

Relationship of Corneal Biomechanics Measured by Corvis ST and Optic Nerve Head Parameters in Healthy Saudi Females

Amira Elagamy^{1,2}, Hessa Khaled Alnasser³, Wafa Saeed Alghamdi³, Mohamed Berika^{4,5}, Dara Aldisi⁶

¹Department of Optometry and Vision Sciences, College of Applied Medical Sciences, King Saud University, Riyadh, Saudi Arabia; ²Mansoura Ophthalmic Center, Faculty of Medicine, Mansoura University, Mansoura, Egypt; ³College of Applied Medical Sciences, King Saud University, Riyadh, Saudi Arabia; ⁴Rehabilitation Science Department, College of Applied Medical Sciences, King Saud University, Riyadh, Saudi Arabia; ⁵Anatomy Department, Faculty of Medicine, Mansoura University, Mansoura, Egypt; ⁶Community Health Sciences Department, College of Applied Medical Sciences, King Saud University, Riyadh, Saudi Arabia

Correspondence: Amira Elagamy, Department of Optometry and Vision Sciences, College of Applied Medical Sciences, King Saud University, Riyadh, Saudi Arabia, Email aelagamy@ksu.edu.sa

Aim: This study assessed the correlation between corneal biomechanical properties measured with Corvis ST (CST) and retinal nerve fiber layer thickness profile, anterior lamina cribrosa surface depth, and other optic nerve head parameters in healthy Saudi females.

Methods: This study included 62 eyes (only right eyes) of 62 healthy Saudi females aged from 20 to 39 yrs. A complete ophthalmologic assessment was performed for all participants. In addition, corneal biomechanical parameters were measured using CST, and optic nerve head parameters were evaluated using spectral domain optical coherence tomography.

Results: This study demonstrated a significant weak positive correlation between circumpapillary retinal nerve fiber layer (cpRNFL) peak angle and only second applanation (A2) length (mm) ($r = 0.293$, $P = 0.021$). Also, this study reported a significant moderate negative association between the C/D ratio and radius ($r = -0.513$, $P = 0.015$). However, there was no significant correlation between corneal biomechanics and ALCSD in this study.

Conclusion: This study reported a significant positive correlation between cpRNFL peak angle and A2-length. In addition, the current study documented a significant moderate negative association between C/D ratio and radius. However, there was no significant correlation between ALCSD and the corneal biomechanical properties in this study. Further research is needed to verify the impact of corneal biomechanics on optic nerve head parameters and further investigate its role in the pathophysiology of glaucoma.

Keywords: corneal biomechanics, circumpapillary retinal nerve fiber layer peak angle, anterior lamina cribrosa surface depth

Introduction

The evaluation of corneal biomechanical properties has important implications for the diagnosis and management of glaucoma.¹ It is essential to determine the risk factors for glaucoma progression to monitor patients with greater risk and to reserve visual acuity.² The role of corneal biomechanics in glaucoma is yet to be fully understood and needs to be further investigated, although many studies^{3,4} evaluated the importance of corneal biomechanics in glaucoma patients and their significant contribution to the disease progression. Evaluation of optic nerve head (ONH) parameters is mandatory for an early diagnosis of glaucoma. In addition, their relationship to the corneal biomechanics needs to be investigated.⁵

Mansouri et al³ demonstrated a weak positive association between corneal hysteresis (CH), corneal resistance factor (CRF), and retinal nerve fiber layer thickness evaluated by scanning laser polarimetry (GDx enhanced corneal compensation (GDxECC)). However, no significant relationship was detected after adjusting the axial length (AL) and central corneal thickness (CCT) by age. Matsuura et al⁶ assessed the association between corneal biomechanics measured by Corneal Visualization Scheimpflug Technology (Corvis ST) (CST) and circumpapillary retinal nerve fiber layer

(cpRNFL) peak angle between the supratemporal and infratemporal peaks measured by optical coherence tomography (OCT). They found a significant association between cpRNFL peak angle and only three CST variables. Their study was the only one that investigated this correlation which necessitates further evaluation for better understanding and validation. Bartolomé et al⁷ investigated the relationship between CH, CRF, Goldman-correlated intraocular pressure (IOPg), and corneal-compensated IOP (IOPcc) using the Ocular Response Analyzer (ORA) and anterior lamina cribrosa surface depth (ALCSD) and other biometric variables in healthy subjects. They reported no significant correlation between IOPcc, IOPg, CH, and ALCSD. No previous study examined the correlation between corneal biomechanics measured by CST and ALCSD and other ONH parameters in healthy Saudi subjects.

This study assessed the correlation between corneal biomechanical properties measured with CST and cpRNFL peak angle, ALCSD measured with OCT in healthy Saudi females. In addition, the association between the RNFL thickness profile and other variables, such as AL, CCT, and body height was performed. Furthermore, the relationship between ALCSD and other variables, such as age, spherical equivalent, IOP, CCT, and AL, was assessed.

Study Design

This study was a cross-sectional, prospective, non-randomized, and observational study. It got the Institutional Review Board (IRB) approval from Health Sciences Colleges Research on Human Subjects, College of Medicine, King Saud University, Riyadh, Saudi Arabia (No. E-22-6620). The study protocol adhered to tenets of the Declaration of Helsinki. Written informed consent was obtained from all participants after the study procedures were explained.

Subjects and Methods

This study included 62 eyes (only right eyes) of 62 healthy Saudi females aged from 20 to 39 yrs. All subjects were recruited from King Saud University (KSU), female section, Riyadh, Saudi Arabia, by non-randomized convenience sampling method from February to April 2022. The study included healthy participants with best-corrected visual acuity of $\geq 20/20$; IOP ≤ 21 mmHg without anti-glaucoma medications and normal-looking optic disc without any signs of glaucomatous or ischemic optic neuropathy. The study excluded participants who have a refractive error of more than 5 dioptres of the sphere and 3 dioptres of the cylinder, amblyopic eye, previous eye surgery including cataract or refractive surgery, neurological disease, macular degeneration, glaucoma or diabetes, ONH abnormalities. A comprehensive ophthalmologic examination was performed for all subjects. In addition, AL and CCT were measured using Oculus Pentacam HR for all participants. Also, body height was measured for each subject.

