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Custom air puff-derived biomechanical variables in a refractive surgery screening setting: Study from 2 centers

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Abstract

Purpose—To assess the ability of air puff-derived biomechanical variables to predict surgeon-perceived candidacy for laser in situ keratomileusis (LASIK).

Setting—Cole Eye Institute, Cleveland Clinic, Cleveland, Ohio, and Emory Eye Institute, Emory University, Atlanta, Georgia, USA.

Design—Retrospective case series.

Methods—Data were collected from refractive surgery screening examinations by 2 surgeons at 2 centers. Disqualified cases (19 eyes and 28 eyes from each surgeon) were judged not to be candidates based on available data including standard variables from the Ocular Response Analyzer. Controls consisted of LASIK candidates ($n = 26$ and 23). Three custom biomechanical variables not available during screening were calculated and compared by group and surgeon.

Results—The hysteresis loop area was significantly different between disqualified cases and controls for both surgeons (Surgeon 1: controls, 121.50 ± 25.38 [SD], disqualified, 107.62 ± 18.50 , $P = .04$; Surgeon 2: controls, 135.89 ± 22.47 , disqualified, 106.11 ± 16.40 , $P < .001$). The area under the curves of the receiver operating characteristics and the cutoff values were statistically significant for the concavity minimum and hysteresis loop area for Surgeon 1 and for all variables except concavity minimum for Surgeon 2. The hysteresis loop area had the highest odds ratio (Surgeon 1, 4.48, Surgeon 2, 20.00). Adjusted R^2 in best-subsets regressions were 40.2% for Surgeon 1 and 62.9% for Surgeon 2.

Conclusions—The hysteresis loop area was predictive of which patients were disqualified for LASIK at different sites. Certain measures of the corneal dynamic response to an air puff might serve as correlates to clinically perceived ectasia risk.

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Corneal topography and tomography are important clinical tools in the assessment of candidacy for corneal refractive surgery.^{1,2} However, some patients still develop postoperative ectasia, even with apparently normal examinations at the initial evaluation.^{3–5} Given the likelihood that abnormalities of corneal biomechanical strength are an early disease driver in keratoconus and a risk factor for development of post-refractive surgery ectasia,⁶ research efforts are underway in the area of corneal biomechanical assessment with the clinical goal of enhancing the sensitivity and specificity of preoperative risk assessment using more direct biomechanical measures.

The Ocular Response Analyzer (Reichert Ophthalmic Instruments) is a dynamic bidirectional applanation device that indirectly measures corneal deformation while stressing it with an air puff. The current commercially available device reports 2 biomechanical variables: corneal hysteresis (CH) and corneal resistance factor (CRF). Both have shown relatively low sensitivity and specificity for detecting early or preclinical ectatic disease.^{7–9} However, custom variables have been derived from alternative analyses of the deformation response that are not commercially available for the dynamic bidirectional applanation device.^{10,11} Some of these variables have been shown to produce better predictive results when compared with the standard CH and CRF, especially for keratoconus diagnosis and severity classification,^{12–14} although their performance in the setting of clinical decision making has not yet been investigated.

To address this gap in information about the relationship between custom dynamic bidirectional applanation device variables and screening decisions in the setting of clinical refractive surgery, the present study aimed to compare the objective dynamic bidirectional applanation device-derived custom variables with subjective surgeon-specific screening criteria between patients who were screened in for or disqualified from refractive surgery.

PATIENTS AND METHODS

Patients were retrospectively selected from the clinical practices of 2 surgeons: W.J.D. at the Cole Eye Institute, Cleveland Clinic, Cleveland, Ohio (Surgeon 1) and J.B.R. at the Emory Eye Center, Emory University, Atlanta, Georgia (Surgeon 2). Thus, 4 groups were formed after initial selection: disqualified patients and a control group for both centers. Candidates were seen between July 2013 and October 2015. The clinical data used in this study were acquired at the initial appointment as part of each surgeon's routine preoperative screening protocol. Institutional Review Board approvals at both Cleveland Clinic and Emory University were obtained for this retrospective chart review study.

Preoperative screening examinations included uncorrected (UDVA) and corrected (CDVA) distance visual acuities, manifest refraction, intraocular pressure measurement, slitlamp, and posterior segment evaluations, Placido topography (Atlas 9000, Carl Zeiss Meditec AG), Scheimpflug tomography (Pentacam, Oculus Optikgeräte GmbH), and dynamic bidirectional applanation device measurements. Patient age, sex, and manifest refraction spherical equivalent (MRSE) were also documented.

