Ocular Rigidity Evaluation After Photorefractive Keratectomy: An Experimental Study

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ABSTRACT

PURPOSE: To evaluate possible changes of the ocular rigidity coefficient in vivo after photorefractive keratectomy (PRK) in a series of rabbit eyes, using an invasive ocular rigidity measurement device.

METHODS: Sixteen eyes of 8 rabbits were used in this study. One eye from each rabbit underwent PRK for −10.00 diopters (D) in a 5-mm optical zone (92 μm) while the fellow eye served as the control. Five weeks later, the rabbits were examined under general anesthesia. The pressure–volume relationship and the ocular rigidity coefficient were determined in all 16 eyes, by injecting 200 μL of saline solution (in increments of 4.5 μL) through the limbus into the anterior chamber, while the intraocular pressure (IOP) was continually monitored with a transducer, up to a maximum limit of 40 mmHg. Data within an IOP range of 10 to 40 mmHg were used to calculate the ocular rigidity coefficient.

RESULTS: The preoperative central corneal thickness was comparable (*P*=.73, paired *t* test) in the pre-PRK eyes (mean: 347.5±17.11 μm) and control eyes (mean: 349.1±17.46 μm). No statistically significant difference was noted in measured ocular rigidity coefficient between eyes treated with PRK and control eyes (mean rigidity coefficient: 0.42±0.12 mmHg/μL [range: 0.23 to 0.56] and 0.47±0.12 mmHg/μL [range: 0.28 to 0.62], respectively, with 95% confidence interval of the difference, lower: −0.10 to upper: 0.015, *P*=.121).

CONCLUSIONS: Photorefractive keratectomy did not significantly alter ocular rigidity measurements in this experimental model. [*J Refract Surg*. 2008;24:173-177.]

For the past two decades, excimer laser refractive surgery has become popular in the field of ophthalmology and is now a common medical practice around the world. Despite the different methods used,[1-4] the objective of laser surgery is to change the curvature of the cornea by removing corneal tissue. Alterations of the corneal thickness due to refractive surgery have influenced the way in which ophthalmologists approach certain aspects of their practice, such as intraocular pressure (IOP) measurements[5-8] and power calculation of intraocular lenses for cataract surgery.[9-12] Along with these alterations induced by corneal tissue removal, additional changes in other ocular parameters such as ocular rigidity may occur.

Ocular rigidity is a measurable physical parameter of the eye that expresses the elastic properties of the globe. In 1937, Friedenwald[13] described this as a "measure of the resistance, which the eye exerts to distending forces," and developed a formula for ocular rigidity. This formula was altered when other investigators performed direct manometric measurements of the ocular rigidity in living human eyes in situ.[14-16] Supporting evidence suggests that ocular rigidity has particular relevance in several clinical situations, such as pathologic myopia (alterations in mechanical properties of myopic sclera), glaucoma, age-related macular degeneration, and changes in ocular blood flow.[17-21]

The purpose of the present study is to examine any possible induced alterations of ocular rigidity due to laser refractive surgery in a series of rabbit eyes that underwent photorefractive keratectomy (PRK).

Figure 1. Ocular rigidity measurement device representation. The computer unit and transducer readout electronics, the mechanical dosage system (similar to an infusion pump) (left), and the saline tubing manifold (right).

MATERIALS AND METHODS

Sixteen eyes of eight pigmented adult male rabbits, weighing 2.5 to 3.5 kg, were used in the study. The animals were treated in accordance with the Association for Research and Vision in Ophthalmology Statement for the Use of Animals in Ophthalmic and Vision Research. The design of the experiment was approved by the local ethics committee for animal research.

In all procedures, the animals were anesthetized by an intramuscular injection of a mixture of xylazine hydrochloride (5 mg/kg) and ketamine hydrochloride (50 mg/kg). An eyelid speculum was placed and two drops of topical anesthesia (proparacaine hydrochloride, Alcaine; Alcon Laboratories, Ft Worth,Tex) were instilled. The central corneal thickness of the eyes was measured by ultrasonic pachymetry (50 MHz, Corneogage; Sonogage Inc, Cleveland, Ohio).

