Correlation Between Corneal Biomechanics and Anterior Segment Parameters in Healthy Saudi Females

Amira Elagamy (✉ aelagamy@ksu.edu.sa)

optometry and Vision Sciences of College of Applied Medical Sciences of King Saud University

Rawan Al-Amri

King Saud University

Mohamed Berika

King Saud University

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Abstract

Background: The ocular response analyzer (ORA) can measure corneal hysteresis (CH), corneal resistance factor (CRF), Goldmann correlated IOP (IOPg) and corneal compensated intraocular pressure (IOPcc).[1] Anterior segment parameters such as central corneal thickness (CCT), thinnest corneal thickness (TCT), apex corneal thickness (Apex CT), corneal volume (CV), anterior chamber depth (ACD), anterior chamber volume (ACV) and corneal astigmatism (CA) can be measured by Pentacam which is a Scheimpflug imaging device.[2]

Many studies [3-10] investigated the correlation between corneal biomechanics and anterior segment parameters in healthy eyes and demonstrated a strong correlation between CH, CRF with CCT. Hwang et al 2013 [7] found that CV was positively correlated with CH, but not CRF. However, Çevik et al 2016 [10] reported positive correlations between CH, CRF, and CV and negative correlations between CH, CRF and both of posterior steep and average posterior K values.

Hwang et al [2] did not show a significant association between CA and all the biomechanical properties. Conversely, Montard et al [4] reported a negative association between CA with CH and CRF. Therefore, there is still debate regarding evaluation of this relation. Up to our knowledge, the correlation between corneal biomechanics and anterior segment parameters in healthy eyes is never investigated in Saudi Arabia.

The purpose of this study was conducted to evaluate the correlation between corneal biomechanics measured with ORA and anterior segment parameters assessed with Oculus Pentacam HR in healthy Saudi females.

Methods: This study was a prospective, non-randomized, cross-sectional, observational and quantitative study. The study included 129 eyes of 129 healthy Saudi females from King Saud University, Riyadh, Saudi Arabia. The mean age was 19.87 ± 1.328 (18 − 29 years). All subjects underwent a comprehensive ophthalmologic examination including refraction, visual acuity measurement, slit-lamp biomicroscopic examination, IOP measurement with an air puffer tonometer, and funduscopy. In addition, anterior segment parameters were measured with Oculus Pentacam HR. Additionally, corneal biomechanical parameters were measured with ORA (Reichert Ophthalmic Instruments). All data was analyzed using a Statistical Package for the Social Sciences (SPSS) version 22.0 software (SPSS Inc., Chicago, Il, USA). Associations between corneal biomechanical parameters and anterior segment parameters were analyzed by Pearson's Correlation coefficients. $P < 0.05$ was considered a statistically significant.

Results: In this study, mean (±SD) spherical equivalent (SE) was -1.62 ± 2.15 diopters and mean (±SD) CCT was 552.41 ± 58.90 μm. Mean (±SD) CH and CRF were 11.61 ± 1.80 and 11.26 ± 1.99 mm Hg, respectively. Correlation between ORA parameters and the anterior segment parameters using Pearson's Correlation Coefficient for all eyes in this study showed only highly significant positive correlation between CCT and each of CH, CRF, IOP g (r = 0.381, P < 0.0001) (r = 0.395, P < 0.0001) (r = 0.304, P < 0.0001) respectively. On the other hand, no significant association was detected between IOP cc and anterior segment parameters in this study

Conclusion: This work is the first one in Saudi Arabia to evaluate the correlation between corneal biomechanics and anterior segment parameters in healthy Saudi females. This study reported a positive correlation between CCT and each of CH, CRF, IOPg. Mild myopic eyes in this study showed a positive association between ASKV and each of CH and CRF. In addition, the mild myopic eyes demonstrated a positive relation between IOP g and ACV. Future prospective studies including males, different ethnic populations, different age groups with large sample sizes, using different imaging techniques, are recommended.

