Published in final edited form as:

Am J Ophthalmol. 2010 August ; 150(2): 163–168.e1. doi:10.1016/j.ajo.2010.02.024.

Comparison of Corneal Biomechanical Properties between Healthy Blacks and Whites Using the Ocular Response Analyzer

Mauro T. Leite¹, Luciana M. Alencar¹, Charlotte Gore¹, Robert N. Weinreb¹, Pamela A. Sample¹, Linda M. Zangwill¹, and Felipe A. Medeiros¹

¹ Hamilton Glaucoma Center, Department of Ophthalmology, University of California San Diego, La Jolla, CA. 9415 Campus Point Drive, La Jolla, CA 92093

Abstract

Purpose—To analyze and compare corneal biomechanical properties in healthy black and white subjects using the Ocular Response Analyzer (ORA; Reichert Inc, Depew, NY) and to evaluate their relationship with other ocular parameters.

Design—Observational cross-sectional study.

Methods—One hundred eighty eyes (46 blacks, 134 whites) of 119 patients (37 blacks, 82 whites) were recruited from the longitudinal Diagnostic Innovations in Glaucoma Study (DIGS) and from the African Descent and Glaucoma Evaluation Study (ADAGES) at the University of California, San Diego. Corneal curvature, axial length, central corneal thickness (CCT), corneal hysteresis (CH) and corneal resistance factor (CRF) were obtained from all participants. Univariable and multivariable regression analyses were used to evaluate the associations between ORA measurements and age, CCT, axial length, corneal curvature and race.

Results—Black subjects had significantly lower values of CH (9.7mmHg versus 10.4 mmHg; $P=0.033$), CRF (9.84mmHg versus 10.70mmHg; $P=0.028$) and CCT (534 μ m versus 562 μ m; $P=0.001$) compared to whites. A significant relationship was found between CH and CCT ($R^2=0.25$; $P<0.001$) and between CRF and CCT ($R^2=0.42$; $P<0.001$). After adjusting for CCT, age, axial length and corneal curvature, the difference between blacks and whites in CH ($P=0.077$) and CRF ($P=0.621$) measurements lost statistical significance.

Corresponding author: Felipe A. Medeiros, Hamilton Glaucoma Center, University of California, San Diego, 9500 Gilman Drive, La Jolla, CA 92093-0946; phone/fax: (858) 822-4592, fmedeiros@eyecenter.ucsd.edu.

This is an original submission and has not been considered elsewhere.

Mauro T Leite and Felipe A Medeiros had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis as well as the decision to submit for publication.

b. Financial disclosures: MT Leite, none; LM Alencar, none; C. Gore, none; RN Weinreb, Heidelberg Engineering, Carl Zeiss Meditec, Inc.; PA Sample, Carl Zeiss (Financial support); LM Zangwill, Carl Zeiss Meditec, Inc. (Financial support), Heidelberg Engineering, GmbH (Financial support), Optovue, Inc. (Financial support), Topcon Medical Systems, Inc.; FA Medeiros, Carl Zeiss, Heidelberg Engineering, Reichert, Inc.

c. Contributions of Authors: Design of the study (MTL, LMA, FAM); analysis and interpretation (MTL, LMA, FAM); writing the article (MTL, LMA, FAM); critical revision of the article and final approval (MTL, LMA, CG, RNW, PAS, LMZ, FAM); data collection (MTL, LMA, CG); provision of materials, patients, or resources (RNW, PAS, LMZ, FAM); statistical expertise (MTL, LMA, FAM); obtaining funding (RNW, PAS, LMZ, FAM); literature search (MTL, CG); administrative, technical, or logistic support (RNW, PAS, LMZ, FAM)

d. Statement about Conformity with Author Information: This study was approved by the University of California San Diego Human Subjects Committee and adhered to Declaration of Helsinki. Informed consent was obtained from all participants.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Conclusion—Black subjects tended to have lower measurements of corneal hysteresis compared to white subjects, however, this was largely explained by differences in corneal thickness. Therefore, it is unlikely that CH would have an independent effect in explaining differences in susceptibility of disease between these two racial groups.