One eye of each rabbit, randomly selected by coin toss, underwent PRK surgery (study group) and the other eye remained intact (control group). Two minutes after topical corneal anesthesia, mechanical epithelium debridement of the central 7.5 mm of the cornea (previously marked with a 7.5-mm trephine) was performed with a brush followed by a myopic photoablation performed using a 193-nm WaveLight Allegretto 4000 excimer laser (WaveLight Laser Technologie AG, Erlangen, Germany) with a fluence of 180 mJ/cm² per pulse at 400 Hz. The laser was programmed for −10.00 diopters (D) and a 5-mm optical zone, removing approximately 92 µm of stromal tissue. Antibiotic ointment (tobramycin and dexamethasone ointment, TobraDex, Alcon) and Ketorolac tromethamine (Acular; Allergan, Irvine, Calif) drops were given to all eyes (study and control eyes) until the corneal epithelium healed completely.

Five weeks after PRK treatment, the pressure–volume relationship and the ocular rigidity coefficient were determined for all 16 eyes using an ocular rigidity device that has been described previously.[20,21] The device consists of three units (Fig 1): the computer unit and transducer readout electronics, the mechanical dosage system (similar to an infusion pump), and the saline tubing manifold. The pressure sensitivity of the system is 0.015 mmHg. The dosage system has a volume resolution of 0.08 µL.

In every eye, 200 µL of balanced saline solution (BSS) was injected (in increments of 4.5 µL; Alcon Laboratories Inc) through the limbus into the anterior chamber, while IOP was continually monitored with a transducer, up to the maximum limit of 40 mmHg. Data within an IOP range of 10 to 40 mmHg were used to calculate the ocular rigidity coefficient (dP/dV in mmHg/µL) as the slope of the IOP versus injected volume curve (Fig 2). The pressure–volume curve and its slope were calculated from the mean values of those measurements. Before each rigidity measurement, BSS was drawn out or added into the eyeball, resulting in an initial intraocular pressure of 10 mmHg.

SPSS for Windows V 14.0 (SPSS Inc, Chicago, Ill) was used to determine statistical significance using the paired t test. Differences were considered statistically significant when $P<.05$.

RESULTS

Preoperative observed central corneal thickness was comparable ($P=.73$, paired t test) in the PRK eyes (mean: 347.5 ± 17.11 µm) and control eyes (mean: 349.1 ± 17.46 µm).

After analysis of pressure–volume curves, 16 values of rigidity coefficient dP/dV (eight values per group) were extracted. No statistically significant difference was noted in measured ocular rigidity coefficient between eyes treated with PRK and control eyes (mean rigidity coefficient: 0.42 ± 0.12 mmHg/µL [range: 0.23 to 0.56 mmHg/µL] and 0.47 ± 0.12 mmHg/µL [range: 0.28 to 0.62 mmHg/µL] in the PRK and con-
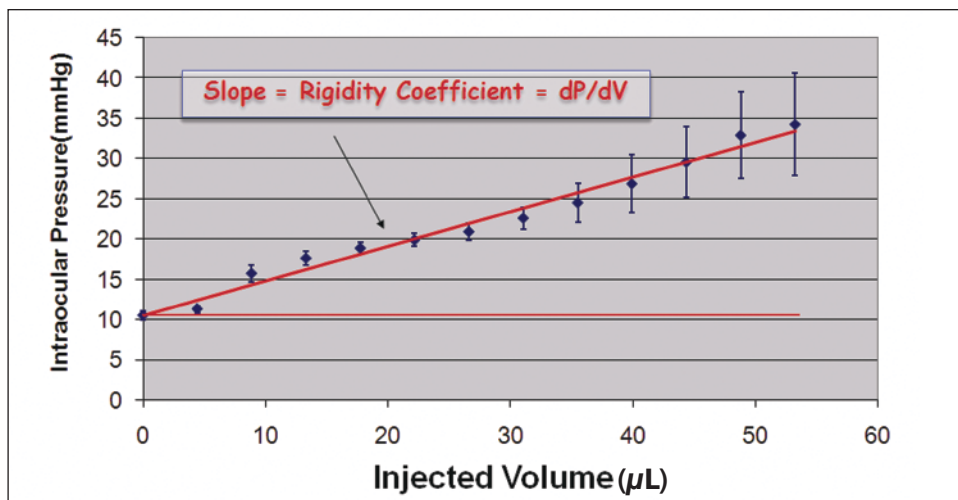
Figure 2. Data within an intraocular pressure (IOP) range of 10 to 40 mmHg were used to calculate the ocular rigidity coefficient (dP/dV in mmHg/µL) as the slope of the IOP versus injected volume curve. The pressure-volume curve and its slope were calculated from the mean values of those measurements.