The disqualified group was comprised of patients advised not to have corneal refractive procedures after initial clinical evaluation because of a subjectively perceived higher risk for postoperative ectasia but without definitive clinical or tomographic signs of keratoconus. To minimize selection bias, the control group consisted of consecutive patients who were deemed suitable for myopic laser in situ keratomileusis (LASIK) after preoperative screening and had LASIK in 2015 with stable follow-up for at least 9 months. Figure 1 shows an example of a tomographic scan for each group. Exclusion criteria included any history of previous ocular surgery, corneal scars, and slitlamp and/or tomographic evidence of keratoconus. In general, the practice pattern of both investigators is to apply a decision about either eye of a refractive surgery candidate to both eyes and thus the patient's overall candidacy.

Standard Dynamic Bidirectional Applanation Device Variables

The method of operation of the dynamic bidirectional applanation device has been described in detail elsewhere.¹⁵ Concisely, a puff of air causes an inward deformation of the cornea and results in a slight concavity. This is followed by a return to its preperturbation convex shape. During this process, the plenum pressure of the air jet chamber is measured and an infrared detector system monitors the intensity of the reflected infrared signal. This quantity is a function of specular reflection of photons from the anterior corneal surface and reaches its peak when the cornea is most planar. The difference between the inward (P_1) and outward (P_2) applanation pressures is reported as the CH and is interpreted as a measure of viscous damping, reflecting the capacity of cornea and other ocular structures to absorb and dissipate energy. The CRF is closely related to CH and is a linear combination of the applanation pressure values, $P_1 - (\kappa \times P_2)$, which biases the CRF toward the pressure associated with the ingoing applanation event. The coefficient κ used in the CRF calculation was empirically set to 0.7 by the manufacturer to maximize the dependence of the CRF on the central corneal thickness.

Custom Dynamic Bidirectional Applanation Device Variables

The infrared intensity, pressure, and time series data from the dynamic bidirectional applanation device were exported using the device's software and analyzed in custom code (Matlab, Mathworks, Inc.) that provides 15 custom variables as previously described by Hallahan et al.¹⁰ From this set of variables, 3 were selected for the current analysis based on previous performance in differentiating normal and keratoconus eyes,¹⁰ as well as surgical changes after refractive surgery¹¹ and corneal crosslinking¹⁶: hysteresis loop area, concavity minimum (Concavity_{min}), and concavity mean (Concavity_{mean}). Their definitions and interpretations are presented in Table 1.

Statistical Analysis

Based on significant intraclass correlation, only the right eye of each patient was included in this assessment. Statistical comparisons were performed only between control and disqualified groups within each surgeon's group and not between surgeons. Statistical analysis was performed using SPSS software (version 20.0, IBM Corp.), Medcalc (version 15.11.4, Medcalc Software bvba), and Minitab software (version 18, Minitab, Inc.). The normality of all data samples was checked with the Shapiro-Wilk test. Data were expressed

as means $\pm$ SD. The means of all variables were evaluated separately for each group using the Student *t* test for independent samples.

In addition, the area under the curve (AUC) of the receiver operating characteristic (ROC) was calculated for all variables, according to the method described by DeLong et al.¹⁷ The *Z* statistic was calculated for each variable with statistically significant values in the AUC analysis to directly compare the discriminative performance of each dynamic bidirectional applanation device variable, as described by Hanley and McNeil.¹⁸ Odds ratios (ORs) were calculated for each variable based on the cutoff values determined by ROC curve analysis. Finally, a binary logistic best subsets regression was fit for each group to characterize the strongest single and multipredictor models of surgeon decision.

RESULTS

The study evaluated 96 eyes of 96 patients. Surgeon 1's group consisted of 19 disqualified eyes and 26 control eyes and Surgeon 2's group consisted of 28 disqualified eyes and 23 control eyes. The minimum detectable difference in hysteresis loop area was 23.71 for Surgeon 1 and 18.98 for Surgeon 2, assuming 80% power in both groups. Table 2 shows the descriptive statistics in each group. Age was not significantly different between any group. The mean keratometry (K) and thinnest point in corneal thickness values were significantly different between disqualified and control eyes in both groups.