INTRODUCTION

Goldmann applanation tonometry (GAT) has been considered the reference standard for intraocular pressure (IOP) measurement for several decades. However, there are numerous sources of error that may significantly influence IOP readings obtained with GAT, notably corneal thickness.^{1, 2} IOP may be overestimated or underestimated in eyes with thick or thin corneas, respectively, resulting in misclassification and mismanagement of a significant number of glaucoma patients and subjects with ocular hypertension. In addition, several clinical trials have shown that corneal thickness is a risk factor for both development as well as progression of glaucoma, and there is speculation that this effect may be independent of its role in affecting GAT measurements.^{3–5}

Important differences have been described in corneal thickness measurements in blacks compared to whites. According to clinic-based^{3, 6–10} and population-based studies,¹¹ blacks have thinner corneas than whites, which can potentially be related to a higher risk of glaucoma development and possibly to the more aggressive rates of disease progression frequently found in the former group. The thickness of the cornea, however, is just one among several corneal physical properties that influence the measurement of IOP with applanation tonometry. Other biomechanical parameters such as elasticity or viscoelastic properties may also influence corneal resistance to applanation and, therefore, IOP measurements obtained by GAT.^{12, 13} Previous investigators have shown that corneal hysteresis (CH), a corneal biomechanical property related to viscoelastic dampening, is reduced in glaucomatous compared to healthy eyes and is a risk factor for glaucoma progression that appears to be independent of corneal thickness.^{14–16} In addition, a recent study suggested that corneal hysteresis, but not corneal thickness, is associated with optic disc surface compliance, which may ultimately be related to glaucoma pathogenesis.¹⁷ Therefore, it is possible that differences in corneal hysteresis could potentially be related to differences in disease outcomes in blacks compared to whites.

Despite the potential relevance of corneal hysteresis, no study has yet compared corneal hysteresis measurements in blacks and whites. The Ocular Response Analyzer (ORA; Reichert Inc, Depew, NY) measures corneal biomechanical properties, such as corneal hysteresis and corneal elasticity by analyzing corneal responses submitted to air jet-induced deformation. The purpose of this study was to analyze and compare corneal biomechanical properties using the ORA in a healthy population of blacks and whites, and investigate their relationship with other ocular parameters.

METHODS

This was an observational cross-sectional study. All participants included in this study were retrospectively selected from the longitudinal Diagnostic Innovations in Glaucoma Study (DIGS) and the African Descent and Glaucoma Evaluation Study (ADAGES)⁸ conducted at the Hamilton Glaucoma Center, University of California, San Diego. Briefly, these studies were designed to evaluate optic nerve structure, visual function, and risk factors in glaucoma. For this particular study, we have included a cohort of healthy participants recruited by advertisement from the general population. Participants were asked to identify their racial category by self-reporting using the National Eye Institute inclusion/enrollment system (<http://orwh.od.nih.gov/pubs/outreach.pdf> [page 22]).

All individuals underwent a complete ophthalmologic examination, including visual acuity assessment, slit-lamp biomicroscopy, gonioscopy, dilated fundoscopic examination using 78-diopter lens, stereoscopic disc photography, and, automated perimetry using the 24-2 Swedish Interactive Threshold Algorithm (SITA; Carl Zeiss Meditec, Inc., Dublin, CA). Central corneal thickness was measured using an ultrasound pachymeter (Pachette DGH 500; DGH Technology, Inc, Philadelphia, PA) over an undilated pupil and the mean of 3 readings was recorded. Corneal curvature was obtained using an autorefractor (Humphrey - Zeiss model S97; Carl-Zeiss Meditec, Dublin, CA). Axial length was acquired with IOLMaster (Carl-Zeiss Meditec, Dublin, CA).