trol groups, respectively, with 95% confidence interval of the difference, lower: −0.10 to upper: 0.015, P=.121). Box plot diagrams are presented in Figure 3. For both distributions, normality was followed (Kolmogorov-Smirnov: 0.200 for both samples, Shapiro-Wilks: 0.563 for the PRK group and 0.399 for the control group).

Figure 4 presents the pressure–volume curves of the mean values from the eight samples for each group. Cohen's d value for our sample size for paired t test was calculated at 0.70. This statistical power for our hypothesis was 65% with type II error 0.35 and type I error or significance level at 0.05.

DISCUSSION

Excimer laser refractive surgery has become a popular surgical procedure for the correction of refractive errors. The excimer laser sculpts a new corneal surface to correct refractive errors by removing central corneal tissue, a process called photoablation. In addition to this process, other induced alterations occur postoperatively such as changes in corneal stromal hydration, curvature, and Bowman's membrane.[1-4] All of these alterations affect corneal rigidity with several potential implications (eg, reduction of IOP applanation measurements in refractive surgery patients).[5-8] Because the ocular wall consists of the cornea (1/6) and the sclera (5/6), it is possible that the changes to the corneal rigidity induced by refractive surgery may affect the ocular rigidity.

Ocular rigidity is a measurable physical parameter of the eye that expresses the elastic properties of the globe. It has been associated with several conditions such as aging, refractive error, long-standing glaucoma, ocular pulsation, blood flow, scleral buckling, and age-related macular degeneration.[17-21] Taking into consideration the multiple correlations of ocular rigidity
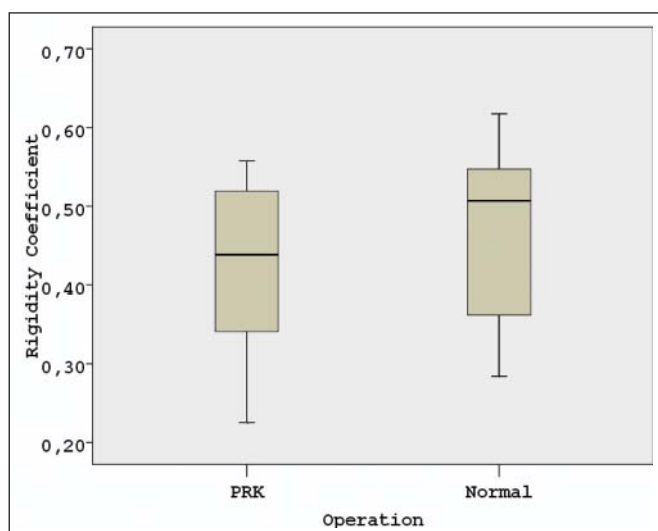

Figure 3. Mean ocular rigidity coefficient in PRK (n=8) and control (n=8) eyes.

with all of these clinical conditions, it is important to investigate the possible impact of the induced corneal changes after PRK in ocular rigidity.