Bakground

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The ocular response analyzer (ORA) can measure corneal hysteresis (CH), corneal resistance factor (CRF), Goldmann correlated IOP (IOPg) and corneal compensated intraocular pressure (IOPcc).[1] Anterior segment parameters such as central corneal thickness (CCT), thinnest corneal thickness (TCT), apex corneal thickness (Apex CT), corneal volume (CV), anterior chamber depth (ACD), anterior chamber volume (ACV) and corneal astigmatism (CA) can be measured by Pentacam which is a Scheimpflug imaging device.[2]

Many studies [3–10] investigated the correlation between corneal biomechanics and anterior segment parameters in healthy eyes and demonstrated a strong correlation between CH, CRF with CCT. Hwang et al 2013 [7] found that CV was positively correlated with CH, but not CRF. However, Çevik et al 2016 [10] reported positive correlations between CH, CRF, and CV and negative correlations between CH, CRF and both of posterior steep and average posterior K values.

Hwang et al [2] did not show a significant association between CA and all the biomechanical properties. Conversely, Montard et al [4] reported a negative association between CA with CH and CRF. Therefore, there is still debate regarding evaluation of this relation. Up to our knowledge, the correlation between corneal biomechanics and anterior segment parameters in healthy eyes is never investigated in Saudi Arabia.

The purpose of this study was conducted to evaluate the correlation between corneal biomechanics measured with ORA and anterior segment parameters assessed with Oculus Pentacam HR in healthy Saudi females.

Methods
Study Design

This study was a prospective, non-randomized, cross-sectional, observational and quantitative study. This study got the approval of institutional review board (IRB) of College of Applied Medical Science, King Saud University, Riyadh, Saudi Arabia (CAMS 021-3940, approved date: 21/11/2018). It is adherent to the tenets of the Declaration of Helsinki 2013. All the participants signed comprehensive consent after explaining all procedures of the study.

Subjects

The study included 129 eyes of 129 healthy Saudi females from King Saud University, Riyadh, Saudi Arabia from January to March 2019. The mean age was 19.87 ± 1.328 years (18–29 years). The inclusion criteria were best-corrected visual acuity of $\geq$ 20/20; IOP of $\leq$ 21 mmHg and normal ocular appearance. Exclusion criteria were participants who have a history of intraocular surgery, refractive surgery, and contact lens use within 2 weeks, the presence of corneal abnormalities such as keratoconus, corneal scarring that would preclude accurate ORA and IOP measurements, or a diagnosis of "glaucoma suspect" or glaucoma. Besides, eyes with IOPcc or IOPg of > 21 mmHg were excluded in this study. All subjects underwent a comprehensive ophthalmologic examination including refraction by auto-refractometry (NIDEK ARK-510A), visual acuity measurement, biomicroscopic examination, IOP measurement with an air puff tonometer, and funduscopy. One eye from each participant was selected randomly.

Measurement of Corneal Biomechanics

Corneal biomechanical parameters were measured with ORA (Reichert Ophthalmic Instruments). First, the patient was instructed to set properly and fixate on the green light, and they were informed that they will only sense a very gentle
Loading [MathJax]/jax/output/CommonHTML/jax.js parameters that were analyzed: CH, CRF, IOPg, and corneal IOPcc for each

patient. The ORA examination was performed at least 3 times. The average values of three measurements were recorded for analysis.

Measurement of Anterior segment parameters

Anterior segment parameters were measured with Oculus Pentacam HR without application of any eye drops. CCT, CV, ACD, ACV, CA, anterior steep keratometric value (ASKV), anterior flat keratometric value (AFKV), posterior steep keratometric value (PSKV), posterior flat keratometric value (PFKV), mean keratometric value (Mean K) within 3 mm distance from the apex were measured.

Statistical Analysis

All data was analyzed using a Statistical Package for the Social Sciences (SPSS) version 22.0 software (SPSS Inc., Chicago, Il, USA). Quantitative variables were reported as mean ± standard deviation (± SD) and range. Associations between corneal biomechanical parameters and anterior segment parameters were analyzed by Pearson's Correlation coefficients. $P < 0.05$ was considered a statistically significant.

Results

This study included 129 eyes of 129 healthy Saudi females ranging in age from 18–29 years. 14 eyes (10.8%) (emmetropes from − 0.50 to + 0.50), 63 eyes (48.8%) (mild myopes from − 0.75 to -3D), 29 eyes (22.4%) (moderate myopes from − 3.25 to -6.00 D), 5 eyes (3.8%) (severe myopes greater than − 6.00 D), 14 eyes (10.8%) (mild hyperopes ≤ + 2.00D), and 4 eyes (3.1%) (moderate hyperopes from + 2.25 to + 5.00D) were enrolled in this study.

