Clinical Comparison of the Proview Eye Pressure Monitor With the Goldmann Applanation Tonometer and the TonoPen

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Objective: To compare intraocular pressure (IOP) values obtained by patients using the new Proview eye pressure monitor (Bausch & Lomb, Rochester, NY) with those measured with the Goldmann tonometer and the TonoPen (Mentor, Norwell, Mass).

Methods: Eighty-six patients (a total of 171 eyes) with a diagnosis of glaucoma or glaucoma suspect successfully completed the study. The IOP was measured by 3 methods in the following order: Goldmann tonometer, TonoPen, and Proview eye pressure monitor. The central corneal thickness was measured by an ultrasonic pachymeter. Separately for each eye, the differences in mean IOP values between measurement methods were assessed with paired t tests and also in multivariate models that tested the dependence of IOP difference on central corneal thickness.

Results: There was a significant difference (P<.001) in the mean IOPs measured by the 3 different methods (Goldmann vs Proview, Goldmann vs TonoPen, and TonoPen vs Proview) for both eyes, and the difference was independent of the central corneal thickness. The differences between IOP measured by Goldmann and Proview were similar in all categories of patient-reported ease of using the Proview.

Conclusions: The IOPs obtained with the Proview eye pressure monitor are significantly lower than those measured with Goldmann tonometer and the TonoPen, and variations of the central corneal thickness do not contribute to the difference. Intraclass correlations of IOP values obtained with the Goldmann and the Proview or TonoPen and Proview are not strong. On the other hand, as expected, measurements with Goldmann and TonoPen agreed fairly well.

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Elevated intraocular pressure (IOP) is one of the most important risk factors for glaucoma, and it is currently the only treatable measure of the disease. Therefore, it is imperative to have an accurate measurement of the IOP in the care of patients with glaucoma. Since its introduction in the 1950s, the Goldmann applanation tonometer has been the gold standard for measuring IOP. However, this instrument can be used only in a physician's office, where a “snapshot” of the IOP is taken.

It is well known that there are circadian variations of the IOP, and these fluctuations are more pronounced in patients with glaucoma.1,2 Studies have demonstrated that IOP peaks and, more importantly, IOP fluctuations are associated with progression of visual field loss in patients with glaucoma even though their office IOP was in the normal range.3,4

Over the years, various portable tonometers have been developed; these include the Perkins,5 TonoPen (Mentor, Norwell, Mass),5 Zeimer and coworkers’ self-tonometer,7 Octuron-S (EPSa Elektronik & Praezisionsbau, Saalfeld, Germany),8 and ProTon (Tomey, Erlangen, Germany).9 These instruments are costly and require a skilled operator. The Schiøtz tonometer that was developed in the early 20th century is also portable and is inexpensive. However, patients have to be in the supine position, and there are multiple sources of error with this technique.

The Proview eye pressure monitor (Bausch & Lomb, Rochester, NY) uses a psychophysical test based on the entoptic phenomenon of pressure phosphenes to evaluate IOP, and it was designed for the patient to use at home. It is a pencil-like device that has a small flat probe, an internal spring, and a readable pressure scale (Figure 1). The device measures the IOP through the eyelid, and it does not require an anesthetic. It is safe, noninvasive, portable, and affordable, and requires no electric or battery source. If proven reliable, the Proview eye pressure monitor could be an important instrument in the detection and management of glaucoma.
A previous study demonstrated close agreement between the Goldmann tonometer and the pressure phosphene tonometer when the IOP measurements by both methods were performed by clinicians. However, it is not known whether the results would be the same if patients themselves took the pressure measurements with the Proview. Therefore, the current study was designed to compare the IOP readings obtained by patients using the Proview with those obtained by physicians using the Goldmann and TonoPen instruments, and to assess the ease and discomfort associated with the use of Proview.