Our results, using control and operated eyes, revealed that removing approximately 25% of the central corneal thickness in rabbit eyes did not result in significantly reduced ocular rigidity measurements. It seems that in the rabbit model, changes made to the cornea after PRK (reduced corneal thickness, change in corneal curvature, and stromal hydration) do not have a significant effect on ocular rigidity measurements. The observed reduction in ocular rigidity measurements in eyes treated with PRK in comparison with control eyes could possibly be due to the fact that photoablation of 25% of the corneal tissue with PRK partially affects the ocular rigidity coefficient measurements but not at a statistically significant level. It is possible that different refractive
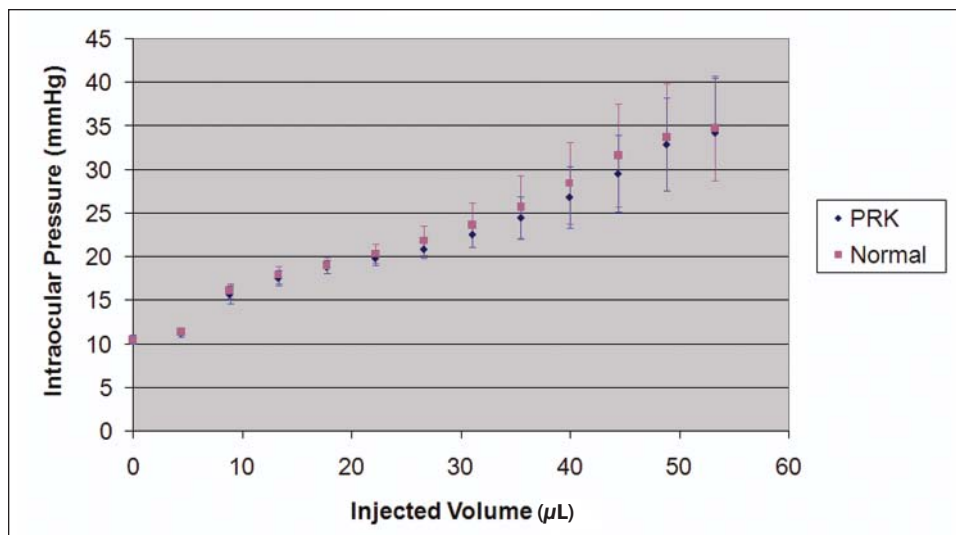
Figure 4. Pressure–volume (mmHg/μL) relation in PRK (n=8) and control (n=8) eyes.

methods (such as LASIK) or larger ablations could have a significant impact on ocular rigidity.

In addition to the examined induced corneal changes by refractive surgery, other sclera shell parameters (such as the shape of the eye) may affect the ocular rigidity coefficient measurements.[18,19] In our study, the measured ocular rigidity coefficient described the total response of the eye without separate evaluation of the function of the contributory components. Although an intricate approach taking these parameters into consideration might be more accurate, it requires complex calculations that make it less functional. It has been proposed that changes in the shape and stress distribution of the scleral shell are the main factors of the observed reduction of ocular rigidity after scleral buckling[19] or increased ocular rigidity in patients with hyperopia.[13] Furthermore, although it seems reasonable to expect ablation-induced alterations in local corneal stiffness, these changes did not result in measurable changes in total ocular rigidity.

An important limitation of the study is the anatomic differences between rabbit and human eyes. The central corneal thickness in rabbits is approximately 20% thinner than in humans and there is no Bowman's layer (which has a crucial role in corneal stability and rigidity). Both of these factors could affect the resulting stability of ocular rigidity after refractive surgery. In addition, another important parameter that should also be examined is the refractive properties of the anterior surface of the cornea that could possibly affect the measured ocular rigidity.

Our study suggests that ocular rigidity does not change significantly after excimer refractive surgery with PRK. It seems that the induced alterations in corneal rigidity with PRK are not significant enough to affect the ocular rigidity measurements. The amount of corneal tissue removed during refractive surgery procedures that could potentially affect ocular rigidity measurements remains unknown. Further investigations are needed to elucidate the possible correlation between ocular rigidity and refractive surgery.

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