Corneal Biomechanical Parameters

Corneal biomechanical parameters were measured using CST with an automatic release mode. A high-speed Scheimpflug camera recorded the process of corneal deformation after applying an air impulse within 8.5 mm of the corneal apex. CST measurement was carried out three times, and the averages of CST parameters were calculated. CST quantifies twelve different parameters which include the biomechanical response of the cornea at the moment of the first and second applanations, (A1/2) time, A1/2 length, A1/2 velocity, A1/2 deformation amplitude, peak distance, highest deformation amplitude, highest concavity time and radius.⁶

Stereoscopic Disk Photography

Stereoscopic disk photography was obtained by spectral domain OCT (3D OCT-2000, Topcon. Fundus photography was gained in a dark room without mydriatic eye drops. RNFL thickness was measured using the RNFL 3.4 mm circle scan. The center of the scan circle was utilized as the disc's center in the analysis. Then the temporal-superior-nasal-inferior-temporal (TSNIT) cpRNFL thickness curve was profiled to measure the angle between the ST and IT peaks of cpRNFL thickness profile. Then, the distance between ST and IT RNFL peaks was converted to an angular value by dividing it by the entire distance and multiplying by 360.⁶

The 3D image (6×6 mm) was recreated at first. Then, the three equidistant planes were made and defined as plane 1, plane 2, and plane 3. In this model, plane 2 corresponds to the mid-horizontal plane, and planes 1 and 3 correspond to the superior and inferior planes, respectively. ALCSD was measured at all planes, defined as the distance from the line

connecting the two Bruch's membrane opening (BMO) edges (reference line) to the anterior LC surface. It was measured in the direction perpendicular to the reference plane at three points: the maximum depth point and two additional points (100 and 200 μm apart from the maximum depth point to the temporal direction). The average of three measurements was taken as the ALCSD of each plane. The average of the ALCSDs from all planes was defined as the mean ALCSD of the eye.⁸

Statistical Analysis

Statistical Package for the Social Sciences (SPSS) version 21.0 software (SPSS Inc., NY, IL, USA) was used for data analysis. The associations between the corneal biomechanical parameters and the cpRNFL peak angle, ALCSD, and the other variables were analyzed using linear regression analysis and Pearson's Correlation coefficients. $P < 0.05$ was considered statistically significant.

Results

Sixty-two eyes were enrolled in this study. The mean age was 21.94 ± 3.67 (20–39) years. The mean spherical equivalent (SE) was -0.93 ± 1.16 (1.00 to -4.25) D. Moreover, the mean AL was 23.43 ± 1.09 mm (20.3–25.9) mm. The mean reported IOP was 17.76 ± 2.29 (13.6–21.0) mmHg. The mean CCT was 567.69 ± 31.07 (494–655) μm . The mean body height of the participants was 159.73 ± 5.8 (149–170) cm. The mean RNFL thickness was 113.14 ± 6.81 (101.0–124.0) μm . The mean disc area was $1.58\text{--}2.72$ (1.58–2.72) mm^2 . The mean C/D ratio was 0.30 ± 0.11 (0.09–0.51). In addition, the mean cpRNFL peak angle was 142.74 ± 20.24 (107–189) degrees. Figure 1 shows the circumpapillary retinal nerve fiber layer (cpRNFL) peak angle. Figure 2 displays a histogram for the distribution of participants within the study sample ($n = 62$) according to cpRNFL peak angle, this study shows that a higher number of participants ($n = 18$) reported cpRNFL peak angle between (123.4 to less than 139.8) degrees, and a lower share ($n = 16$) reported a cpRNFL peak angle between (139.8 to less than 156.2) degrees, and the lowest share of participants ($n = 4$) reported cpRNFL peak angle between (172.6 to 189) degrees.

Regarding the measurement of ALCSD in this study, 40 eyes were excluded because of poor visibility of LC and difficult identification of the anterior LC surface in certain areas of the images due to prominent shadows of retinal blood vessels. Therefore, the ALCSD of only 22 eyes was measured. This study showed the mean ALCSD at the superior, middle, and inferior planes was 248.56 ± 88.87 , 276.83 ± 106.06 , and 214.11 ± 93.09 μm , respectively. The mean ALCSD was 246.35 ± 89.98 μm . Demographics and Clinical Data of the subjects are shown in Table 1. Descriptive statistics for corneal biomechanics parameters measured in this study are summarized in Table 2 and Figure 3 shows corneal biomechanical parameters measured using CST.

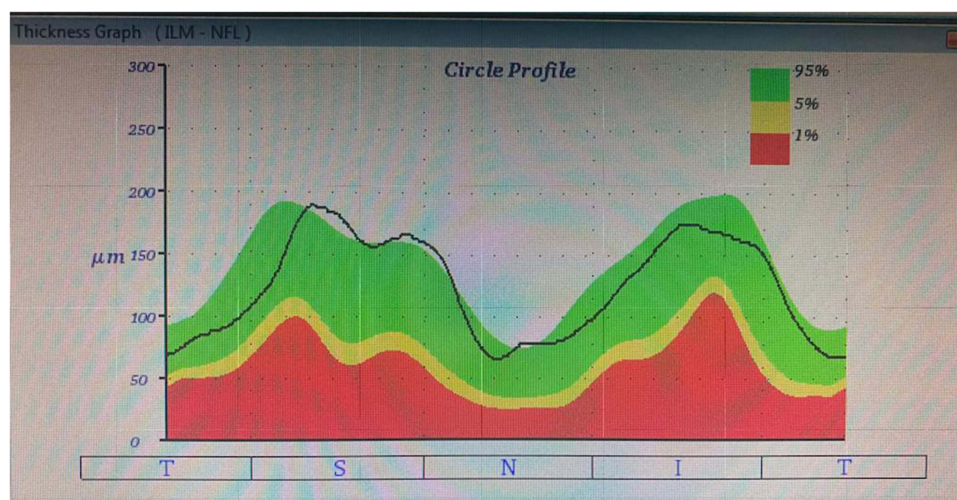


Figure 1 The Circumpapillary Retinal Nerve Fiber Layer (cpRNFL) Peak Angle.

