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Original Article

Ophthalmology Section

Measurement of Corneal Biomechanical Properties using Corneal Visualisation Scheimpflug Technology and Ocular Response Analyser in Healthy Saudi Female Adults: A Cross-sectional Study

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ABSTRACT

Introduction: Corneal biomechanics is a relatively new discipline of research that focuses on the physical and biological interactions in the anterior part of the eye. Corneal biomechanics is influenced by a wide range of variables, including environmental influences, hydration, and hormone changes. Central Corneal Thickness (CCT), Intraocular Pressure (IOP), and age are other variables that might impact the corneas. The biomechanical properties of the cornea, at any level of cell to tissue to the sub-organ, might cause serious corneal diseases.

Aim: To measure the corneal biomechanial properties in healthy Saudi females.

Materials and Methods: This cross-sectional study was conducted in the Department of Optometry and Vision Science, College of Applied Medical Science, King Saud University, Riyadh, Saudi Arabia on 53 right eyes of Saudi female participants from April 2021 to April 2022. The IOP, CCT, and the corneal biomechanical properties at the first applanation (time-T1, velocity-V1, length-L1, deformation amplitude-DA1), second applanation (time-T2, velocity-V2, length-L2, deformation amplitude-DA2), highest concavity (Highest Concavity Time-HCT, Highest Concavity Radius-HCR, Highest Concavity Deformation Amplitude-HCDA), and Peak Distance (PD) were evaluated by using Corneal Visualisation Scheimpflug Technology (CST) whereas, Ocular Response Analyser (ORA) was used for the comparison of biomechanical properties. The statistical analysis of the data was done by applying statistical package IBM Statistical Package for the Social Sciences (SPSS) (version 24) and conducting Analysis of Variance (ANOVA) tests.

Results: The mean age of the participants was 20.74±1.89 years, mean Spherical Equivalent (SE) refraction was -1.41±1.97 Diopters (D), the mean IOP was 16.82±1.96 mmHg, and the mean CCT was 569.43±27.22 μm for the right eyes. The results showed that the two most affecting factors in the biomechanical parameters were IOP and CCT. A potential association was found between first applanation time (T1) and corneal speed during the first applanation (V1) for both IOP and CCT ($p<0.001$) in the linear regression analysis, while a significant difference was observed in V1 ($p=0.029$) in SE. In the second applanation, a significant association was found in T2 with IOP ($p<0.001$) and CCT, cord length of the second applanation (L2) with CCT, and V2 with SE, IOP, and CCT was observed. A significant association between time and SE ($p=0.034$) was notice in the highest concavity parameter. However, deformation amplitude exhibited the significant association between SE and IOP, radius with IOP and CCT, and the PD with SE, IOP, and CCT ($p<0.001$).

Conclusion: Most of the corneal biomechanical parameters were affected with CCT and IOP. Thus, the biomechanical characteristics of the cornea can be used to compare normal eyes with pathological eyes.

Keywords: Central corneal thickness, Corneal hysteresis, Deformation amplitude, Intraocular pressure, Peak distance