Table 3 shows the custom and standard variables comparisons for the dynamic bidirectional applanation device. Of the 5 variables evaluated (CH, CRF, hysteresis loop area, Concavity_{min}, and Concavity_{mean}), only the hysteresis loop area was statistically different between disqualified and control patients in both clinical practices. Table 4 shows the ROC curve and AUC analysis results, whereas Figure 2 shows the ROC curves in each group. For Surgeon 1, Concavity_{min} and hysteresis loop area had statistically significant ROC curves and cutoff values, whereas for Surgeon 2, all variables except Concavity_{min} were significantly different in the control and disqualified groups. The *Z* tests between variables that were significantly different were performed within each surgeon group. The objective of performing *Z* tests is to compare their performance as predictors of clinical decision by doing a pairwise comparison of 2 AUCs. For Surgeon 1, the *Z* value for the 2 variables (Concavity_{min} and hysteresis loop area) was 0.619 with a 95% confidence interval of the difference of -0.143 to 0.214 ($P = 0.7$). Table 5 shows the results of the multiple *Z* tests of Surgeon 2's variables, for which only the comparison between hysteresis loop area and Concavity_{mean} approached significance ($P = .07$). Of all the standard and custom variables studied, the hysteresis loop area showed the highest OR value for each practice among the dynamic bidirectional applanation device variables (Table 6).

Finally, geometric parameters were also analyzed to check for their discriminatory behavior in each dataset (Table 4). In the Surgeon 1 dataset, the AUC for mean K was and the thinnest point in corneal thickness showed a statistically significant ROC curve (both $P < .001$). In the Surgeon 2 dataset, only the thinnest point in corneal thickness showed a statistically significant ROC curve ($P < .001$). For both surgeons, none of the geometric variable's ROC

curves were statistically different from the dynamic bidirectional applanation device variables.

Binary logistic best-subset regression analyses for each surgeon were performed to provide a secondary assessment of how the 7 tomographic and biomechanical variables (listed in Table 4) related to surgeon decision. The single variable thinnest point in corneal thickness was the strongest lone predictor of each surgeon's decision about LASIK eligibility, with an adjusted R^2 of 27.8% for Surgeon 1 and 49.5% for Surgeon 2. The optimal models for each surgeon included 3 variables: for Surgeon 1, thinnest point in corneal thickness, mean K, and Concavity_{min} (adjusted R^2 = 40.2% and Mallows C_p = 2.0) and for Surgeon 2, thinnest point in corneal thickness, CRF, and Concavity_{mean} (adjusted R^2 = 62.9% and Mallows C_p = 2.0).

DISCUSSION

Until now, the behavior of the dynamic bidirectional applanation device in the setting of refractive surgery screening has not been explicitly investigated. Previous studies have demonstrated variable sensitivity and specificity for standard and custom variables for differentiating various clinical and surgical states,^{7–10,15,19} but have not directly related candidate variables to the surgeon's decision to recommend LASIK. In the present study, the custom variable hysteresis loop area was the most consistent predictor of clinical decision making across both surgeon sites and was the only air puff-derived variable that demonstrated statistical significance in both practices.

Hallahan et al.¹⁰ demonstrated that among 15 custom variables derived at the Cleveland Clinic, Concavity_{min}, hysteresis loop area, and Concavity_{mean} had the 3 highest AUC values when comparing keratoconic and normal eyes. Similarly, in the present study, the Concavity_{min} and hysteresis loop area had the highest AUC values, but only the hysteresis loop area was a statistically significant discriminator of clinical decision across both surgeon practices. The method by which the hysteresis loop area is calculated represents a more comprehensive measure of hysteresis than CH because it encompasses the majority of the corneal stress–strain response over the response cycle rather than just air-puff pressure difference between the 2 applanation endpoints.^{10,20} The discriminative advantage of a variable such as hysteresis loop area might be that it quantifies response features beyond a single temporal value or signal feature and therefore gains sensitivity to elastic and viscous response components while reducing variability by increasing spatial and temporal sampling. This increase in signal-to-noise performance could account for the high ORs found for hysteresis loop area and supports its correlation to the clinically perceived risk for postoperative ectasia across experienced surgeon practices.