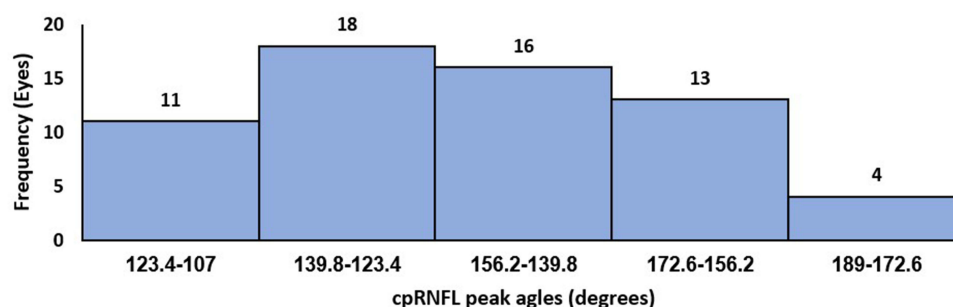


Figure 2 Histogram of the Circumpapillary Retinal Nerve Fiber Layer (cpRNFL) Peak Angles (in Degrees).

This study demonstrated a significant weak positive correlation between cpRNFL peak angle and only A2-length (mm) ($r = 0.293$, $P = 0.021$). However, this study documented no significant correlation between cpRNFL peak angle and the other corneal biomechanical properties. Also, no significant correlation between cpRNFL peak angle and the other variables (age, SE, AL, CCT, IOP, body height) was reported in this study. The correlation between the cpRNFL peak angle and all variables is shown in Table 3. The adjusted R^2 and corrected Akaike Information Criterion (AICc) measurements were used to evaluate the goodness of fit test for obtaining the optimum model predict cpRNFL peak angle based on this study sample which is to use A2-length parameter, with Beta coefficient = 13.723, $P = 0.02$. Tables 4 and 5 show multiple regression model results with cpRNFL as dependent variable. The linear fitting model shows that a rise of one (mm) in A2-Length leads to an increase of 13.72 degrees in the cpRNFL peak angle considering all other parameters are constant. Figure 4 shows the linear fitting model between the A2-Length and cpRNFL peak angle.

Pearson correlation analysis demonstrated that RNFL has a significant moderate negative association with AL ($r = -0.446$, $P = 0.037$). The linear fitting model between the peripapillary RNFL thickness and AL shows that an increase of

Table 1 Demographics and Clinical Data of the Subjects (n = 62 Eyes)

Demographic Variable	Mean \pm SD	Range
Age (Years)	(21.94 \pm 3.67)	(20–39)
SE (D)	(−0.93 \pm 1.16)	(−4.25–1.0)
AL (mm)	(23.43 \pm 1.09)	(20.3–25.9)
Body Height (cm)	(159.73 \pm 5.8)	(149–170)
CCT (μ m)	(567.69 \pm 31.07)	(494–655)
IOP (mmHg)	(17.76 \pm 2.29)	(13.6–21.0)
RNFL (μ m)	(113.14 \pm 6.81)	(101.0–124.0)
Disk Area (mm ²)	(2.18 \pm 0.32)	(1.58–2.72)
C/D Ratio	(0.30 \pm 0.11)	(0.09–0.51)
cpRNFL (T) (Degrees) Peak Angle	(142.74 \pm 20.24)	(107–189)
Superior Plane ALCSD (μ m)	(248.56 \pm 88.87)	(126.0–423.33)
Middle Plane ALCSD (μ m)	(276.38 \pm 106.06)	(128.0–484.0)
Inferior Plane ALCSD (μ m)	(214.11 \pm 93.09)	(105.67–447.0)
Mean ALCSD (μ m)	(246.35 \pm 89.98)	(130.22–432.33)

Abbreviations: SE, Spherical Equivalent; AL, Axial Length; CCT, Central Corneal Thickness; IOP, Intraocular Pressure; RNFL, Retinal Nerve Fiber Layer; C/D ratio, Cup to Disc Ratio; cpRNFL, Circumpapillary Retinal Nerve Fiber Layer; ALCSD, Anterior Lamina Cribrosa Surface Depth; SD, Standard Deviation.

Table 2 Descriptive Statistics of the Corneal Biomechanical Parameters Measured by Corvis ST

Parameter	Mean \pm SD	Range
A1 Time (ms)	(7.14 \pm 0.36)	(6.54, 8.17)
A2 Time (ms)	(21.63 \pm 0.37)	(20.81, 22.65)
A1 Length (mm)	(2.36 \pm 0.29)	(1.77, 2.92)
A2 Length (mm)	(2.19 \pm 0.43)	(1.43, 3.14)
A1 Velocity (m/s)	(0.13 \pm 0.02)	(0.08, 0.16)
A2 Velocity (m/s)	(-0.25 \pm 0.03)	(-0.37, -0.2)
Peak Distance (mm)	(4.83 \pm 0.27)	(4.33, 5.77)
Highest Concavity Deformation Amplitude (mm)	(1.02 \pm 0.11)	(0.82, 1.37)
Highest Concavity Time (ms)	(17.06 \pm 0.59)	(14.78, 19.09)
Radius (mm)	(8.27 \pm 0.83)	(6.55, 11.02)

Abbreviations: A1, First Applanation; A2, Second Applanation.

one mm unit in AL resulted in a decrease of 3.47 μ m in RNFL thickness in this study sample. Figure 5 shows the linear fitting model between the peripapillary RNFL thickness and AL. Moreover, this study found a moderately positive association between the peripapillary RNFL thickness and CCT ($r = 0.445$, $P = 0.038$). The linear fitting model shows an increase of one mm unit in CCT resulting in a rise of 0.08 μ m in RNFL thickness in this study sample. Figure 6 shows the linear fitting model between the peripapillary RNFL thickness and CCT.