All eyes included in this study had best-corrected visual acuity of 20/40 or better, normal fundus examination results with a healthy appearance of the optic disc and retinal nerve fiber layer, open-angle at gonioscopy, and normal visual field. A normal visual field was defined as a mean deviation and a pattern standard deviation within the 95% normal confidence limits and glaucoma hemifield test results within normal limits. Participants were excluded if they had previous use of anti-glaucoma medication or any previous ocular surgery. Intraocular pressure was not used as an inclusion or exclusion criterion.

Corneal biomechanical properties were measured using software version 2.02 of the ORA. Briefly, the ORA utilizes an air pulse to flatten the corneal surface causing the cornea to shift inward, passing from a flat to a concave state. As the air pulse decreases, the cornea returns first to a flat state, and then to its initial convex shape. An electro-optical collimator-detector records the two applanation events (P1 and P2) produced by the bidirectional movement of the cornea. The time difference between the first and the second applanation is approximately 20 milliseconds, short enough to ensure that eye position or ocular pulse does not change during examination.

The device provides four different readings. Corneal hysteresis is defined as the numerical difference between the two applanation states ($P1 \text{ minus } P2$), being an indicator of viscoelastic dampening. Corneal-compensated IOP (IOPcc) is an IOP measurement that minimizes corneal influence. It is calculated as $(P1 - k) * P2$. Where k is a constant derived from previous studies evaluating eyes that underwent corneal change induced by LASIK.¹⁸ IOP goldmann (IOPg) is the Goldmann applanation tonometer correspondent in this device, and is calculated as the average of P1 and P2. Corneal resistance factor (CRF) is a measurement of another corneal biomechanical property, the resistance to deformation. To ensure quality of the readings, images were reviewed and images with applanation peaks on the ORA waveform that were fairly symmetrical in height were included. Also, we included only measurements with a wavelength score of 7 or higher marked as best signal value. We obtained at least two measurements per eye and selected the one with the highest quality score for the analysis. These scores are a direct reflection of signal quality and reliability of measurements. Although strict cut-off points for wavelength score have not yet been determined in the literature, a score over 7 has been suggested by the manufacturer (David Taylor, Reichert Inc, personal communication) as indicative of good quality.

Statistical Analysis

Initially, we used univariable models to evaluate differences in ocular biomechanical properties and other ocular parameters between blacks and whites. Subsequently, we built multivariable models to evaluate differences in corneal biomechanical parameters, i.e., CH and CRF, in blacks versus whites while adjusting for differences in other parameters such as age, corneal thickness, axial length and corneal curvature. The multivariable models were built in two steps. First, differences in CH and CRF between blacks and whites were adjusted for age, corneal thickness, axial length and corneal curvature; simultaneously, in a

full model. Then, a reduced multivariable model was built adjusting only for covariates that significantly influenced CH and CRF, based on results from the full model.

In addition, we studied the association among corneal properties (CH, CRF, CCT, axial length and curvature) using linear regression models.

Generalized estimating equations with robust standard error in a Huber-White matrix sandwich were used to adjust for potential correlations between both eyes of the same individual.

Statistical analyses were performed with commercially available software (STATA v. 10.0; StataCorp, College Station, TX and SPSS v.16.0; SPSS Inc, Chicago, IL). A P value less than 0.05 was considered statistically significant.

RESULTS

The study included a total of 181 eyes (135 whites, 46 blacks) of 119 participants (82 whites, 37 blacks). The mean (standard deviation) age of the included subjects was 64.13 (13.33) years, ranging from 24 to 90 years. On average, white subjects were older than blacks (66 years versus 58 years; $P=0.009$).

Table 1 shows the results of the comparison of ocular parameters between blacks and whites. Mean CCT was significantly lower in blacks compared to whites (534 μ m versus 562 μ m; $P=0.001$). Blacks had significantly lower CH values compared to whites (9.7mmHg versus 10.4 mmHg; $P=0.033$) and CRF measurements were also significantly lower in blacks than whites (9.84mmHg versus 10.70mmHg; $P=0.028$). No statistically significant difference between blacks and whites was found for axial length, corneal curvature, IOPg, IOPcc and GAT measurements.