In this study, mean (± SD) spherical equivalent (SE) was − 1.62 ± 2.15 diopters and mean (± SD) CCT was 552.41 ± 58.90 μm. Mean (± SD) CH and CRF were 11.61 ± 1.80 and 11.26 ± 1.99 mm Hg, respectively. Participant demographic data, anterior segment parameters and ORA parameters of all eyes are shown in Table 1.

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Table 1

Participant demographic data, anterior segment parameter and ORA parameters of all eyes (N = 129 eyes)

	Minimum	Maximum	Mean	Std. Deviation
Age	18	29	19.87	1.328
Sphere	-7.25	4.5	-1.3256	2.16993
Cylinder	-3	0	− .6047	.65528
Spherical equivalent (SE)	-7.375	3.875	-1.62791	2.155993
Intraocular pressure (IOP)	12	21	19.434	1.7627
Corneal compensated intraocular pressure (IOPcc)	6.4	21.1	14.180	3.2485
Goldmann correlated intraocular pressure (IOPg)	8.8	22.1	14.696	3.1864
Corneal resistance factor (CRF)	6.9	17.3	11.2647	1.99292
Corneal hysteresis (CH)	7.8	15.3	11.612	1.8039
Central corneal thickness (CCT)	472	652	552.416	58.9009
Corneal volume (CV)	52.5	70.5	64.8643	40.98289
Anterior chamber depth (ACD)	2.09	3.69	5.0724	18.77004
Anterior chamber volume (ACV)	82	250	166.2849	40.64951
Corneal astigmatism (CA)	0	3.4	2.4616	15.76527
Anterior steep keratometric value (ASKV)	40.1	48.9	43.271	4.7729
Anterior flat keratometric value (AFKV)	38.8	47.2	45.616	33.4768
Posterior steep keratometric value (PSKV)	-7.1	-5.8	-5.973	4.4500
Posterior flat keratometric value (PFKV)	-6.8	-5.3	-6.047	.2329
Mean keratometric value (Mean K)	39.7	48	42.666	4.5446

Pearson's Correlation Coefficient for all eyes (129 eyes) and for mild myopic eyes only (63 eyes) detected no significant association between corneal biomechanics and both age and SE (Tables 2 & 3). Correlation between ORA parameters and the anterior segment parameters for all eyes in this study showed only highly significant positive correlation between CCT and each of CH, CRF, IOP g (r = 0.381, P < 0.0001) (r = 0.395, P < 0.0001) (r = 0.304, P < 0.0001) respectively. On the other hand, no significant association was detected between IOP cc and anterior segment parameters in this study (Tables 4–7) (Figs. 1–3).

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Table 2
Correlation between corneal biomechanics and both age & spherical equivalent in all eyes

	Age		SE	
	Pearson Correlation	P-value	Pearson Correlation	P-value
IOPcc	-0.047	0.600	-0.118	0.184
IOPg	-0.076	0.392	-0.133	0.132
CRF	-0.093	0.295	-0.014	0.873
CH	-0.053	0.549	0.060	0.497
P < 0.05 will be considered statistically significant.				

Table 3
Correlation between corneal biomechanics and both age & spherical equivalent in mild myopic eyes

	Age		SE	
	Pearson Correlation	P-value	Pearson Correlation	P-value
IOPcc	0.063	0.626	-0.007	0.957
IOPg	0.038	0.769	-0.101	0.431
CRF	-0.074	0.564	-0.147	0.249
CH	-0.055	0.666	-0.093	0.470
P < 0.05 will be considered statistically significant.				

Table 4
Correlation between CH and anterior segment parameters for all eyes

		CCT	CV	ACD	ACV	CA	ASKV	AFKV	PSKV	PFKV	Mean K
CH	Pearson Correlation	.381	−.116	.125	−.081	−.150	.207*	−.065	−.155	−.112	.154
	P-value	.000**	.191	.158	.363	.091	.018	.465	.079	.206	.081
	N	129	129	129	129	129	129	129	129	129	129
P < 0.05 will be considered statistically significant (*)											
** Highly significant											