INTRODUCTION

Cornea is very essential for human eye vision, as 70% of the refractive power of the whole eye is provided by the cornea. Any changes in the features of cornea can lead to eye problems [1,2]. Biomechanical characteristics play a vital role in marinating shape and transparency of the cornea and have been a subject of study since 1970 [3,4]. Biomechanical properties clinically improve various treatments and management procedures that interact mechanically with the eye [5]. A keen interest in ocular biomechanical properties has emerged among refractive and glaucoma specialists due to their utilisation in the screening, diagnosis and treatment [6]. The biomechanics of cornea are affected by several variables, including elasticity [7], moisture content [8], viscosity [9] and corneal stroma thickness [10,11]. The stroma is the principal load-bearing layer among the five layers of cornea [12]. Numerous research studies have reported that eyes with keratoconus [13], Fuchs corneal dystrophy [14], glaucoma [15] and after refractive surgery have considerably different corneal biomechanics in contrast to normal eyes [16,17]. Thus, a greater understanding of corneal biomechanics is crucial for the diagnosis and treatment of the aforementioned disorders [18]. Also, the refractive surgery for the prediction of the development of ectasia requires detailed information about corneal biomechanics [19]. Various studies have addressed a strong correlation between Corneal Hysteresis (CH) and Corneal Resistance Factor (CRF) with Central Corneal Thickness (CCT) [20-22]. A study conducted by Hwang HS et al., reported that Corneal Volume (CV) was positively correlated with CH but not with CRF [23]. However, Çevik SG et al., illustrated a positive correlation between CH, CRF and CV and a negative correlation between CH, CRF and both of posterior steep and average posterior values [24]. Meanwhile, Montard R et al., reported significant association between CH and CRF with corneal pachymetry, but not with corneal compensated IOP (IOPcc) [25]. Hence, more studies are required to observe the trend of corneal biomechanics and anterior segment parameters. Recently, ORA and CST have been the two main tools available for the study of corneal biomechanical properties [26]. The ORA, a bidirectional applanation tonometery, is used to measure CH, CRF and IOP [27-29]. The ORA has many shortcomings, such as poor repeatability and it is easily influenced by morphological features of cornea [27]. Therefore, CST was designed based on Scheimpflug imaging technology, which can capture more than 10 biomechanical characteristics of corneal deformation after an air puff [30]. These biomechanical values and associated factors in the healthy cornea should be known to verify the changes in these parameters. Therefore, the present study aimed to evaluate the corneal biomechanical metrics in healthy Saudi females by CST and ORA.

MATERIALS AND METHODS

The present cross-sectional, time-bound study was performed on the healthy eyes of 53 healthy Saudi females in Department of Optometry and Vision Science, College of Applied Medical Science, King Saud University, Riyadh, Saudi Arabia, from April 2021 to April 2022. Ethical approval (IRB Approval ID E-20-5624) was obtained from the Office of Human Research Protection (OHRP) at the College of Medicine, KSU, Riyadh, Saudi Arabia.

Inclusion and Exclusion criteria: The present study included the healthy right eyes of young females in the 18-24 years of age range who had never had any eye surgery, were free from ocular or systemic diseases and had refractive error of less than -6.00 D. Participants who were unable to complete all the examinations, as well as pregnant and lactating females, were excluded.

Study Procedure

All the participants were subjected to an extensive eye examination to detect any eye problem. A Snellen chart was applied for slit-lamp microscopy and visual acuity tests to examine the Best Corrected Visual Acuity (BCVA). An auto kerato-refracto-tonometer (TRK-1P Topcon, Tokyo, Japan) was used to determine refractive power and a fundus examination was conducted to assess the fundus. After all these investigations, biomechanical properties were measured using ORA and CST.

All the subjects signed the consent form after knowing the procedure and objectives of the study. The examinations were conducted by a qualified optometrist using the same devices between 10:00 and 13:00 hours and recorded the average of each parameter was recorded. The CST measurements were recorded thrice per participant, with a time interval of one minute between each measurement and data storage as well as processing operations was noted on the CST instrument. The parameters measured with CST were considered reliable according to the "OK" quality index displayed on the device monitor.

The ORA measurement was also performed three times on each participant with a time interval of 5-min between each measurement. The high-quality index (It is the waveform score measured with the ORA) greater than seven was employed and the average value was selected for the analysis. ORA (ORA; Reichert Ophthalmics, Depew, NY) is a dynamic bidirectional applanation device used to analyse corneal biomechanics in a simpler, non invasive way. It has ability to calculate the CH and CRF to improve the accuracy of IOP measurement by using corneal biomechanical data. It provides two distinct IOP parameters: IOPg and the IOPcc. It functions by sending an air pulse that moves the cornea inward and slightly convex before it comes back to its natural form. This response is used to detect corneal biomechanical properties in a very short span of time—about 20 milliseconds—and after this process cornea regains to its normal shape [31].