Patients with a diagnosis of glaucoma or glaucoma suspect were recruited from the Glaucoma Service of Duke University Eye Center, Durham, NC. The study protocol was approved by the institutional review board of Duke University, and informed consent was obtained from all participants. Inclusion criteria were age greater than 19 years, diagnosis of glaucoma (with mild visual field defect such as early nasal steps) or glaucoma suspect, IOP by Goldmann tonometry greater than 8 mm Hg, and visual acuity of 20/80 or better. Exclusion criteria were tremor, previous penetrating keratoplasty or abnormal cornea precluding accurate measurement of IOP by Goldmann tonometry, or temporal visual field defects that prevented perception of the phosphene. The IOP was measured by 3 methods in the following order: Goldmann tonometry, TonoPen, and Proview eye pressure monitor. Skilled clinicians performed Goldmann tonometry and TonoPen tonometry, and patients obtained measurements with the Proview eye pressure monitor. Two readings were made for each method and the average was used in the analysis.

Goldmann tonometry was performed in a standard manner. For TonoPen tonometry, the instrument was calibrated each day before use, and readings of the highest reliability (standard error of the mean, ≤5% of the average) were obtained.

Patients were then asked to obtain IOP readings with the Proview device. They were given the diagrammed instruction sheet from the manufacturer, and a clinician went over the steps with them before the procedure. The right hand was used to hold the device and measure IOP in the left eye, and the left hand to measure IOP in the right eye. In brief, the patient was instructed to keep the head straight and look down and to the side. While keeping the eyelid partially open, the patient gently pressed the Proview probe against the upper eyelid just below the edge of the eyebrow at the top of the nose (Figure 2). The pressure was slowly increased until a dark spot surrounded with a ring of light, a phosphene, was perceived. The device was then immediately removed and measurement on the scale was recorded. A 2-minute interval was allowed between the different methods. The central corneal thickness (CCT) was measured by an ultrasound pachymeter (Pachette 2; DGH Technology Inc, Exton, Pa). Six readings were taken and averaged. In addition, the ease of using the Proview eye pressure monitor and the discomfort associated with its use were assessed.

For each eye, the differences in mean IOP values between measurement methods were assessed by paired t tests and also in multivariate models that tested the dependence of IOP difference on CCT with the Wilks A test. Intraclass correlations of IOP values for measurement methods were computed separately for the right and left eyes. An analysis of variance was used to determine whether there was a difference among categories of ease for the difference between the IOPs measured by the Goldmann and Proview instruments.

Ninety-one patients were recruited into the study and 86 successfully completed the study. Five subjects were unable to successfully perform IOP measurement with the Proview instrument because they either were unable to see the phosphene or could not physically perform the procedure. Of the 86 participants, 48 were female and 38 male. The age of the patients ranged from 27 to 83 years, and visual acuity from 20/20 to 20/80. No discomfort was associated with the use of the Proview eye pressure monitor.

Ease of use of the Proview was assessed by the following grading system: 1, very easy; 2, easy; 3, moderate; 4, difficult; and 5, very difficult. Seventy patients (81%) described using the Proview as “easy” or “very easy,” whereas 6 (7%) described its use as “difficult.” The mean CCT was 549 μm (range, 449-637 μm) in the right eye and 552 μm (range, 452-629 μm) in the left eye. In the right eye, the mean IOPs were 17.2 mm Hg (range, 9-44 mm Hg), 15.6 mm Hg (10-39.5 mm Hg), and 13.8 mm Hg (8.27.5 mm Hg) by Goldmann, TonoPen, and Proview, respectively, and in the left eye, the values were 16.2 mm Hg (8.5-25 mm Hg), 14.7 mm Hg (8-23.5 mm Hg), and 13.4 mm Hg (8-23 mm Hg), respectively.