Not surprisingly, geometric variables, especially thinnest point in corneal thickness, were also correlated with LASIK disqualification. In secondary analyses with the primary goal of characterizing their relationship to each surgeon's disqualification practice patterns, the thinnest point in corneal thickness and mean K were analyzed alongside the dynamic bidirectional applanation device variables in ROC analyses and best-subsets regression analyses. The latter produced marginally predictive regression models of surgeon decisions that reflected potential post hoc differences in disqualification characteristics. A corneal

thickness metric was the strongest lone correlate for both surgeons and this probably reflects both the availability of the variable at the time of screening and the common practice pattern of excluding patients from LASIK based on corneal thickness considerations. A corneal curvature metric was in the best 3-predictor model only for Surgeon 1, and the remaining variables in the 3-predictor models were all dynamic bidirectional applanation device variables. Corneal biomechanical variables are obtained through an entirely different (dynamic) methodology than corneal thickness and curvature metrics (static). The latter are much more established elements of the screening process and thus more likely to directly influence the surgeons' decisions, and the present study provides new insight into the association of both types of data with clinical decision making in the setting of LASIK screening.

The current study was designed to determine whether and to what degree various dynamic bidirectional applanation device variables corresponded to a surgeon's perception of risk as indicated by the final binary disposition of the patient (LASIK was offered versus LASIK was not offered); this is different in concept and design from the question of whether and to what degree the dynamic bidirectional applanation device variables can predict the development of post-LASIK ectasia. The study was retrospective in nature and limited in terms of sample size and the number of surgeons across which to compare the performance of variables. Comparisons were performed within each practice as well across practices to reduce the impact of the dynamic bidirectional applanation device generation and software version as confounding factors and to enhance the generalizability of the findings. Even though the sample sizes were large enough to support statistically significant differences in the dynamic bidirectional applanation device's custom variables across both sites, the demonstrated differences between cohorts reinforce the likelihood of surgeon or site-specific differences in behavior of the dynamic bidirectional applanation device's variables related to differences in patient characteristics, sample sizes, and surgeon practice patterns. The investigators were not masked to standard dynamic bidirectional applanation device variables (CH and CRF) during the clinical screening process, hence these variables were available to each surgeon according to their standard practice patterns together with the other clinical information available at the screening visit. Although a prospective design with masking of standard dynamic bidirectional applanation device variables would have removed the effect of CH and CRF on clinical decision making, the intent of the study was to assess the ability of a custom dynamic bidirectional applanation device variable that was *not* available at the time of screening to predict a clinical decision given each surgeon's present practice pattern, which includes use of the standard variables from the only currently U.S. Food and Drug Administration-approved device for clinical corneal biomechanical measurement. The retrospective design also reduces the risk that the surgeons would inadvertently bias their screening decisions based on a priori knowledge of the study design and purpose. Despite the lack of masking to CH and CRF, these variables were not consistent predictors of surgical decision across sites and the ORs were consistently higher for the hysteresis loop area, a variable that both investigators were masked to because of the post hoc nature of the calculation.

In summary, this study demonstrated that a custom biomechanical variable derived from the output of a widely available clinical device was a predictor of clinically determined LASIK

candidacy across 2 academic practices. Although previous studies have focused on the ability of biomechanical metrics to differentiate normal eyes from those with manifest or preclinical ectasia, the current results suggest that measures of viscoelastic corneal behavior correlate with clinical impressions of post-LASIK ectasia risk. These findings support the clinical relevance of corneal biomechanical measurement in a refractive surgery screening setting and punctuate the need for ongoing efforts to devise more direct measures of corneal biomechanical properties for clinical use.

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WHAT WAS KNOWN

- Standard and investigator-derived measures of the cornea's dynamic response to an air puff have been shown to have varying degrees of predictive value for discriminating normal and keratoconic eyes.
- Although a motivation for such work is to explore the usefulness of such variables for refractive surgery screening, no previous study has investigated the relationship between these variables and clinical decision making in refractive surgery screening patients without manifest signs of keratoconus.

WHAT THIS PAPER ADDS

- This was the first study to characterize the relationship between air puff-based biomechanical measurements and clinical decisions on LASIK candidacy.
- Corneal thickness and mean K were predictors of LASIK disqualification.
- Several dynamic bidirectional applanation device variables were significant predictors of LASIK disqualification; however, 1 custom variable the hysteresis loop area was significant across both practices and had the highest OR for disqualification.

Figure 1.

A: Example of tomography from a control group patient. The CDVA was 20/15 and MRSE error was -4.75 diopters (D). **B:** Example of tomography from a patient disqualified from LASIK. Note the decentered apex associated with a thin cornea (thinnest point = $468\text{ }\mu\text{m}$) and anterior and posterior corneal elevation and steep features co-localizing with the thinnest point. The CDVA was 20/20 and MRSE error was -6.25 D (ABS = absolute scale; BFS = best fit sphere; CDVA = corrected distance visual acuity; LASIK = laser in situ keratomileusis; MRSE = manifest refraction spherical equivalent; Pachy = pachymetry).