Another non contact device, named as Corneal visualisation Scheimpflug Technology (CST), were also used for the measurement of corneal biomechanical parameters. It captures cross-sectional images of the cornea after the application of an air puff for 30 milliseconds, using a high-speed Scheimpflug camera which takes over 4,300 images per second [32]. The cornea underwent from natural to three distinct conditions due to the air puff, which includes, the first applanation (A1), second applanation (A2) and the highest concavity. As the cornea deforms in response to the air puff, the Intraocular Pressure (IOP) can be determined at the point of first applanation. All the corneal deformation responses to the air puff are captured by the CST in around 100 milliseconds. A study reported in 2016 stated that CST was able to give one important parameter known as biomechanically corrected IOP (bIOP-CorVis), which is obtained in terms of corneal dynamic reactions and physical corneal structures [33]. This IOP is impacted by biomechanical properties, including maximum concavity radius, age and Central Corneal Thickness (CCT). The formula for bIOP-CorVis is given below [34,35]:

$bIOP=C_{CCT1}\times C_{AP1}\times C_{age1}+C_{CCT2}\times C_{age2}+C_{DCR}+a_{19}$

$C_{CCT1}=(a_1\times CCT^3+a_2\times CCT^2+a_3\times CCT+a_4)$

$C_{AP1}=(a_5\times AP1+a_6)$

$C_{age1}=(a_7\times\{Ln(Beta)\}^2+a_8\times\{Ln(Beta)\}+a_9)$

$C_{CCT2}=(a_{10}\times CCT^3+a_{11}\times CCT^2+a_{12}\times CCT+a_{13})$

$C_{age2}=(a_{14}\times\{Ln(Beta)\}^2+a_{15}\times\{Ln(Beta)\}+a_{16})$

$Beta=0.5852\times exp(0.0111\times age\{year\})$

$C_{DCR}=a_{17}\times HCR+a_{18}$

Where C_{CCT1}, C_{AP1} and C_{age1} denoted CCT, air pulse and age at applanation 1, whereas, C_{CCT2} and C_{age2} represent the CCT, age at applanation 2 and C_{DCR} represents the correction based on biomechanical response (HCR). The constants are denoted as a_1 to a_{19}. The achieved adjustment of biomechanical parameter is therefore found more accurate. The current study is a part of ongoing project and there is no overlap among the results of the study.

STATISTICAL ANALYSIS

The statistical analysis of the data was done by using the IBM SPSS statistical package (version 24.0). The normality of the data was checked using the Shapiro-Wilk normality test. An Analysis of Variance (ANOVA) was carried out for all the dependent variables according to the different diagnostic categories, with multiple comparisons made to distinguish the diagnostic differences, taking p-value <0.05 as statistically significant. Dependent variables analysed were time, velocity and length for the investigated studies (IOP, CCT, SE).

RESULTS

The right eyes of 53 healthy Saudi female adults with a mean age of 20.74±1.89 years (range: 18-26 years) and a mean Spherical Equivalent (SE) of -1.41±1.97 D were included in the study. The average value of Central Corneal Thickness (CCT) in all the subjects was found 569.43±27.22 μm [Table/Fig-1]. The mean values for the first applanation, second applanation and highest concavity parameters are presented in [Table/Fig-2]. The present study demonstrated a substantial correlation between T1 and V1 regarding IOP and CCT in the first applanation; but only a significant difference in V1 was found for SE. On the other hand, the second applanation demonstrated a substantial correlation in T2 with IOP and CCT, L2 with CCT and V2 with SE, IOP and CCT [Table/Fig-3-5]. However, the highest concavity parameters showed a significant association of time with SE, deformation amplitude with SE and IOP; the radius with IOP and CCT and the PD with SE, IOP and CCT [Table/Fig-6a,b,7].