Table 5
Correlation between CRF and anterior segment parameter for all eyes

		CCT	CV	ACD	ACV	CA	ASKV	AFKV	PSKV	PFKV	Mean K
CRF	Pearson Correlation	.395	− .084	.168	− .021	− .102	.167	− .071	− .105	− .065	.094
	P-value	.000**	.344	.056	.810	.252	.059	.425	.237	.467	.291
	N	129	129	129	129	129	129	129	129	129	129
P < 0.05 will be considered statistically significant (*)											
** Highly significant											

Table 6
Correlation between IOP g and anterior segment parameters for all eyes

		CCT	CV	ACD	ACV	CA	ASKV	AFKV	PSKV	PFKV	Mean K
IOP g	Pearson Correlation	.304	− .145	.119	.138	− .127	.089	− .040	− .123	.136	.081
	P-value	.000**	.101	.177	.119	.152	.315	.657	.164	.124	.362
	N	129	129	129	129	129	129	129	129	129	129
P < 0.05 will be considered statistically significant (*)											
** Highly significant											

Table 7:
Correlation between IOP cc and anterior segment parameters for all eyes

		CCT	CV	ACD	ACV	CA	ASKV	AFKV	PSKV	PFKV	Mean K
IOP cc	Pearson Correlation	-.056	.070	.055	.124	.105	-.119	.007	.112	.144	-.143
	P-value	.528	.433	.535	.160	.234	.179	.938	.204	.104	.106
	N	129	129	129	129	129	129	129	129	129	129
P < 0.05 will be considered statistically significant (*)											
(**) Highly significant											

Correlation between ORA parameters and the anterior segment parameters for mild myopic eyes (63 eyes) in this study found a significant positive correlation between CH and both CCT & ASKV (r = 0.403, P = 0.001) (r = 0.302, P = 0.016) respectively. In addition, a significant positive correlation was demonstrated between CRF and both CCT & ASKV (r = 0.381, P = 0.002) (r = 0.279, P = 0.027) respectively. Furthermore, the current study detected a significant positive correlation between IOP g and both CCT & ACV (r = 0.321, P = 0.010) (r = 0.335, P = 0.007) respectively. On the

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other hand, no significant association was detected between IOP cc and the anterior segment parameters (Tables 8–11).

Table 8:
Correlation between CH and anterior segment parameters in mild myopic eyes

		CCT	CV	ACD	ACV	CA	ASKV	AFKV	PSKV	PFKV	Mean K
CH	Pearson Correlation	.403	-.176	-.219	.012	-.215	.302	-.098	-.224	-.146	.245
	P-value	.001**	.168	.085	.923	.090	.016*	.446	.078	.254	.053
	N	63	63	63	63	63	63	63	63	63	63
P < 0.05 will be considered statistically significant											

Table 9
Correlation between CRF and anterior segment parameters in mild myopic eyes

		CCT	CV	ACD	ACV	CA	ASKV	AFKV	PSKV	PFKV	Mean K
CRF	Pearson Correlation	.381	− .103	− .142	.119	− .145	.279	− .098	− .149	− .120	.162
	P-value	.002**	.420	.265	.352	.256	.027*	.446	.245	.348	.203
	N	63	63	63	63	63	63	63	63	63	63
P < 0.05 will be considered statistically significant (*)											
(**) Highly significant											

Table 10
Correlation between IOP g and anterior segment parameters in mild myopic eyes

		CCT	CV	ACD	ACV	CA	ASKV	AFKV	PSKV	PFKV	Mean K
IOP g	Pearson Correlation	.321	− .163	− .170	.335	− .183	.210	− .045	− .172	.179	.134
	P-value	.010*	.202	.183	.007**	.152	.098	.726	.177	.160	.296
	N	63	63	63	63	63	63	63	63	63	63
P < 0.05 will be considered statistically significant (*)											
(**) Highly significant											

Table 11
Correlation between IOP cc and anterior segment parameters in mild myopic eyes

		CCT	CV	ACD	ACV	CA	ASKV	AFKV	PSKV	PFKV	Mean K
IOP cc	Pearson Correlation	− .113	.147	.165	.189	.151	− .122	.020	.167	.166	− .207
	P-value	.378	.250	.195	.138	.237	.343	.875	.192	.193	.104
	N	63	63	63	63	63	63	63	63	63	63

P < 0.05 will be considered statistically significant.