There was a significant difference (P<.001) between methods for the mean IOP measurements in both eyes (Table 1). For Goldmann and Proview, the difference in IOP measurements was similar across a wide spectrum of corneal thickness (Figure 3). The Wilks A test indicated that the difference was independent of CCT (P=.70 for the right eye and P=.26 for the left eye). In the right eye, only 30% of the Proview readings were within ±2 mm Hg of the Goldmann readings and 51% within 3 mm Hg; these figures were 47% and 61%, respectively, for the left eye (Figure 4). The relationship between the IOP values obtained with Goldmann and Proview are shown in Figure 5; for Goldmann and TonoPen in Figure 6; and for Proview and TonoPen in Figure 7. The intraclass correlations between the IOP values obtained with Goldmann and Proview were 0.07 for the right eye and 0.23 for the left eye. For Goldmann and TonoPen, the co-
The intraclass correlations were 0.79 and 0.78 for the right and left eyes, respectively. For TonoPen and Proview, the intraclass correlations were 0.20 and 0.39 for the right and left eyes, respectively. The differences between IOP measured by Goldmann and Proview were similar in all categories of patient-reported ease of using the Proview, and there was no statistical significance for either eye (Table 2).

**Table 1. Difference in IOP Between Methods**

<table>
<thead>
<tr>
<th>Method</th>
<th>No. of Eyes</th>
<th>Mean (SD)</th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-P</td>
<td>OD 86</td>
<td>3.4 (4.2)</td>
<td>3.0</td>
<td>−6.0 to 16.5</td>
</tr>
<tr>
<td></td>
<td>OS 85</td>
<td>2.8 (3.5)</td>
<td>2.5</td>
<td>−5.5 to 14.0</td>
</tr>
<tr>
<td>G-T</td>
<td>OD 86</td>
<td>1.6 (1.7)</td>
<td>1.3</td>
<td>−1.5 to 8.0</td>
</tr>
<tr>
<td></td>
<td>OS 85</td>
<td>1.5 (1.8)</td>
<td>1.0</td>
<td>−3.0 to 7.0</td>
</tr>
<tr>
<td>P-T</td>
<td>OD 86</td>
<td>−1.8 (3.9)</td>
<td>−1.5</td>
<td>−14.5 to 5.5</td>
</tr>
<tr>
<td></td>
<td>OS 85</td>
<td>−1.3 (3.1)</td>
<td>−1.0</td>
<td>−3.0 to 7.0</td>
</tr>
</tbody>
</table>

Abbreviations: G, Goldmann applanation tonometer; IOP, intraocular pressure; P, Proview eye pressure monitor (Bausch & Lomb, Rochester, NY); T, TonoPen (Mentor, Norwell, Mass).

*The difference in IOP was statistically significant (P < .001) for both eyes in each comparison of method.

Invented by Fresco, the Proview eye pressure monitor is based on an entoptic phenomenon or phosphene (Greek for “to show a light”), which is a sensation of light elic-
ited by nonphotic stimuli. The likely basis of its operation was thought to follow the Imbert-Fick law: the perception of a phosphene occurs when the retina is deformed, which occurs with the application of a force over a given area, which can then be related to pressure. The site of a phosphene in the retina was suggested to be bipolar cells, or the parts of rod and cone cells lying inside the external limiting membrane.

We separately analyzed IOP measurements obtained with the Proview from each eye because measurements were obtained with different hands. Although the IOP difference between the Goldmann and Proview was smaller for the left eye (a mean of 2.78 mm Hg vs 3.40 mm Hg), it was statistically significant for both eyes (P < .001 for both eyes).

It is not known whether the position of the eye on inferiortemporal rotation when the Proview was used affects the IOP and therefore the measurement readings. However, this is unlikely a significant factor. Axial length, refractive status, condition of the vitreous, and previous eye surgery may play a role in the IOP measurements with the Proview, and these were not analyzed in the present study.

Two recent abstracts published by the Association for Research in Vision and Ophthalmology reported a mean difference in IOPs between the Proview and Goldmann instruments of 0.5 mm Hg (with a range from −5 to +16 mm Hg) and 3.2 mm Hg. The IOPs obtained with the Proview eye pressure monitor in our study were significantly lower than those measured with Goldmann tonometer and the TonoPen. It is a remote possibility that the order in which the IOP was taken contributed significantly to the difference because at least 2 minutes was allowed to elapse between measurement methods. Recpe et al noted that the time interval between successive IOP measurements should be 2 or 10 minutes for accurate tonometry. The mean IOPs measured by TonoPen were lower than those by Goldmann tonometry. Although the TonoPen tonometry was always performed after Goldmann tonometry, we do not believe that drying and therefore thinning of the cornea is a factor responsible for the IOP difference, because patients were frequently reminded to blink their eyes during the measurements. It is well known that the CCT affects the measurement of IOP by Goldmann tonometer and, to a lesser degree, by TonoPen, although contradictory reports exist in the literature. A meta-analysis of literature found that the mean corneal thickness of eyes reported to be normal was 544 µm by ultrasonic pachymetry. The mean CCT in our group of patients was 549 µm (right eye) and 552 µm (left eye). Race, age, sex, and a history of diabetes have all been reported to influence corneal thickness, and our group of patients was not homogeneous.