Characteristics	Mean±Standard deviation	Range
Age (Years)	20.74±1.89	18 to 26
Spherical Equivalent (SE) (Diopter)	-1.41±1.97	-5.50 to 3.25
Intraocular Pressure (IOP), mmHg	16.82±1.96	13.50 to 21.90
Central Corneal Thickness (CCT) in μm	569.43±27.22	528 to 658

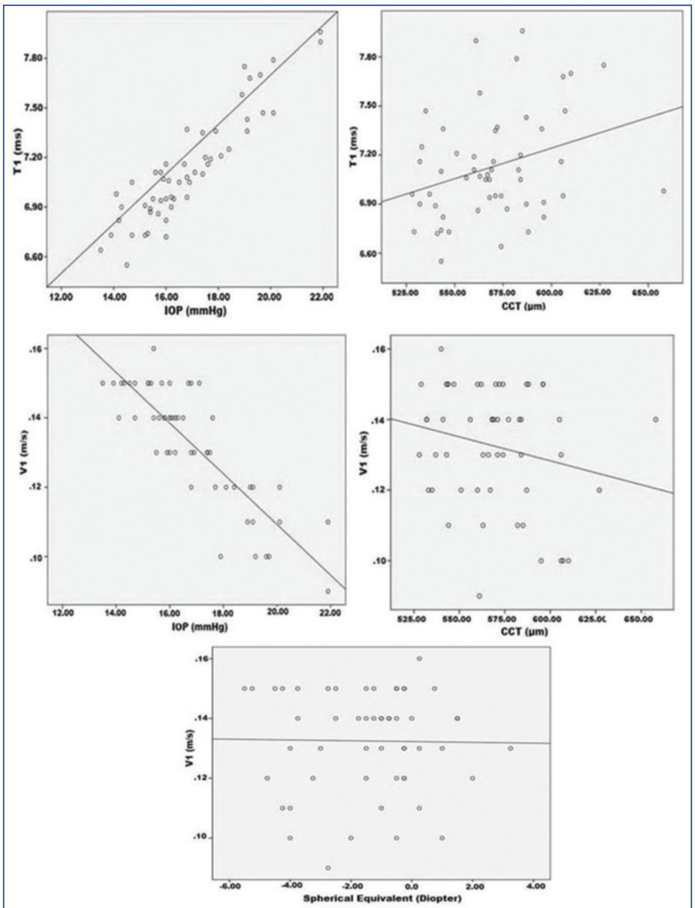
[Table/Fig-1]: Demographic and ocular features of participants.

Characteristics		Mean±Standard deviation	Range
First Applanation (A1)	T1 (ms)	7.13±0.33	6.55 to 7.96
	L1 (mm)	2.39±0.31	1.79 to 3.04
	V1 (m/s)	0.13±0.02	0.09 to 0.16
Second Applanation (A2)	T2 (ms)	21.77±0.37	20.92 to 22.36
	L2 (mm)	2.25±0.51	1.40 to 4.72
	V2 (m/s)	-0.26±0.03	-0.33 to -0.18
Highest concavity	Time (ms)	17.07±0.50	15.02 to 17.79
	DA (mm)	1.04±0.09	0.84 to 1.27
	Radius (mm)	8.1004±0.87	6.43 to 11.34
	Peak Distance (PD) (mm)	4.9183±0.25	4.25 to 5.47