No statistically significant association was found between CCT and both axial length ($P=0.569$) and corneal curvature ($P=0.496$). Axial length was significantly associated with corneal curvature ($P<0.001$). For each 1mm increase in axial length, the curvature was reduced by 0.82D.

Figure 1 shows a locally weighted scatterplot smoothing (LOWESS) of CH versus CCT measurements according to racial group. The observed relationship was close to linear. A significant association was seen between CH and CCT, with lower CH measurements in eyes with thinner corneas, for both blacks ($R^2=0.41$; $P<0.001$) and white subjects ($R^2=0.16$; $P<0.001$), with no statistically significant difference between the two groups ($P=0.08$, for interaction variable). Considering all participants from both racial groups, each 100 μ m increase in corneal thickness was associated with a 2.14 mmHg increase in CH.

A multivariable model was then built to evaluate differences in CH measurements between the two racial groups (Table 3). Only age and CCT were significantly associated with CH. Differences in CH measurements between blacks and whites were not statistically significant in the full multivariable model ($P = 0.07$) as well as in a reduced multivariable model adjusting only for age and CCT ($P = 0.120$).

Table 4 shows the correlations between CRF and other clinical and ocular parameters. A significant association was also seen between CRF and CCT, with lower CRF measurements in eyes with thinner corneas. Figure 2 shows a LOWESS scatterplot of CRF versus CCT measurements according to race, which showed a nearly linear pattern of association. Significant relationships between CRF and CCT were observed for both blacks ($R^2=0.59$; $P<0.001$) and white subjects ($R^2=0.32$; $P<0.001$), but the difference between the two groups

did not reach statistical significance ($P = 0.06$, for interaction variable). Considering all subjects from both racial groups, each 100 μm increase in corneal thickness was associated with a 3.11 mmHg increase in CRF. Table 4 shows the results of a multivariable regression model for CRF including race and other clinical and ocular parameters as independent variables. Only CCT showed a statistically significant relationship with CRF with no statistically significant coefficient associated with race ($P = 0.621$). When adjusted for CCT only, CRF differences between blacks and whites were not statistically significant ($P = 0.759$).

DISCUSSION

In the present study, black subjects had lower CH and CRF values when compared to whites. However, these differences became non-significant when adjusted for differences in central corneal thickness between the two racial groups. Therefore, our findings suggest that differences in corneal hysteresis between blacks and whites are largely due to differences in corneal thickness measurements found between these two groups, rather than reflecting an additional structural difference between their corneas.

Previous studies have shown that glaucomatous patients have lower values of corneal hysteresis compared to normal subjects.^{14, 16, 19} Congdon et al.¹⁴ found that lower corneal hysteresis values are related to visual field progression, even after adjusting for CCT. In another study by Wells et al.,¹⁷ corneal hysteresis measurements were associated with increased deformation of the optic disc surface, i.e., optic disc compliance, when eyes were submitted to an artificial elevation of the IOP. Although the relationship between corneal hysteresis and glaucoma pathogenesis has not yet been elucidated, these studies suggest a potential role of corneal hysteresis measurements as a simple test that could be of prognostic significance in glaucoma. Although we found differences in corneal hysteresis measurements between blacks and whites in our study, they were largely explained by differences in CCT between the two groups. Therefore, it is unlikely that CH would have a large independent effect in explaining differences in susceptibility to glaucoma damage between these two racial groups.

A significant relationship was seen between CCT and CH in our study. For each 100 μm of increase in CCT we found a 2.14mmHg increase in CH. This association has been also reported by Mangouritas et al.¹⁵ They found that the relationship between CCT and CH was strong for normal patients and only moderate for treated glaucomatous patients. The authors suggested that glaucomatous patients have, in addition to thickness, different corneal biomechanical properties that may be related to the pathogenesis of the disease. In the present study, we evaluated the relationship between CH and CCT separately according to race. No significant difference was found, suggesting that changes in central thickness and CH have the same relationship in both racial groups. Therefore, for the same corneal thickness a similar average CH value would be expected in both races.