Regarding the correlation between corneal biomechanics and ONH parameters: This study documented only a significant moderate negative association between the C/D ratio and radius ($r = -.513$, $P = 0.015$). Figure 7 shows

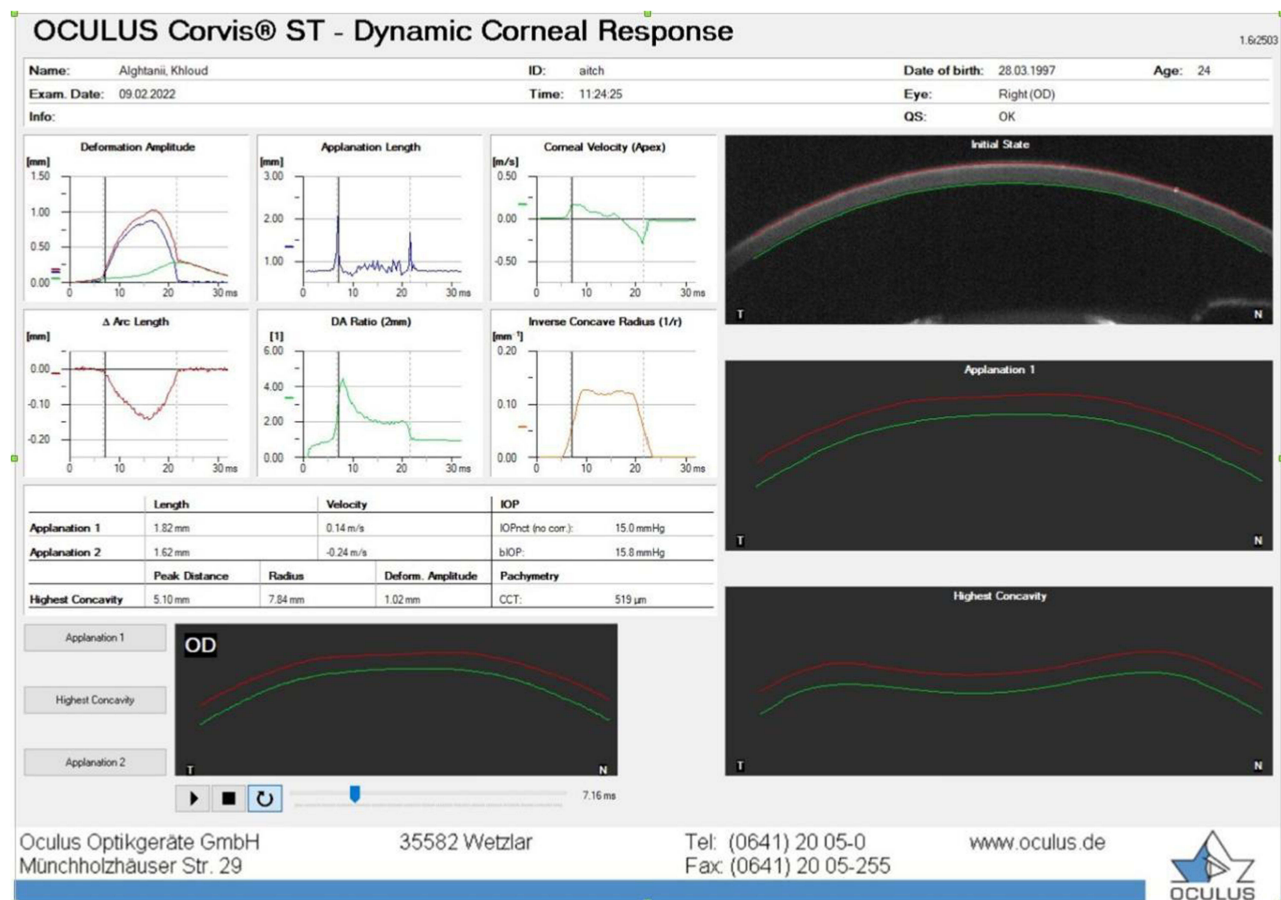
**Figure 3** The Corneal Biomechanical Parameters Measured using Corvis-ST.

Table 3 Correlation Between Circumpapillary Retinal Nerve Fiber Layer Peak Angle and All Variables

Parameter	Pearson Correlation Coefficient	P value
Age	0.159	0.217
AL	−0.249	0.051
CCT	0.048	0.711
IOP	−0.042	0.747
Body Height	−0.219	0.087
A1 Time	0.013	0.917
A2 Time	0.011	0.933
A1 Length	−0.043	0.738
A2 Length	0.293	0.021*
A1 Velocity	−0.038	0.769
A2 Velocity	0.166	0.196
Peak Distance	−0.173	0.179
Highest Concavity Deformation Amplitude	0.014	0.912
Highest Concavity Time	0.157	0.224
Radius	0.0	0.998

Abbreviations: AL, Axial length; CCT, Central Corneal Thickness; IOP, Intraocular Pressure; A1, First Applanation; A2, Second Applanation. * Significant at $P < 0.05$.

Table 4 Multiple Regression Model Results with Circumpapillary Retinal Nerve Fiber Layer Peak Angle as Dependent Variable

Parameter	Coefficient	Standard error	P value
Age	299.47	343.03	0.387
AL	0.73	0.80	0.365
CCT	−2.75	3.14	0.386
IOP	−0.02	0.11	0.847
Body Height	−1.39	2.46	0.574
A1 Time	−0.57	0.48	0.244
A2 Time	2.31	16.89	0.892
A1 Length	0.54	17.38	0.975
A2 Length	−4.14	10.90	0.706
A1 Velocity	12.02	7.46	0.114
A2 Velocity	−312.98	297.88	0.299
Peak Distance	306.74	190.24	0.114
Highest Concavity Deformation Amplitude	−1.89	27.52	0.946
Highest Concavity Time	97.17	70.37	0.174
Radius	1.29	5.76	0.824
Adjusted R ²	0.044 (p=0.315)		
AICc	561.6		

Abbreviations: AL, Axial Length; CCT, Central Corneal Thickness; IOP, Intraocular Pressure; A1, First Applanation; A2, Second Applanation; AICc, Akaike Information Criteria; H, Highest.