Discussion

This study aimed to assess the correlation between corneal biomechanics and anterior segment parameters in healthy Saudi females. This study demonstrated a significant positive correlation between CCT and each of CH, CRF, IOPg. This finding matched with many studies [3-10] which documented a strong correlation between CCT and each of CH, CRF. However, no significant association between CV and all corneal biomechanical properties was reported in our study. This result disagreed with Çevik et al [10] who reported positive correlations between CV and each of CH, CRF, and Hwang et al [7] who found a significant positive correlation between CV and CH, but not CRF. Our study did not demonstrate a significant association between CA and all the biomechanical properties. This result agreed with Hwang et al [7] study. On the other hand, Montard et al [4] reported a negative association between CA and each of CH and CRF.

Concerning correlation between ORA parameters and keratometric values for all eyes (129 eyes): the present study showed no association, which was in agreement with Kamiya et al [12] who reported no correlation between mean K value and CH and CRF in patients with a mean age of 39 years. On the other hand, the association between ORA parameters and keratometric values for mild myopic eyes (63 eyes) in this study found a significant positive correlation between ASKV and each of CH and CRF. Çevik et al 2016 [10] reported a negative correlation between CH, CRF with both posterior steep and average posterior K values. Furthermore, many studies [7, 8, 9, 13-17] reported an association between mean k and CH only. Additionally, Lim et al [6] and Bueno-Gimeno et al [8] found a significant relationship between lower CH and CRF values with flatter corneal curvature in children. Moreover, Narayanaswamy et al [18] confirmed a significant negative association between CH and CRF and corneal radius of curvature. Narayanaswamy et al [18] documented that lower CH and CRF were associated with flatter corneas in 1136 Chinese patients (mean age 55 years).

CH and CRF in the current study showed no significant association with ACD and ACV in all eyes which agreed with Hwang et al. [7] However, this finding was not in agreement with Çevik et al 2016 [10] who reported positive associations between ACD and CRF and Chang et al [13] who confirmed a significant association between ACD measured by the IOLMaster and CH only not CRF. On the other hand, mild myopic eyes (63 eyes) in our study showed a highly significant positive correlation between IOP g and ACV. This result matched with Cui et al 2019 [19] who detected a significant association between ACV and a lower deformation altitude (DA), higher stiffness parameter (SP-A1), and higher biomechanical intraocular pressure (bIOP). Cui et al 2019 [19] study used corneal visualization Scheimpflug technology (Corvis ST; Oculus Inc., Wetzlar, Germany), to measure the corneal biomechanics. This technology uses an additional high-speed Scheimpflug camera to identify changes in corneal shape.

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Our study found no association between corneal biomechanics and age in adult Saudi females. This result matched with Lim et al,[6] Buey et al 2014, [11] Kamiya et al, [12] and Chang et al. [13] However, this finding disagreed with Çevik et al [10] and Narayanaswamy et al [18] who reported a significant negative association between age and each of CH and CRF.

As regards the relation between the corneal biomechanics and SE, the current study did not show any significant relation which matched with Lim et al [6] and Kamiya et al. [12] On the other hand, this finding disagreed with Buey et al 2014 [11] who showed a very weak, but significant, correlation between CH and refractive error. Jiang et al [20] documented a positive correlation between refraction and each of CH and CRF but a negative correlation to each of IOP and IOPcc. Jiang et al [20] concluded that the mechanical strength in the anterior segment of the high myopic eyes may be compromised which increases the risk of glaucoma.

The limitations of this study are a small sample size, restricted age range and only females were included.

Conclusion

This work is the first one in Saudi Arabia to evaluate the correlation between corneal biomechanics and anterior segment parameters in healthy Saudi females. This study reported a positive correlation between CCT and each of CH, CRF, IOPg. Mild myopic eyes in this study showed a positive association between ASKV and each of CH and CRF. In addition, the mild myopic eyes demonstrated a positive relation between IOP g and ACV. Future prospective studies including males, different ethnic populations, different age groups with large sample sizes, using different imaging techniques, are recommended.

Abbreviations

Ocular response analyzer (ORA)

Corneal hysteresis (CH)

Corneal resistance factor (CRF)

Goldmann correlated IOP (IOPg)

Corneal compensated intraocular pressure (IOPcc).