The CRF is a measurement of corneal resistance to deformation and, theoretically, reflects elasticity, another biomechanical property. We found a significant relationship between central corneal thickness and CRF in the present study. For each 100 μm of increase in CCT we found a 3.11 mmHg increase in CRF. A study by Liu and Roberts¹³ demonstrated that differences in corneal elasticity could have a higher influence on applanation tonometry than corneal thickness alone. Medeiros et al.,¹² reported that CRF could influence IOPg measurements even after adjusting for CCT, however, neither CCT nor CRF influenced IOPcc readings. Both of these studies concluded that thickness plays a role on corneal elasticity; however, other corneal properties are being measured by CRF. In our study, no

difference in the relationship between CCT and CRF was found when evaluating each race separately.

Other ocular characteristics may potentially influence measurements of the ORA. We also evaluated the effect of corneal curvature and axial length on CH and CRF measurements. There are only a few reports in the literature referring to this relationship. Chang et al.,²⁰ in a study with children, found that lower CH was associated with increased axial length but not with corneal curvature. In a study by Franco et al.,²¹ corneal curvature was not related to CH in both normal and post-Lasik patients. In the present study we did not find a significant relationship between corneal curvature and axial length with ORA measurements. However, our study included only a small range of corneal curvatures (40 to 48D) and axial lengths (21 to 27mm). Therefore, further studies with a broader range of corneal curvatures and axial lengths should be performed to clarify this issue.

Our study has limitations. By including only healthy subjects, we were not able to evaluate differences in corneal biomechanics between races in glaucomatous patients. Evaluation of glaucoma patients can be complicated by the potential effects of treatment on intraocular pressure and on corneal biomechanical properties. Future longitudinal studies should be designed to elucidate the relationship between CH and CRF and susceptibility to glaucoma damage. Another limitation is that we relied exclusively on corneal biomechanical properties as assessed by the ORA. Although this instrument has been widely used in the literature to provide estimates of corneal biomechanical properties, no studies have yet validated ORA parameters against actual measurements of the physical properties of the cornea. Future studies should aim at validating and comparing ORA parameters with other methods of evaluating corneal biomechanical properties.

In conclusion, although black participants tended to have lower measurements of corneal hysteresis compared to white participants, this was largely explained by differences in corneal thickness and, therefore, it is unlikely that CH would have an independent effect in explaining differences in susceptibility of disease between these two racial groups.

Acknowledgments

a. Funding/support: Supported in part by CAPES Ministry of Education of Brazil grant BEX1327/09-7 (MTL), NEI EY08208 and NEI EY14267 (PAS) and NEI EY11008 (LMZ)

e. Other Acknowledgments: none

References

1. Bhan A, Browning AC, Shah S, Hamilton R, Dave D, Dua HS. Effect of corneal thickness on intraocular pressure measurements with the pneumotonometer, Goldmann applanation tonometer, and Tono-Pen. *Invest Ophthalmol Vis Sci* 2002;43:1389–92. [PubMed: 11980851]
2. Whitacre MM, Stein RA, Hassanein K. The effect of corneal thickness on applanation tonometry. *Am J Ophthalmol* 1993;115:592–6. [PubMed: 8488910]
3. Brandt JD, Beiser JA, Kass MA, Gordon MO. Central corneal thickness in the Ocular Hypertension Treatment Study (OHTS). *Ophthalmology* 2001;108:1779–88. [PubMed: 11581049]
4. Gordon MO, Beiser JA, Brandt JD, et al. The Ocular Hypertension Treatment Study: baseline factors that predict the onset of primary open-angle glaucoma. *Arch Ophthalmol* 2002;120:714–20. discussion 829–30. [PubMed: 12049575]
5. Leske MC, Connell AM, Wu SY, Hyman LG, Schachat AP. Risk factors for open-angle glaucoma. The Barbados Eye Study. *Arch Ophthalmol* 1995;113:918–24. [PubMed: 7605285]