the linear fitting model between the C/D ratio and radius. Radius is defined as the central curvature radius at the highest concavity. The linear fitting model between radius (μm) and C/D ratio shows an increase of 0.1 in C/D ratio resulting in a decrease of 4.58 mm in radius of this study sample. However, there was no significant correlation between the corneal biomechanics and ALCSO. **Figure 8** shows ALCSO measured by spectral domain OCT. Furthermore, no significant association was detected between ALCSO and the other variables in this study. **Table 6** shows descriptive statistics of ALCSO and the other ONH parameters. **Table 7** shows the correlation between ALCSO, the other ONH parameters, and

Table 5 Optimum Model Results with Circumpapillary Retinal Nerve Fiber Layer Peak Angle as Dependent Variable

Parameter	Coefficient	Standard error	P value
A2-Length	13.723	5.791	0.021*
Adjusted R ²	0.070 (p=0.021)		
AICc	548.4		

Abbreviations: A2, Second Applanation; AICc, Akaike Information Criteria. * Significant at P<0.05.

the other variables. Table 8 shows the correlation between the corneal biomechanics, ALCSD, and the other ONH parameters. On the other hand, IOP reported a significant strong positive correlation with A1-time (ms) ($r = 0.938$, $P < 0.001$), a strong negative correlation with A1-V (ms) ($r = -0.854$, $P < 0.001$), a moderately negative correlation with highest concavity deformation amplitude (mm) ($r = -0.766$, $P < 0.001$). Furthermore, this study found a significant moderate positive association correlation between CCT (μm) and A2-length (mm) ($r = 0.522$, $P = 0.013$).

Discussion

This study found that the mean cpRNFL peak angle was 142.74 ± 20.24 (107–189) degrees compared to 130.6 ± 25.4 (77.8–207.0) degrees in Matsuura et al⁶. The current study demonstrated a significant weak positive correlation between cpRNFL peak angle and only A2-length. A2-length is defined as the length of the flattened cornea at the second applanation. However, Matsuura et al⁶ reported a significant correlation between cpRNFL peak angle and A1-length, A1-time, and A2-time. “A1/2 time” is defined as the length of time from the initiation of the air puff to the first (cornea moves inwards) or second applanation (cornea moves outwards). A1-length is defined as the length of the flattened cornea at the first applanation. Matsuura et al⁶ evaluated the cpRNFL peak angle and its relations in 97 eyes of 97 young healthy Japanese volunteers compared to 62 eyes of 62 healthy Saudi females in our study. This variance in ethnicity and sample size may explain the dissimilar findings of the two studies.

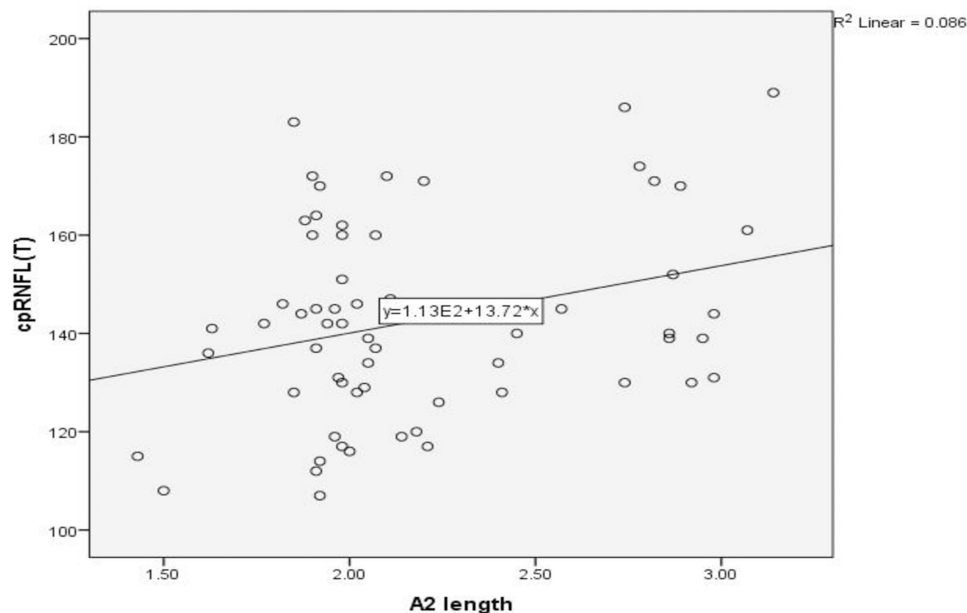


Figure 4 The Linear Fitting Model between A2-Length (mm) and cpRNFL Peak Angle (Degrees).

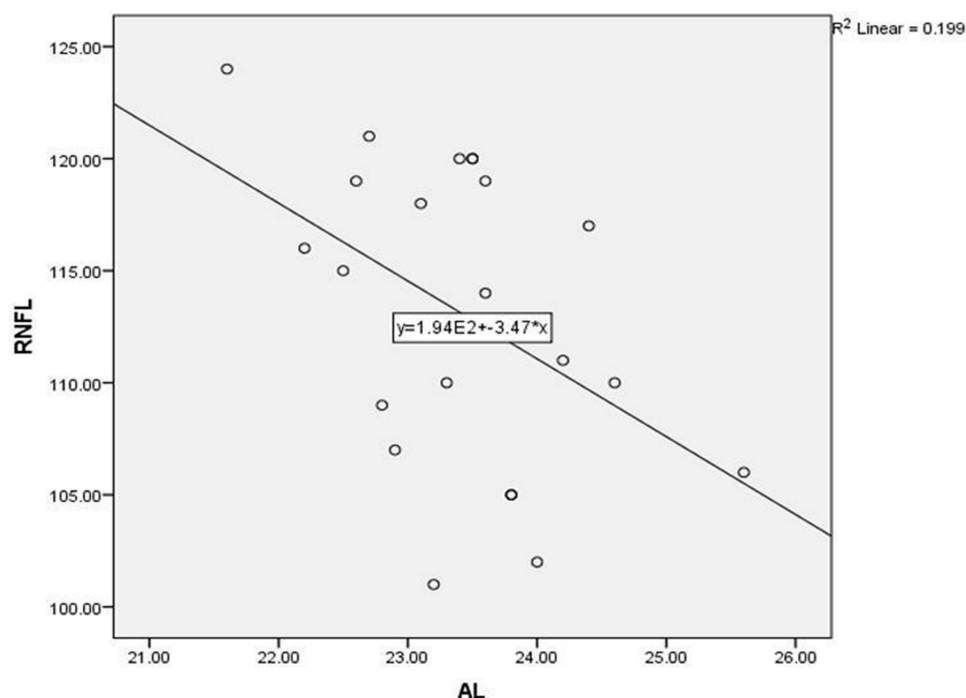


Figure 5 The Linear Fitting Model between the Peripapillary Retinal Nerve Fiber Layer Thickness (μm) and the Axial Length (mm).