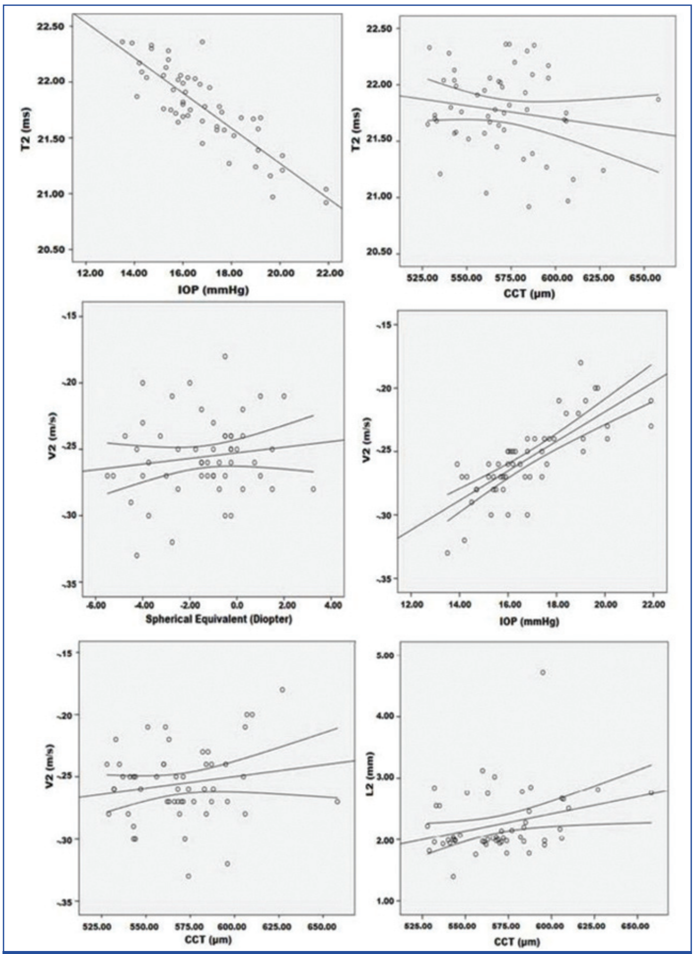
[Table/Fig-2]: CST parameters.

	First Applanation (A1), p-value (Standardised Coefficient (SC))			Second Applanation (A2), p-value (Standardised Coefficient (SC))		
Parameters	T1	L1	V1	T2	L2	V2
Age (years)	0.671 (-0.018)	0.575 (-0.081)	0.360 (0.065)	0.513 (0.049)	0.756 (-0.042)	0.360 (-0.076)
SE (D)	0.856 (0.007)	0.640 (-0.066)	0.029 (-0.155)	0.812 (-0.018)	0.243 (0.157)	0.002 (0.272)
IOP (mmHg)	<0.001 (0.907)	0.268 (0.160)	<0.001 (-0.850)	<0.001 (-0.838)	0.051 (0.270)	<0.001 (0.790)
CCT (µm)	<0.001 (0.294)	0.254 (0.161)	0.004 (-0.205)	0.038 (-0.155)	0.029 (0.295)	0.047 (0.164)

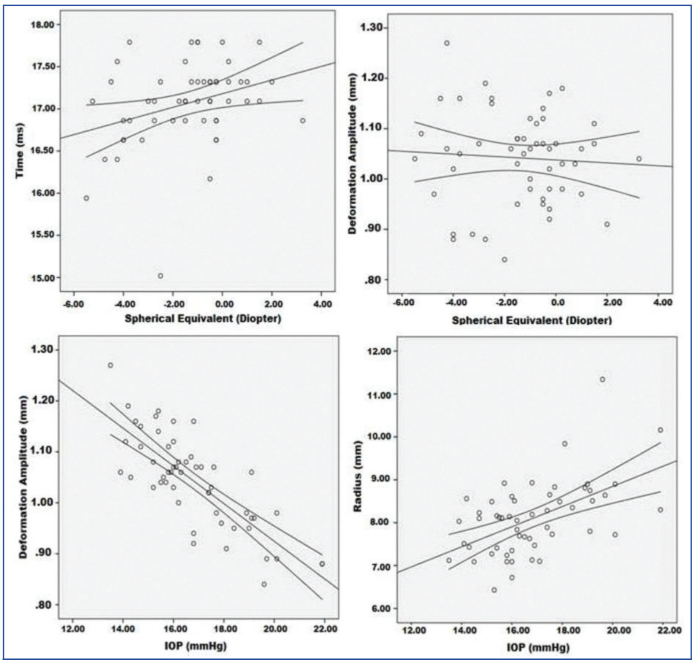
[Table/Fig-3]: Association between different ocular factors with each parameter taken by CST during first and second applanation. ANOVA was used.



[Table/Fig-4]: Significant CST parameters at the first Applanation (A1) moment.



[Table/Fig-5]: Significant CST parameters at the second Applanation (A2) moment.



[Table/Fig-6a]: Significant CST parameters at the highest concavity moment.