Figure 2.

Receiver operating characteristic curves for 5 biomechanical variables in the discrimination of patients disqualified from LASIK and those scheduled for LASIK at centers 1 (A) and 2 (B) (CH = corneal hysteresis; ConcavMean = concavity mean; ConcavMin = concavity minimum; CRF = corneal resistance factor; HLA = hysteresis loop area; LASIK = laser in situ keratomileusis).

Table 1

Variables derived from the signal of the dynamic bidirectional applanation device.

Variable	Operational Definition	Interpretation
CRF [*]	$P_1 - (0.7 \times P_2)$	Difference in applanation pressures, weighted toward pressure required to produce first applanation, maximizing correlation to CCT
CH [*]	$P_2 - P_1$	Difference in pressures between the 2 applanation events, ie, single cross-section of the pressure-deformation relationship
Concavity _{min} [†]	Minimum applanation intensity between peak intensity of 1st and 2nd applanation event	Depth and irregularity (non-planarity) of deformation
Concavity _{mean} [†]	Mean applanation intensity between peak intensity of 1st and 2nd applanation event	Depth and irregularity of deformation, averaged
Hysteresis loop area [†]	Area enclosed by pressure vs. applanation function	Hysteresis aggregated over entire deformation cycle except concavity

Concavity_{mean} = concavity mean; Concavity_{min} = concavity minimum; CCT = central cornea thickness; CH = corneal hysteresis; CRF = corneal resistance factor

^{*} Dynamic bidirectional applanation device standard variable

[†] Dynamic bidirectional applanation device custom variable

Table 2

Age and corneal tomographic characteristics of the group disqualified from LASIK and the control group.

Variable	Mean $\pm$ SD		P Value
	Disqualified Group	Control Group	
Age (y)			
Surgeon 1	31.16 $\pm$ 5.53	33.38 $\pm$ 9.13	.19
Surgeon 2	33.61 $\pm$ 8.08	36.38 $\pm$ 11.13	.15
Km (D)			
Surgeon 1	44.86 $\pm$ 1.29	43.34 $\pm$ 1.34	<.001 *
Surgeon 2	44.20 $\pm$ 1.12	43.37 $\pm$ 1.23	<.001 *
TPCT (μ m)			
Surgeon 1	514.47 $\pm$ 37.08	556.08 $\pm$ 26.88	<.001 *
Surgeon 2	508.23 $\pm$ 23.05	560.60 $\pm$ 31.48	<.001 *

Km = mean keratometry; TPCT = thinnest point in corneal thickness

* Statistically significant

Table 3

Preoperative variables derived from the dynamic bidirectional applanation device in the patients disqualified from LASIK group and the patients scheduled for LASIK (control group).

Variable	Mean $\pm$ SD		P Value
	Disqualified Group	Control Group	
Concavity _{min}			
Surgeon 1 *	58.99 $\pm$ 9.21	65.88 $\pm$ 11.76	.04 †
Surgeon 2 ‡	51.96 $\pm$ 8.51	56.31 $\pm$ 8.32	.07
Concavity _{mean}			
Surgeon 1 *	140.88 $\pm$ 21.68	153.64 $\pm$ 27.13	.10
Surgeon 2 ‡	132.72 $\pm$ 15.44	154.14 $\pm$ 20.21	<.001 †
CRF (mm Hg)			
Surgeon 1 *	9.67 $\pm$ 1.97	10.73 $\pm$ 2.09	.90
Surgeon 2 ‡	9.39 $\pm$ 1.57	12.12 $\pm$ 1.78	<.001 †
CH (mm Hg)			
Surgeon 1 *	10.19 $\pm$ 1.72	10.83 $\pm$ 1.44	.18
Surgeon 2 ‡	9.84 $\pm$ 1.29	12.00 $\pm$ 1.79	<.001 †
HLA $\times 10^3$			
Surgeon 1 *	107.62 $\pm$ 18.50	121.50 $\pm$ 25.38	.04 †
Surgeon 2 ‡	106.11 $\pm$ 16.40	135.89 $\pm$ 22.47	<.001 †

CH = corneal hysteresis; Concavity_{mean} = concavity mean; Concavity_{min} = concavity minimum; CRF = corneal resistance factor; HLA = hysteresis loop area

* Dynamic bidirectional applanation device hardware v 2.0, software v 4.0

† Statistically significant

‡ Dynamic bidirectional applanation device hardware v 2.11, software v 3.01

Table 4

Comparison of the AUC of the ROC, cutoff, sensitivity, and specificity between standard and custom variables.