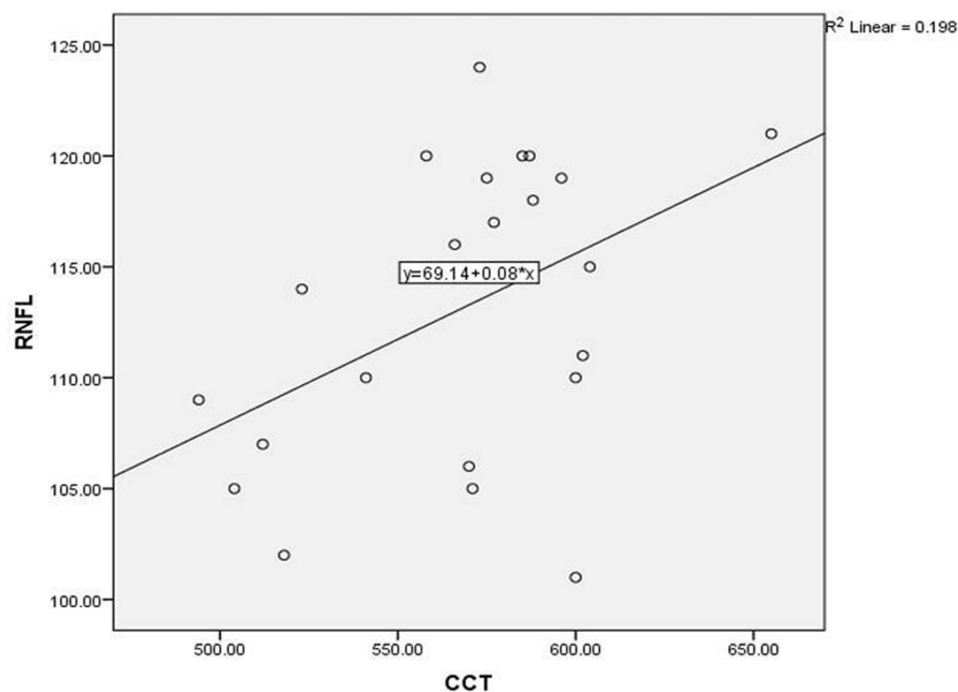


Figure 6 The linear fitting model between the Peripapillary Retinal Nerve Fiber Layer Thickness (μm) and Central Corneal Thickness (μm).

The current study reported no statistically significant correlation between cpRNFL peak angle and AL. Conversely, Matsuura et al⁶ reported a significant correlation between cpRNFL peak angle and AL. This finding can be explained by the small AL 23.43 ± 1.09 (20.3–25.9) mm in our study compared to the longer AL 25.2 ± 1.3 (22.6–28.5) mm in their research. Matsuura et al⁶ confirmed that cpRNFL peak angle was shallower in eyes with longer AL which was in agreement with Yoo et al.⁹ They suggested that eyes with poor corneal energy absorption evidenced by shorter A1-

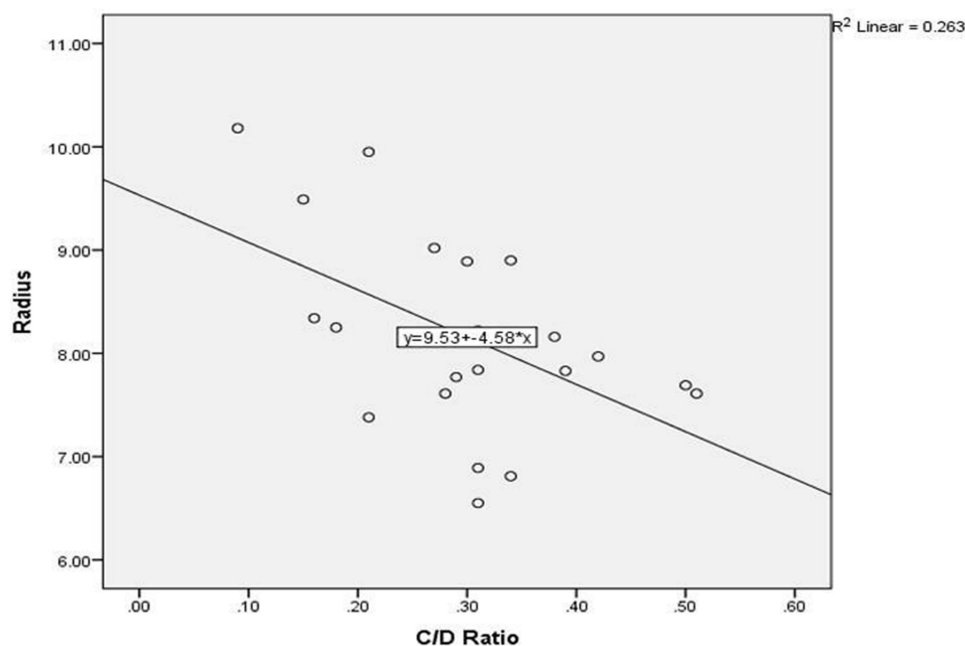


Figure 7 The Linear Fitting Model between Radius (mm) and C/D Ratio.