ORA Results

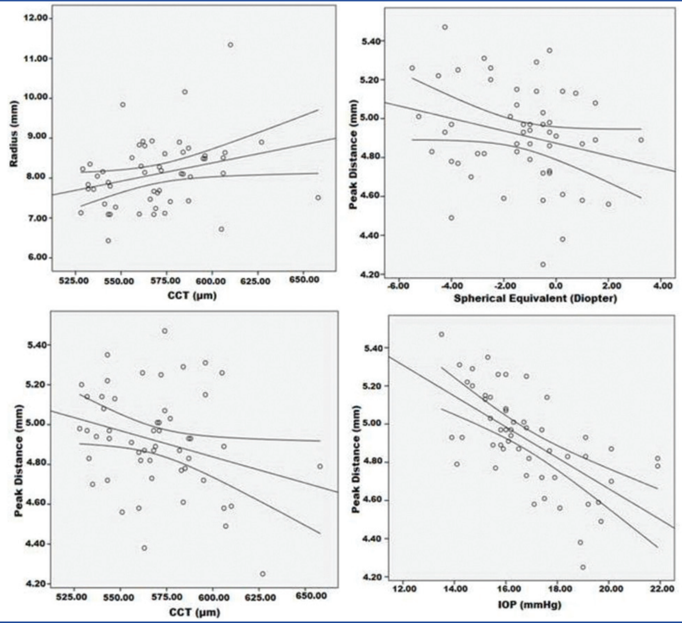
To ensure the accuracy, only 40 females were available at the same time to record the corneal biomechanical features. An insignificant association was observed between the parameters and refractive errors (emmetropia, hyperopia and low to moderate myopia) [Table/Fig-8,9].

Comparison between IOPcc and bIOP

Using the paired samples t-test, the analysis revealed a significant difference (p-value <0.001) between the IOP measurements produced by ORA and CST. A weak positive correlation was observed between the CST and ORA readings for IOP (r=0.463, p=0.003). As shown in [Table/Fig-10], CST had a higher mean, with a mean difference of 3.59 (95% confidence interval: 3.17-4.02).

DISCUSSION

The accurate knowledge of corneal biomechanical parameters is important for achieving precise IOP measurement and



[Table/Fig-6b]: Significant CST parameters at the highest concavity moment.

Parameters	Highest concavity, p-value (Standardised Coefficient (SC))			
	Time	Deformation amplitude	Radius	Peak Distance (PD)
Age (years)	0.940 (0.010)	0.369 (0.078)	0.261 (0.134)	0.414 (0.078)
SE (D)	0.034 (0.298)	0.028 (-0.192)	0.837 (0.024)	<0.001 (-0.365)
IOP (mmHg)	0.580 (-0.077)	<0.001 (-0.802)	<0.001 (0.559)	<0.001 (-0.659)
CCT (µm)	0.192 (-0.178)	0.447 (-0.064)	0.014 (0.290)	0.004 (-0.279)

[Table/Fig-7]: Correlation analysis of highest concavity parameters.

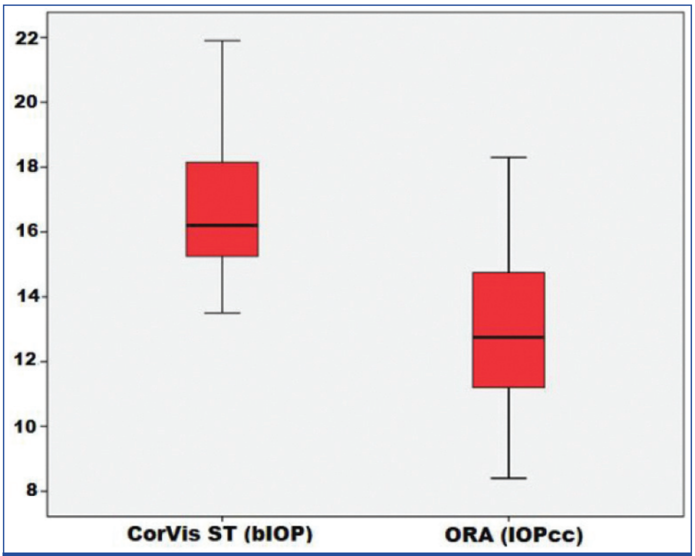
Parameters	Mean±Standard deviation	Range
Age (years)	20.45±1.87	18 to 24
Spherical Equivalent (SE) (D)	-1.38±1.86	-4.75 to 3.25
IOPcc (mmHg)	13.10±2.50	8.40 to 18.30
IOPg (mmHg)	14.36±3.15	8.70 to 20.40
CH (mmHg)	12.15±1.62	9.20 to 15.10
CRF (mmHg)	11.55±1.97	7.60 to 15.10