Central corneal thickness (CCT)

Thinnest corneal thickness (TCT)

Apex corneal thickness (Apex CT)

Corneal volume (CV)

Anterior chamber depth (ACD)

Anterior chamber volume (ACV)

Corneal astigmatism (CA)

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Anterior steep keratometric value (ASKV)

Anterior flat keratometric value (AFKV)

Posterior steep keratometric value (PSKV)

Posterior flat keratometric value (PFKV)

Mean keratometric value (Mean K)

Declarations

Ethics approval and consent to participate:

The study got the approval of Research Ethics Committee of College of Applied Medical Sciences, King Saud University. All procedures performed in this study were in accordance with Helsinki declaration and its later amendments. All the participants signed comprehensive consent after explanation of the possible consequences of the study prior to investigations.

Consent to publish:

Not applicable

Availability of data and materials:

Not applicable

Competing interests:

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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Authors' Contributions

Conception or design of the work: Elagamy, A and Al-Amri R.

Data collection: Al-Amri R

Data analysis and interpretation: Elagamy, A and Al-Amri R

Drafting the article: Elagamy, A and Berika M

Critical revision of the article: Elagamy, A and Berika M

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Final approval of the version to be published: Elagamy, A and Berika M

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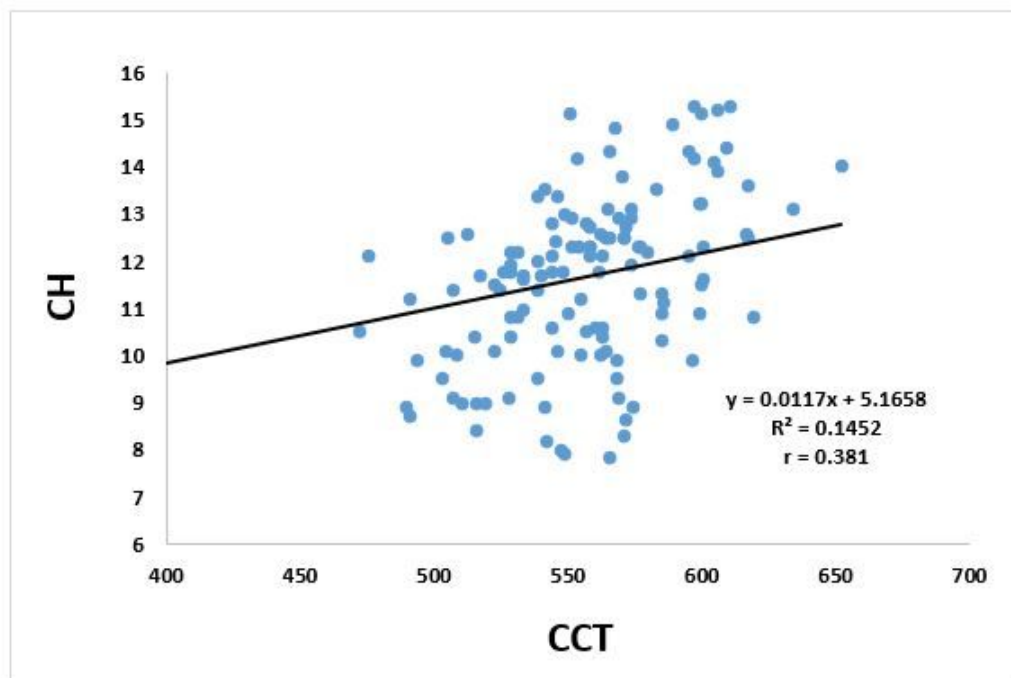
Figures