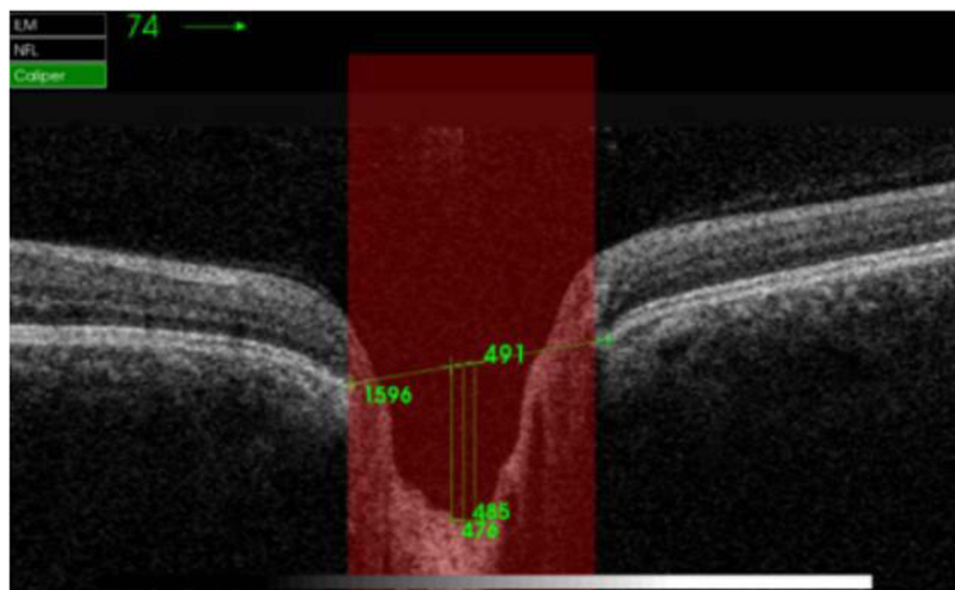


Figure 8 Anterior Lamina Cribrosa Surface Depth (ALCSD) Measured by Spectral Domain OCT.

length, shorter A1-time, and shorter A2-time have sharp stretched posterior pole of retina demonstrated by shallow cpRNFL peak angle away from the influence of elongated AL. Understanding the impact of corneal biomechanics on cpRNFL thickness profiles is important to recognize retinal structure in eyes with myopia and structural changes in glaucomatous eyes and it needs more attention.

This study showed the mean ALCSD (22 eyes) was $246.35 \pm 89.98 \mu\text{m}$ compared to $371.88 \pm 114.62 \mu\text{m}$ in Elagamy et al¹⁰. Bartolomé et al⁷ reported mean ALCSD (74 eyes) was $329.15 \pm 60.85 \mu\text{m}$. Furlanetto et al¹⁰ demonstrated that the mean ALCSD (57 eyes) was $353 \pm 70 \mu\text{m}$. The differences in ALCSD may be explained by the different sample sizes in these studies.

Table 6 Descriptive Statistics of ALCSD and the Other Nerve Head Parameters (n = 22 Eyes)

Parameter	Mean \pm SD	Range
Superior Plane ALCSD (μm)	(248.56 \pm 88.87)	(126.0, 423.33)
Middle Plane ALCSD (μm)	(276.38 \pm 106.06)	(128.0, 484.0)
Inferior Plane ALCSD (μm)	(214.11 \pm 93.09)	(105.67, 447.0)
Mean ALCSD (μm)	(246.35 \pm 89.98)	(130.22, 432.33)
RNFL (μm)	(113.14 \pm 6.81)	(101.0, 124.0)
Disk Area (mm^2)	(2.18 \pm 0.32)	(1.58, 2.72)
C/D Ratio	(0.30 \pm 0.11)	(0.09, 0.51)

Abbreviations: SD, standard deviation; ALCSD, anterior lamina cribrosa surface depth; RNFL, retinal nerve fiber layer; C/D cup to disc ratio.

Table 7 Correlation between ALCSD and the Other Optic Nerve Head Parameters and the Other Variables (n = 22)

Parameter	Statistic	Age	SE	AL	CCT	IOP
Superior Plane ALCSD	<i>r</i>	-0.244	0.014	0.047	0.265	-0.120
	<i>p</i> -value	0.273	0.951	0.835	0.234	0.596
Middle Plane ALCSD	<i>r</i>	-0.149	0.070	0.109	0.341	0.081
	<i>p</i> -value	0.507	0.757	0.628	0.121	0.720
Inferior Plane ALCSD	<i>r</i>	-0.098	0.115	0.018	0.297	-0.063
	<i>p</i> -value	0.666	0.612	0.938	0.180	0.781
Mean ALCSD	<i>r</i>	-0.173	0.072	0.065	0.323	-0.029
	<i>p</i> -value	0.442	0.752	0.775	0.142	0.897
RNFL	<i>r</i>	0.047	0.293	-0.446	0.445	0.057
	<i>p</i> -value	0.834	0.185	0.037*	0.038*	0.801
Disk Area	<i>r</i>	-0.256	-0.077	-0.162	0.210	0.048
	<i>p</i> -value	0.249	0.732	0.471	0.349	0.833
C/D Ratio	<i>r</i>	-0.115	0.043	-0.012	0.216	-0.090
	<i>p</i> -value	0.611	0.850	0.957	0.335	0.692

Abbreviations: ALCSD, anterior lamina cribrosa surface depth; RNFL, retinal nerve fiber layer; C/D cup to disc ratio; SE, Spherical equivalent; AL, Axial length; CCT, Central corneal thickness; IOP, Intraocular pressure. * Significant at $P < 0.05$.

This study found a significant moderate negative association between the C/D ratio and radius. Radius is defined as the central curvature radius at the highest concavity. However, our study discovered no association between corneal biomechanics and optic disc area. This finding matched Insull et al¹¹ who reported no correlation between optic disc area and CH.

