of inherent flaws, including 1) it does not take into account hippus during measurement, 2) the measure-

**TABLE 2**

<table>
<thead>
<tr>
<th>Mean Difference (mm)</th>
<th>Limits of Agreement (mm)</th>
</tr>
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<tbody>
<tr>
<td>Colvard (scotopic) vs OPD-Scan (mesopic)</td>
<td>-0.14</td>
</tr>
<tr>
<td>Colvard (scotopic) vs Procyon (scotopic)</td>
<td>0.01</td>
</tr>
<tr>
<td>Procyon (mesopic) vs OPD-Scan (mesopic)</td>
<td>-0.71</td>
</tr>
<tr>
<td>Procyon (scotopic) vs OPD-Scan (mesopic)</td>
<td>0.14</td>
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ment is subjective and monocular, and 3) it can only measure pupil size under scotopic conditions.

The Procyon pupillometer may be much more accurate than the Colvard pupillometer, because it addresses a number of the disadvantages inherent to the Colvard pupillometer. For example, the Procyon pupillometer accounts for hippus, is objective, and takes binocular measurements. Moreover, measurements can be taken at three different illumination levels. The disadvantages of the Procyon pupillometer are that it is expensive and, similar to the Colvard, has no function other than pupillometry.

The OPD-Scan is a multifunction instrument used by refractive surgeons for a variety of applications, including wavefront measurement, corneal topography, and autorefraction, in addition to pupil measurement. Although the manufacturer, NIDEK Co Ltd, claims the machine measures mesopic pupil size, in this study the OPD-Scan "mesopic" pupil was, in fact, closer to the Procyon pupillometer and Colvard pupillometer scotopic pupil size. From the results obtained in this study, we believe that the OPD-Scan is actually measuring a scotopic pupil and not a mesopic pupil. If corneal topography and aberrometry are already being performed with the OPD-Scan, then the surgeon could use the pupil size data from the OPD-Scan rather than carry out this measurement on a different instrument.

REFERENCES