Figure 1

Correlation between corneal hysteresis (CH) and central corneal thickness (CCT) for all eyes
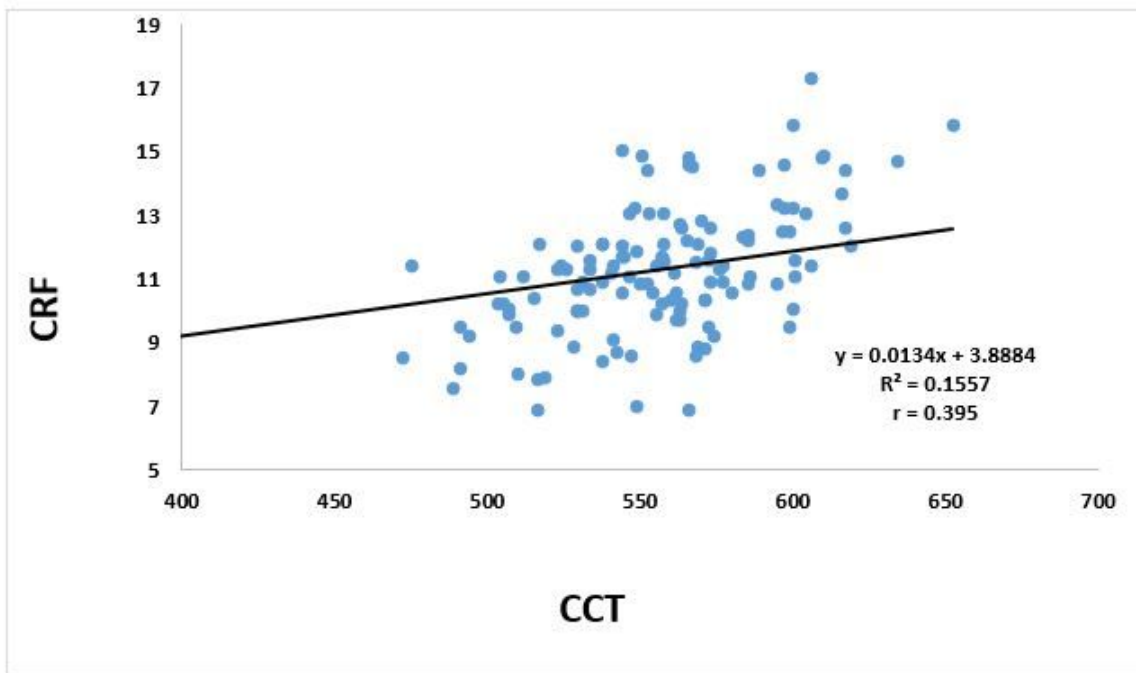
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Figure 2

Correlation between corneal resistance factor (CRF) and central corneal thickness (CCT) for all eyes
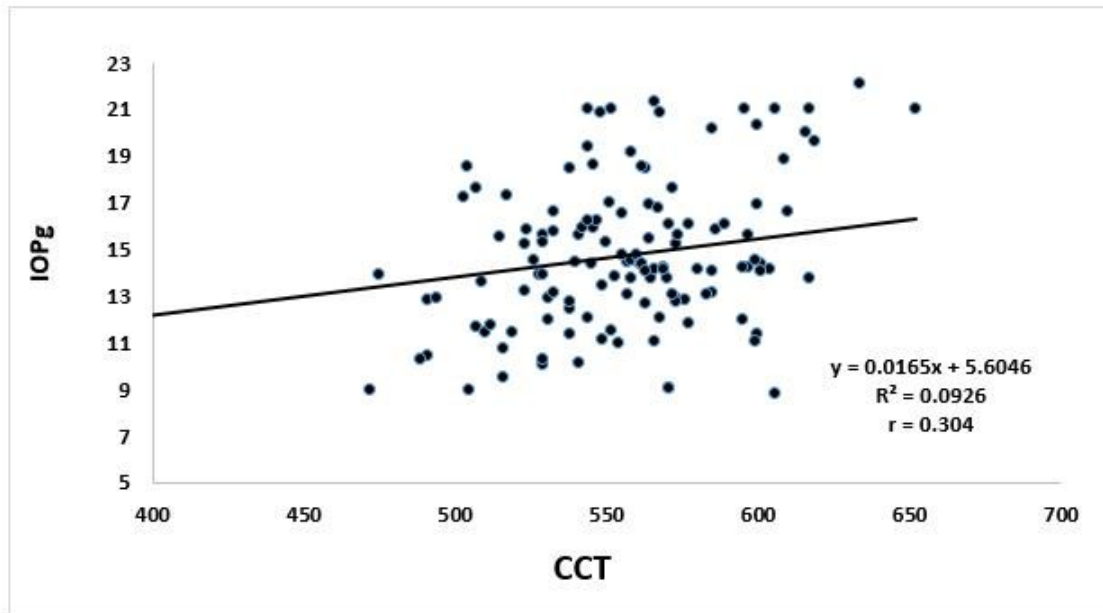

Figure 3

Correlation between Goldmann correlated IOP (IOPg) and central corneal thickness (CCT) for all eyes