Pressure Phosphene Tonometry Versus Goldmann Applanation Tonometry for Measuring Intraocular Pressure Before and After LASIK

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ABSTRACT

PURPOSE: To compare pressure phosphene tonometry with Goldmann applanation tonometry for measuring intraocular pressure (IOP) before and after LASIK.

METHODS: Forty-three (18 men and 25 women) consecutive healthy patients underwent complete pre-and postoperative LASIK ophthalmologic assessments including manifest and cycloplegic refraction, keratometry, and central corneal thickness. Three repetitive sets of pressure phosphene tonometry and Goldmann applanation tonometry measurements were performed the day before and 3 months following uneventful LASIK.

RESULTS: Mean preoperative spherical equivalent refraction was −4.70±2.50 diopters (D) (range: −12.90 to −1.50 D) and mean preoperative keratometry was 43.95±1.08 D. After LASIK, spherical equivalent refraction was +0.23±0.11 D and mean keratometry was 39.46±2.28 D. Preoperative pressure phosphene tonometry (12.16±1.98 mmHg) and Goldmann applanation tonometry (12.01±1.55 mmHg) IOP measurements were similar. Postoperative IOP was 10.30±1.16 mmHg with Goldmann applanation tonometry and 12.20±1.62 mmHg with pressure phosphene tonometry. The postoperative IOP difference between Goldmann applanation tonometry and pressure phosphene tonometry was 1.71±1.43 mmHg (P<.0001), a change that was strongly correlated with changes in central corneal thickness (R=0.75, P<.0001) and keratometry (R=0.72, P<.0001). No such correlations were found with pressure phosphene tonometry.

CONCLUSIONS: Goldmann applanation tonometry-measured IOP decrease after LASIK is strongly correlated with a decrease in central corneal thickness and changes in keratometry, whereas pressure phosphene tonometry-measured IOP is independent of corneal thickness. Pressure phosphene tonometry appears to be a more reliable method for recording tonometry in these patients. [J Refract Surg. 2007;23:405-409.]

Ablation of corneal tissue in photorefractive procedures, including LASIK, inherently changes corneal thickness and contour. Measurement of intraocular pressure (IOP) by conventional applanation tonometry is closely related to the corneal profile and may, therefore, be considerably affected by such procedures. Erroneous measurements of IOP have significant clinical and medicolegal implications. The increasing popularity of photorefractive surgery raises important concerns regarding monitoring and management of IOP in individuals who have undergone these procedures. As such, the novel methods of measuring IOP that have been developed must be evaluated and appraised to assure the continued provision of sound patient care.

Pressure phosphene tonometry is performed by a small hand-held device first introduced by Fresco in 1997. The tonometer is based on the entopic phenomenon of the pressure phosphene, which is a subjective impression of a bright halo induced by local deformation of the retina produced by the application of a force over the globe. When applied over a given area, this force can subsequently be related to pressure. Measurement of IOP using the pressure phosphene tonometer is simple and noninvasive. The device is applied directly over a closed eyelid and the IOP is read by means of the graticule as soon as the phosphene is perceived by the patient. Previous studies have shown IOP measurement with pressure phosphene tonometry to be in close agreement with Goldmann applanation tonometry. Because the pressure phosphene tonometer is not concerned with applanation of
The cornea, measured IOP is independent of corneal thickness. Consequently, it can be expected that measurements with pressure phosphene tonometry will be unaffected by photorefractive procedures and may be more accurate for evaluating IOP in patients who have undergone such procedures.

The purpose of this study was to clinically evaluate and compare IOP measurements using the pressure phosphene tonometer with those using the Goldmann applanation tonometer in the same patients before and after LASIK surgery.

**PATIENTS AND METHODS**

This comparative case series consists of 43 consecutive apparently healthy patients (18 men and 25 women) who gave their informed consent to participate in the study. Mean patient age was 31.4±9.7 years (range: 20 to 57 years). Because the parameters used in this study were derived from routine preoperative examinations and evaluations, no added risk was generated and no institutional review board approval was necessary.