6. Aghaian E, Choe JE, Lin S, Stamper RL. Central corneal thickness of Caucasians, Chinese, Hispanics, Filipinos, African Americans, and Japanese in a glaucoma clinic. *Ophthalmology* 2004;111:2211–9. [PubMed: 15582076]
7. La Rosa FA, Gross RL, Orengo-Nania S. Central corneal thickness of Caucasians and African Americans in glaucomatous and nonglaucomatous populations. *Arch Ophthalmol* 2001;119:23–7. [PubMed: 11146722]
8. Sample PA, Girkin CA, Zangwill LM, et al. The African Descent and Glaucoma Evaluation Study (ADAGES): design and baseline data. *Arch Ophthalmol* 2009;127:1136–45. [PubMed: 19752422]
9. Shimmyo M, Ross AJ, Moy A, Mostafavi R. Intraocular pressure, Goldmann applanation tension, corneal thickness, and corneal curvature in Caucasians, Asians, Hispanics, and African Americans. *Am J Ophthalmol* 2003;136:603–13. [PubMed: 14516799]
10. Torres RJ, Jones E, Edmunds B, Becker T, Cioffi GA, Mansberger SL. Central corneal thickness in Northwestern American Indians/Alaskan Natives and comparison with White and African-American persons. *Am J Ophthalmol* 2008;146:747–51. [PubMed: 18672219]
11. Nemesure B, Wu SY, Hennis A, Leske MC. Corneal thickness and intraocular pressure in the Barbados eye studies. *Arch Ophthalmol* 2003;121:240–4. [PubMed: 12583791]
12. Medeiros FA, Weinreb RN. Evaluation of the influence of corneal biomechanical properties on intraocular pressure measurements using the ocular response analyzer. *J Glaucoma* 2006;15:364–70. [PubMed: 16988597]
13. Liu J, Roberts CJ. Influence of corneal biomechanical properties on intraocular pressure measurement: quantitative analysis. *J Cataract Refract Surg* 2005;31:146–55. [PubMed: 15721707]
14. Congdon NG, Broman AT, Bandeen-Roche K, Grover D, Quigley HA. Central corneal thickness and corneal hysteresis associated with glaucoma damage. *Am J Ophthalmol* 2006;141:868–75. [PubMed: 16527231]
15. Mangouritsas G, Morphis G, Mourtoukos S, Feretis E. Association between corneal hysteresis and central corneal thickness in glaucomatous and non-glaucomatous eyes. *Acta Ophthalmol*. 2008
16. Schroeder B, Hager A, Kutschan A, Wiegand W. Measurement of viscoelastic corneal parameters (corneal hysteresis) in patients with primary open angle glaucoma. *Ophthalmologie* 2008;105:916–20. [PubMed: 18415104]
17. Wells AP, Garway-Heath DF, Poostchi A, Wong T, Chan KC, Sachdev N. Corneal hysteresis but not corneal thickness correlates with optic nerve surface compliance in glaucoma patients. *Invest Ophthalmol Vis Sci* 2008;49:3262–8. [PubMed: 18316697]
18. Luce DA. Determining in vivo biomechanical properties of the cornea with an ocular response analyzer. *J Cataract Refract Surg* 2005;31:156–62. [PubMed: 15721708]
19. Ang GS, Bochmann F, Townend J, Azuara-Blanco A. Corneal biomechanical properties in primary open angle glaucoma and normal tension glaucoma. *J Glaucoma* 2008;17:259–62. [PubMed: 18552609]
20. Chang PY, Chang SW, Wang JY. Assessment of corneal biomechanical properties and intraocular pressure with Ocular Response Analyzer in childhood myopia. *Br J Ophthalmol*. 2009
21. Franco S, Lira M. Biomechanical properties of the cornea measured by the Ocular Response Analyzer and their association with intraocular pressure and the central corneal curvature. *Clin Exp Optom* 2009;92:469–75. [PubMed: 19694758]

Biography

Mauro T. Leite, MD is a glaucoma specialist and a post-doctoral fellow at the Hamilton Glaucoma Center, University of California. Dr. Leite has received his medical degree and completed his residency in ophthalmology at the Federal University of Sao Paulo, Brazil.