[Table/Fig-8]: Demographic data and ORA parameters (sample size: 40).

Parameters	Hyperopia (n=5)	Emmetropia (n=8)	Myopia (n=27)	Mean difference	p-value
	Mean±Standard deviation				
Age (years)	21.80±2.12	20.13±1	21±2.05	0.80	0.660
IOPcc (mmHg)	13.28±1.99	13.2±2.56	13.06±2.64	0.22	0.830
IOPg (mmHg)	14.11±3.05	14.21±3.52	14.42±3.22	0.30	0.811
CH (mmHg)	11.80±1.98	11.94±1.41	12.23±1.55	0.43	0.508
CRF (mmHg)	11.19±2.40	11.33±1.97	11.64±1.90	0.45	0.568

[Table/Fig-9]: ORA parameters with refractive errors. ANOVA was used.

correction, especially in subjects with corneal disorders. These parameters are also important after refractive surgery and for understanding the pathogenesis of corneal degenerative diseases such as keratoconus and glaucoma [36]. In the present study, various corneal biomechanical parameters of adult females were evaluated. The results revealed that CCT and IOP were the two main factors affecting the corneal biomechanical parameters. Out of 53 participants, the results of 40 healthy participants (mean age: 20.45±1.87 years, mean SE: -1.38±1.86 diopter) also were measured using ORA and this data was compared with the results of CST to validate the accuracy. All these parameters were noticed statistically insignificant with the refractive error groups. The IOP measured with CST and ORA were found weak and positively correlated (r=0.463, p-value=0.003). A study done by Wang W et



[Table/Fig-10]: Box plot for CST and ORA mean difference comparison of IOP (CST mean: 16.6950 mmHg, ORA mean: 13.1025 mmHg).

al., reported that the most notable specifications CCT, IOP, HCDA and V1 for the comparison of L1, L2 and PD [36]. While as the prominent noteworthy specifications according to Sashia BN et al.'s study were IOP, followed by T1, T2, CCT, HCR and HCDA [37].

Various studies have reported that biomechanical parameters determined by CST are independent of gender [38-40]. However, a research study conducted by Salouti R et al., found the different values of V1 and HCT for males and females [41]. Another study performed in Brazil reported a significantly low effect of CCT on corneal biomechanical parameters on Brazilian participants' eyes, with a mean patient age of 35.80±12.83 years and a range of 21.07 to 78.84 years [42]. An earlier study on 89 healthy Brazilian participants' eyes (mean age: 27.50±6.30, range: 12.54 to 39.70 years) was performed using CST to find any relationship between age and corneal biomechanical parameters. The results showed that only HCT was affected by age, because with age the cornea becomes stiffer and less viscoelastic as a result of an increase in the cross-linkage of collagen fibrils [43]. However, a similar study conducted on 108 healthy Chinese children (32 girls and 76 boys, mean age: 10.80±4.13 years, range: 4 to 18 years) reported no statistically significant relation of age with CST parameters, but CST parameters were found highly influenced by CCT and IOP [44]. The children and young adults may not have any significant effect, but the potent effect might be in old generation. A previous study reported an assessment of corneal biomechanical properties on 177 Spanish healthy populations (mean age: 33.27±7.65, range: 20-56 years) and results revealed weak association between CH and refractive error; these changes may affect IOP and hence increasing the risk of glaucoma with the age [45]. Another research carried on 215 healthy Saudi individuals (mean age: 33.6±11.75 years) for the corneal biomechanics using ORA reported a statistical difference between males and females in CH (p-value: 0.020) and CRF (p-value: 0.047) [46]. Moreover, a study carried out on the healthy black and white US participants revealed that healthy black subjects had even lower CH and CRF in comparision to white subjects, but the differences were insignificant [47]. However, the results obtained in the present study showed that the values of CH and CRF were close to each other irrespective of the age, in contrast to earlier reported studies [43,44]. This study has provided a reference database for corneal biomechanical properties in Saudi adult females, but more studies in this area are needed with ORA and CST in different age groups.