Pre- and postoperative assessment included a complete ophthalmic examination consisting of manifest and cycloplegic refraction, keratometry, and determination of central corneal thickness using ultrasonic pachymetry (Pachette-500; DGH Inc, Exton, Pa). Tonometry was performed before and 3 months after an eventful LASIK procedure by means of the pressure phosphene tonometer (Proview eye pressure monitor; Bausch & Lomb, Rochester, NY) and Goldmann applanation tonometer (Haag-Streit, Koeniz, Switzerland). All measurements were performed by two experienced masked observers who used the same instruments on both occasions. All of the instruments are calibrated periodically and undergo regular technical maintenance. The measurements were taken at similar times of the day. Intraocular pressure was arbitrarily measured first by the Goldmann applanation tonometer and then by the pressure phosphene tonometer. The LASIK procedure was performed by a single surgeon (G.S.) using the NIDEK (Gamagori, Japan) MK-2000 microkeratome and NIDEK EC-5000 excimer laser. Flap diameter ranged between 6 and 8 mm, with an intended thickness of 130 µm. The procedure was performed under topical anesthesia using oxybuprocaine 0.4%, and a tapering dose of topical dexamethasone 1% was prescribed for application postoperatively.

The pressure phosphene tonometry device was applied through a closed eyelid without topical anesthetic. Patients were instructed to look down and outwards and the tonometer was applied on the superior nasal portion of the eyelid. They were asked to indicate as soon as the pressure phosphene was perceived. Three repetitive sets of pressure phosphene tonometry and Goldmann applanation tonometry measurements were performed at each visit and the mean values were recorded.

Data from only the right eye of each patient were included in the analysis. Data were analyzed using the t test, and the Pearson correlation coefficient was used to assess the relationship between IOP and other parameters. For this study, it was assumed that the LASIK procedure itself does not influence IOP.

**RESULTS**

The Table and Figure 1 summarize IOP measurements by Goldmann applanation tonometry and pressure phosphene tonometry before and after LASIK. The mean preoperative spherical equivalent refraction was −4.70±2.50 diopters (D) (range: −1.50 to −12.90 D), and the mean preoperative keratometry value was 43.95±1.08 D. After LASIK, the mean spherical equivalent refraction was +0.23±0.11 D and postoperative keratometry was 39.46±2.28 D. No statistically significant difference was noted in the preoperative IOP measurements by pressure phosphene tonometry and by Goldmann applanation tonometry. The mean preoperative IOP was 12.01±1.55 mmHg for Goldmann applanation tonometry and 12.16±1.58 mmHg for pressure phosphene tonometry. Postoperative IOP measurement was 10.30±1.16 mmHg for Goldmann applanation tonometry and 12.20±1.62 mmHg for pressure phosphene tonometry. The preoperative difference in IOP between pressure phosphene tonometry and Goldmann applanation tonometry was 0.15±1.12 mmHg (P=.41), whereas the postoperative difference in IOP was 1.81±0.28 mmHg (P<.0001). This change in Goldmann applanation tonometry-measured IOP was

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IOP = intraocular pressure

*Table: Intraocular Pressure Using Pressure Phosphene Tonometry (PPT) and Goldmann Applanation Tonometry (GAT) Before and After LASIK*
IOP Measurement After Refractive Surgery/Shemesh et al

strongly correlated with changes in corneal thickness and in keratometry following the procedure, whereas no such correlations were found with pressure phosphene tonometry-measured IOP. The mean change in pachymetry after LASIK was 68.73±73 µm. Changes in IOP, keratometry, and pachymetry are shown in Figures 2 and 3.

DISCUSSION

The inherent changes in central corneal thickness that occur following photorefractive procedures have distinct implications on subsequent conventional IOP measurements. Goldmann applanation tonometry is based on a balance of applanating forces that are directly related to corneal rigidity (the Imbert-Fick law), and optimal IOP measurement with the tonometer is achieved at a central corneal thickness of 0.52 mm. It is well documented that increased corneal thickness leads to higher estimations of IOP and, as such, if corneal thickness decreases, IOP measurements will be underestimated. A meta-analysis published by Doughty and Zaman revealed that a 10% difference in central corneal thickness can result in as much as a 3.4±0.9 mmHg difference in IOP. Furthermore, several studies on the effect of photorefractive procedures on IOP have documented significant decreases in postoperative IOP values, thus questioning the reliability of these measurements and leading to the proposal of several methods and techniques for determining the true IOP in patients who have undergone photorefractive procedures.