No significant correlation between corneal biomechanics measured by CST and ALCSD was detected in this study. Bartolomé et al⁷ measured corneal biomechanics by ORA. They reported only a significant weak association between CRF and lamina cribrosa thickness ($r = 0.264$; $P = 0.045$). However, they did not demonstrate any relationship between

Table 8 Correlation Between the Corneal Biomechanics and ALCSO and the Other Nerve Head Parameters

Parameter	Statistic	A1 Time	A2 Time	A1 Length	A2 Length	A1-V	A2-V	PD	Highest Concavity DA	HC Time	Radius
Superior Plane ALCSO	r	-0.102	0.294	-0.054	0.221	0.209	-0.200	0.195	0.326	0.094	-0.191
	p-value	0.651	0.184	0.811	0.323	0.351	0.372	0.384	0.139	0.677	0.396
Middle Plane ALCSO	r	0.150	0.022	-0.009	0.333	0.016	0.075	-0.083	0.026	0.027	-0.063
	p-value	0.506	0.923	0.968	0.130	0.943	0.740	0.714	0.907	0.906	0.780
Inferior Plane ALCSO	r	-0.024	0.154	0.155	0.272	0.160	0.158	-0.002	0.039	-0.007	-0.098
	p-value	0.917	0.492	0.491	0.221	0.478	0.483	0.992	0.863	0.975	0.663
Mean ALCSO	r	0.017	0.159	0.032	0.297	0.130	0.018	0.031	0.131	0.039	-0.122
	p-value	0.940	0.480	0.888	0.179	0.564	0.936	0.891	0.561	0.863	0.590
RNFL	r	0.019	0.123	0.029	0.122	-0.085	0.235	-0.047	-0.025	0.253	0.008
	p-value	0.933	0.586	0.898	0.588	0.706	0.293	0.836	0.912	0.257	0.971
Disk Area	r	-0.061	0.154	-0.262	-0.076	0.015	-0.065	0.166	0.301	0.144	-0.369
	p-value	0.786	0.493	0.239	0.736	0.946	0.772	0.460	0.173	0.523	0.091
C/D Ratio	r	-0.075	0.224	0.022	-0.046	0.206	-0.280	0.201	0.354	0.106	-0.513
	p-value	0.740	0.317	0.923	0.839	0.358	0.207	0.369	0.106	0.639	0.015*

Abbreviations: ALCSO, anterior lamina cribrosa surface depth; RNFL, retinal nerve fiber layer; C/D cup to disc ratio. A1-V: A1-velocity; A2-V: A2-velocity; PD: peak distance; Highest Concavity-DA, Highest Concavity deformation amplitude; HC-time: highest concavity-time. * Significant at $P < 0.05$.

ALCSO and IOPcc, IOPg, CH. On the other hand, Sun et al¹² evaluated the relationship between corneal stiffness parameters and LC curvature in normal tension glaucoma. They used the mean adjusted LC curvature index (maLCCI) to measure LCD by swept-source optical coherence tomography (SS-OCT). However, in this study, ALCSO was measured from the BMO reference plane to the surface of anterior LC by spectral domain OCT (3D OCT-2000, Topcon). Unlike ALCSO, the maLCCI does not depend on the variations in BMO location. They demonstrated that younger age ($P = 0.010$), thinner CCT ($P = 0.002$), and lower stiffness parameters at applanation 1 (SP-A1) ($P < 0.001$) were significantly associated with greater maLCCI. Furthermore, no significant association was detected between ALCSO and the other variables in this study, such as age, SE, IOP, and CCT. This finding matched Elagamy et al¹³ and Seo et al⁸ who did not detect any correlation between ALCSO and age, refractive errors, IOP, CCT, or disk area. In addition, this study and Elagamy et al¹³ confirmed that ALCSO did not correlate with AL. This result mismatched Seo et al⁸ study that found a significant negative correlation between ALCSO and AL. They included subjects with $AL > 25$ mm (high myopic eye, ≥ -8.0 D). The mean AL in our study and Elagamy et al¹³ was 23.43 ± 1.09 mm and 23.50 ± 0.872 , respectively. This disagreement may be explained by the differences in mean AL between the studies. Furthermore, no significant association between ALCSO and RNFL was reported in the current study. This result matched Elagamy et al¹³ and Ren et al¹⁴.

Pearson correlation analysis demonstrated that the peripapillary RNFL thickness has a significant moderate negative association with AL. Yoo et al⁹ and Porwal et al¹⁵ confirmed the significant association between the peripapillary RNFL thickness and AL.

Moreover, this study found a significant moderate positive association between the peripapillary RNFL and CCT. Mohamed et al¹⁶ documented a significant positive association between the CCT and RNFL thickness ($r = 0.621$, $P \leq 0.001$). However, this result disagreed with Pakravan et al¹⁷ who found no correlation between the peripapillary RNFL thickness and CCT ($P = 0.66$). On the other hand, no association between the corneal biomechanics and the peripapillary RNFL thickness was found in our study. This result agreed with Mansouri et al³ who did not confirm any significant association between CH and CRF and retinal nerve fiber layer thickness measured by GDxECC after modifying CCT and AL by age.

IOP in this study showed a significant strong positive correlation with A1-time, a strong negative correlation with A1-V, and a moderately negative correlation with the highest concavity deformation amplitude. In agreement with our findings, Asaoka et al¹⁸ found that IOP measured with Goldmann applanation tonometry (IOP-G) showed a positive correlation with A1-time, a negative correlation with A1-V, and maximum deformation amplitude. Furthermore, this study found a significant moderate positive association between CCT and A2-length. This finding matched Asaoka et al¹⁸ who confirmed that CCT was a predictor of A2-length.

This study has the following limitations. First, all participants were Saudi females; hence, the findings might not apply to males in Saudi Arabia and other countries. Second, the small sample size was another limitation due to a technical error in CST which forced us to stop data collection. Third, the inability to measure ALCSO in many eyes due to poor visibility of the anterior LC surface and the limitation of Topcon 3D OCT-2000.

Conclusion

This study reported a significant positive correlation between cpRNFL peak angle and A2-length. In addition, the current study documented a significant moderate negative association between C/D ratio and radius. However, there was no significant correlation between ALCSO and the corneal biomechanical properties in this study. Evaluation of the association between ALCSO and corneal biomechanics may help to understand the impact of the corneal biomechanical parameters on lamina cribrosa depth and thickness. Further studies are recommended on larger study populations including males, different ethnic populations, high myopic eyes, glaucomatous eyes, and different age groups using advanced imaging techniques, such as swept-source OCT or enhanced depth imaging OCT, to verify the impact of corneal biomechanics on ONH parameters and further investigate its role in the pathophysiology of glaucoma.

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Disclosure

The authors report no conflicts of interest in this work.

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