Theoretically, the IOP measurements with the Proview should not be influenced by corneal thickness, and this was found to be the case in a group of 22 patients undergoing laser in situ keratoplasty. Therefore, we analyzed the dependence of IOP difference between the Gold-
manning and Proview on corneal thickness, in an effort to determine whether the underestimate or overestimation of IOPs by Goldmann tonometry was based on differences in CCT. The CCT in our patients ranged from 449 to 637 μm, and these wide variations did not contribute to the IOP difference obtained with the 2 methods. Regardless of the CCT, a similar IOP difference was present. Scleral thickness differences may play a role in the accuracy of the Proview, but its influence has not yet been determined.

We also determined whether the difficulty with use of the Proview could explain the discrepancy in IOP readings compared with the Goldmann instrument, and we found no difference in all categories of patient-reported ease of using the device. Further analysis showed no strong correlation between the IOPs measured with the Goldmann and Proview, and no correction factor could be derived and used to accurately estimate the IOP with this new device. In fact, the Proview tonometer was found to act like a spring moving inside a cylinder with friction, leading to nonlinearity and irreproducibility. Further studies are needed in larger samples to assess whether the Proview will allow us to gauge a range of IOP fluctuation in the same patient.

In summary, we found that the IOPs obtained with the Proview eye pressure monitor were significantly lower than those measured with the Goldmann tonometer and the TonoPen. Furthermore, the intraclass correlation between the IOP values obtained with the Goldmann and the Proview instruments was low, indicating very little agreement between these 2 methods of measuring IOP. Therefore, these data suggest that the IOPs measured by the Proview eye pressure monitor do not correlate well with those obtained by Goldmann tonometer. Whether the IOP measurements by the Proview are reproducible for a specific individual patient and, if so, whether the difference compared with Goldmann tonometry is constant over a range of IOPs in the same patient need to be determined. Nevertheless, our results demonstrated that the Proview eye pressure monitor failed to measure the IOP accurately in our study sample of patients.

Table 2. Difference in IOP by Goldmann and Proview Instruments for Each Category of Ease

<table>
<thead>
<tr>
<th>Category of Ease</th>
<th>No. of Eyes</th>
<th>IOP Difference, mm Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Right Eye</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very easy</td>
<td>43</td>
<td>3.4 (4.0)</td>
</tr>
<tr>
<td>Easy</td>
<td>27</td>
<td>3.4 (4.8)</td>
</tr>
<tr>
<td>Moderate</td>
<td>10</td>
<td>4.2 (6.4)</td>
</tr>
<tr>
<td>Difficult</td>
<td>6</td>
<td>2.3 (3.2)</td>
</tr>
<tr>
<td>P value</td>
<td></td>
<td>.87</td>
</tr>
<tr>
<td>Left Eye</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very easy</td>
<td>42</td>
<td>2.7 (3.0)</td>
</tr>
<tr>
<td>Easy</td>
<td>27</td>
<td>2.8 (3.8)</td>
</tr>
<tr>
<td>Moderate</td>
<td>10</td>
<td>3.0 (4.5)</td>
</tr>
<tr>
<td>Difficult</td>
<td>6</td>
<td>2.6 (3.8)</td>
</tr>
<tr>
<td>P value</td>
<td></td>
<td>.98</td>
</tr>
</tbody>
</table>

Abbreviation: IOP, intraocular pressure.
*Proview eye pressure monitor (Bausch & Lomb, Rochester, NY).

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REFERENCES