Park et al suggested measuring IOP over the nasal side (flap hinge) of the cornea when using Goldmann applanation tonometry because the peripheral thickness outside the ablation zone is undisturbed: the observed reduction in IOP following LASIK was, in fact, statistically lower than the IOP measured on the central cornea. The pneumotonometer has also been found to reliably measure IOP after LASIK for myopia, although other studies have shown that non-contact tonometry is also affected by photorefractive procedures. A tonometer with a smaller applanating surface should theoretically be affected to a lesser degree by structural changes that occur in the cornea: IOP measurements by the Tono-Pen (Reichert, Depew, NY) were shown to be less affected by corneal thickness than Goldmann applanation tonometry, possibly attributable to its small (1.02 mm) applanating surface.

The pressure phosphene tonometer is based on a novel tonometric technique, which is independent of corneal thickness or rigidity. The psychophysical phenomenon of the pressure phosphene is perceived as a light surrounded by a dark inner halo and a light outer halo that can be produced by the application of a force over the globe. The source of the pressure phosphene is thought to be the bipolar cells or parts of the rods.
and cones that are situated anterior to the external limiting membrane of the retina.\textsuperscript{12,13} Deformation of the retina by the application of the pressure phosphene tonometry device on the nasal part of the closed upper eyelid produces a sensation of a temporally located phosphene.\textsuperscript{1} Intraocular pressure is read off the graticule as soon as the patient indicates the sensation of the phosphene. With appropriate instruction, the device is easy to use and causes no discomfort to the patient. Pressure phosphene tonometry has been evaluated in previous studies and its values were found to be in close agreement with those produced by Goldmann applanation tonometry.\textsuperscript{1,14} Other studies have suggested, however, that some patients are unable to perceive the phosphene and that large discrepancies are common between phosphene and applanation tonometry.\textsuperscript{13,15} No difficulties in perception of the phosphene were reported by the participants in the current study and there was good correlation in the preoperative pressure phosphene tonometry and Goldmann applanation tonometry measurements of IOP. Conversely, a statistically significant postoperative difference was found in Goldmann applanation tonometry- and pressure phosphene tonometry-measured IOP. As expected, we found a significant decrease in Goldmann applanation tonometry-measured IOP values after LASIK. No such change was observed with pressure phosphene tonometry-measured IOP. The reduction in Goldmann applanation tonometry-measured IOP was strongly correlated with the change in central corneal...
thickness and the change in mean keratometry after LASIK. This correlation seems to validate the association between the corneal profile and applanation tonometry. The fact that no analogous correlation was observed in phosphene tonometry indicates that it is independent of these parameters.

Although Goldmann applanation tonometry remains the gold standard in IOP measurement, it should be recognized that it may not be optimal under certain conditions, particularly following photorefractive surgery. Other devices, such as the phosphene tonometer, should be regarded as complementary for validating IOP.

Reliability of IOP measurement in patients who have undergone LASIK procedures is of major importance. LASIK-treated eyes are regularly prescribed topical corticosteroid drops and need to be closely monitored for induced elevation in IOP. In addition, inaccurate IOP readings may compromise future diagnosis and treatment of glaucoma in patients who have undergone photorefractive procedures.

The findings of the current study support those of other authors who have documented the effect of refractive surgery on Goldmann applanation tonometry. Intraocular pressure measurements may be surprisingly low in LASIK-treated eyes. The decrease in Goldmann applanation tonometry-measured IOP is closely correlated with the decrease in central corneal thickness and in changes in keratometry. In contrast, no such effect was seen in pressure phosphene tonometer-measured IOP, which is independent of corneal thickness. Despite the limitations of the study, a small number of patients, it appears that the pressure phosphene tonometer is a more reliable method for recording tonometry in these patients.

REFERENCES