Figure 1. Locally weighted scatterplot smoothing (LOWESS) of corneal hysteresis (CH), as measured by the Ocular Response Analyzer, and central corneal thickness (CCT) in blacks and whites.

Figure 2. Locally weighted scatterplot smoothing (LOWESS) of corneal resistance factor (CRF), as measured by the Ocular Response Analyzer, and central corneal thickness (CCT) in blacks and whites.

Table 1Mean $\pm$ standard deviation of clinical and ocular variables for healthy blacks and whites.

Parameter	Whites (n= 135 eyes)	Blacks (n= 46 eyes)	P value
Age (years)	66.00 $\pm$ 11.9	58.41 $\pm$ 15.7	0.009
CCT ^a (μ m)	562 $\pm$ 36.8	534.09 $\pm$ 39.4	0.001
GAT ^b (mmHg)	16 $\pm$ 2.9	15.77 $\pm$ 2.81	0.658
AL ^c (mm)	23.90 $\pm$ 1.21	23.77 $\pm$ 1.15	0.579
Corneal Curvature (D)	43.28 $\pm$ 1.68	43.76 $\pm$ 1.65	0.148
ORA ^d Parameters			
CH ^e (mmHg)	10.44 $\pm$ 1.6	9.70 $\pm$ 1.72	0.033
CRF ^f (mmHg)	10.70 $\pm$ 1.8	9.84 $\pm$ 1.92	0.028
IOPg ^g (mmHg)	16.36 $\pm$ 4.35	15.57 $\pm$ 3.37	0.273
IOPcc ^h (mmHg)	16.69 $\pm$ 4.2	16.80 $\pm$ 3.16	0.874

^a: Corneal central thickness;^b: Goldmann applanation tonometer;^c: Axial Length;^d: Ocular Response Analyzer;^e: Corneal hysteresis;^f: Corneal Resistance Factor;^g: Intraocular pressure equivalent to Goldmann;^h: Corneal compensated intraocular pressure.

Table 2

Results of multivariable regression analysis of the association between corneal hysteresis, as measured by the Ocular Response Analyzer, and clinical/ocular variables.

CH ^a (mmHg)	Coefficient (RSE ^e)	P value
Age (per year)	−0.027 (0.011)	0.013
Race ^b	−0.49 (0.28)	0.077
CCT ^c (per 100μm)	1.84 (0.35)	<0.001
AL ^d (per mm)	0.02 (0.113)	0.857
Corneal Curvature (per diopter)	0.116 (0.089)	0.194

^a: corneal hysteresis as the dependent variable;

^b: Whites = 0; Blacks = 1;

^c: corneal central thickness;

^d: axial length;

^e: robust standard error.

Table 3

Results of multivariable regression analysis of the association between corneal resistance factor, as measured by the Ocular Response Analyzer, and clinical/ocular variables.

CRF ^a (mmHg)	Coefficient (RSE ^e)	P value
Age (per year)	−0.01 (0.013)	0.429
Race ^b	−0.14 (0.29)	0.621
CCT ^c (per 100μm)	2.97 (0.33)	<0.001
AL ^d (per mm)	0.02 (0.135)	0.866
Corneal Curvature (per diopter)	0.13 (0.10)	0.195

^a: corneal resistance factor as the dependent variable;

^b: Whites = 0; Blacks = 1;

^c: corneal central thickness;

^d: axial length;

^e: robust standard error.