Variable	Mean AUC $\pm$ SD	P Value (Area = 0.5)	Cutoff	Sensitivity (%)	Specificity (%)
Km					
Surgeon 1	0.799 $\pm$ 0.070	<.001 *	44.25	73.7	84.6
Surgeon 2	0.599 $\pm$ 0.082	.22	44.70	50.0	82.6
TPCT					
Surgeon 1	0.800 $\pm$ 0.070	<.001 *	542	79.0	73.1
Surgeon 2	0.923 $\pm$ 0.035	<.001 *	533	92.9	73.9
Concavity _{min}					
Surgeon 1	0.698 $\pm$ 0.080	.01 *	60.50	57.9	76.9
Surgeon 2	0.641 $\pm$ 0.079	.07	46.29	35.7	91.3
Concavity _{mean}					
Surgeon 1	0.646 $\pm$ 0.083	.08	158.10	79.0	50.0
Surgeon 2	0.798 $\pm$ 0.061	<.001 *	137.55	60.7	87.0
CRF					
Surgeon 1	0.660 $\pm$ 0.085	.06	9.90	68.4	65.4
Surgeon 2	0.877 $\pm$ 0.048	<.001 *	10.40	78.6	82.6
CH					
Surgeon 1	0.630 $\pm$ 0.088	.14	10.00	57.9	69.2
Surgeon 2	0.847 $\pm$ 0.056	<.001 *	10.90	85.7	78.3
HLA					
Surgeon 1	0.665 $\pm$ 0.083	.04 *	120000	79.0	61.5
Surgeon 2	0.873 $\pm$ 0.050	<.001 *	114810	78.6	87.0

AUC = area under the curve; CH = corneal hysteresis; Concavity_{mean} = concavity mean; Concavity_{min} = concavity minimum; CRF = corneal resistance factor; HLA = hysteresis loop area; Km = mean keratometry; ROC = receiver operating characteristic; TPCT = thinnest point in corneal thickness

* Statistically significant

Table 5

Z test results for statistically significant dynamic bidirectional applanation device variables in Surgeon 2's group.

Variable	Concavity _{mean}			CRF			CH		
	Z Value (95% CI)	P Value		Z Value (95% CI)	P Value		Z Value (95% CI)	P Value	
HLA	1.846 (−0.001, 0.154)	.07		0.099 (−0.088, 0.097)	.9		0.390 (−0.103, 0.154)	.7	
CH	0.622 (−0.105, 0.203)	.5		0.835 (−0.041, 0.101)	.4		—	—	
CRF	1.127 (−0.059, 0.217)	.3		—	—		—	—	

CH = corneal hysteresis; CI = confidence interval; Concavity_{mean} = concavity mean; CRF = corneal resistance factor; HLA = hysteresis loop area

Table 6

The ORs and CIs for statistically significant variables at each surgeon's clinical site.

Group/Risk Factor	Disqualified Group (%)	Control Group (%)	OR	95% CI	P Value
Surgeon 1					
Concavity _{min} <60.50	52.6	23.1	3.70	1.02, 13.35	.04
HLA <120,000	73.7	38.5	4.48	1.23, 16.29	.02
TPCT <542 µm	73.7	30.0	9.33	2.37, 36.71	.001
Km >44.25 D	78.9	15.4	15.4	3.52, 67.36	<.001
Surgeon 2					
Concavity _{mean} <137.55	57.1	13.0	8.89	2.14, 36.99	.003
CRF < 10.4 mm Hg	75.0	17.4	14.25	3.60, 56.44	<.001
CH < 10.9 mm Hg	82.1	21.7	16.56	4.15, 66.13	<.001
HLA <114810	75.0	13.0	20.00	4.53, 88.27	<.001
TPCT <533 µm	89.3	26.1	23.61	5.18, 107.60	<.001

CH = corneal hysteresis; CI = confidence interval; Concavity_{mean} = concavity mean; Concavity_{min} = concavity minimum; CRF = corneal resistance factor; HLA = hysteresis loop area; Km = mean keratometry; OR = odds ratio; TPCT = thinnest point in corneal thickness