Limitation(s)

The present study was performed on young females and small sample size is also considered a limiting factor. No significant difference between the biomechanical parameters were found because of young age range. The results presented in the present study need to be further confirmed by longitudinal cohort studies with larger sample size of different age groups of males and females with different ethnicities. For the comparison between the ORA and CST, more studies must be done after including the CCT in the comparison with IOP to give a better idea on the different results taken with the two devices.

CONCLUSION(S)

The present study provides information that the CCT and IOP are the main factors affecting the biomechanical parameters. The parameters taken with CST and ORA instruments were compared and only a weak, positively linked significant difference was found between the IOP generated with CST and ORA.

REFERENCES

[1] Zhang G, Jiang J, Wei Q, Qu C. Effects of accommodation on geometrical parameters of human lens: A systematic review and meta-analysis. Heliyon. 2024;10(8):e29298.

[2] Kundu G, Shetty R, D'Souza S, Khamar P, Nuijts RMMA, Sethu S, et al. A novel combination of corneal confocal microscopy, clinical features and artificial intelligence for evaluation of ocular surface pain. Plos One. 2022;17(11):pe0277086. Available from: https://doi.org/10.1371/journal.pone.0277086.

[3] Da Silva F, Lira M. Intraocular pressure measurement: A review. Surv Ophthalmol. 2022;67(5):1319-31. Available from: https://doi.org/10.1016/j.survophthal.2022.03.001.

[4] Ávila FJ, Marcellán MC, Remón L. On the relationship between corneal biomechanics, macrostructure, and optical properties. J Imaging. 2021;7(12):280. Available from: https://doi.org/10.3390/jimaging7120280.

[5] Wang Y, Cao H, Chen W, Bao F, Elsheikh A. How can corneal biomechanics help with clinical applications? Front Bioeng Biotechnol. 2023;11:1186938. Available from: http://doi.org/10.3389/fbioe.2023.1186938.

[6] Wong SH, Tsai JC. Telehealth and screening strategies in the diagnosis and management of glaucoma. J Clin Med. 2021;10(16):3452. Available from: https://doi.org/10.3390/jcm10163452.

[7] Li R, Qian X, Gong C, Zhang J, Liu Y, Xu B, et al. Simultaneous assessment of the whole eye biomechanics using ultrasonic elastography. IEEE Trans Biomed Eng. 2022;70(4):1310-17. Available from: https://doi.org/10.1109/TBME.2022.3215498.

[8] Jesus V, Beatrize R, Ruben M, Raimundo J. Effects of water drinking on corneal biomechanics: The association with intraocular pressure changes. Indian J Ophthalmol. 2022;70(4):1222-28. Available from: https://doi.org/10.4103/ijo.IJO_1845_21.

[9] Torres-Netto EA, Abdshahzadeh H, Abrishamchi R, Hafezi NL, Hillen M, Ambrósio R Jr, et al. The impact of repetitive and prolonged eye rubbing on corneal biomechanics. J Refract Surg. 2022;38(9):610-16. Available from: https://doi.org/10.3928/1081597X-20220715-03.

[10] De Stefano VS, Ford MR, Seven I, Dupps WJ Jr. Depth-dependent corneal biomechanical properties in normal and keratoconic subjects by optical coherence elastography. Transl Vis Sci Technol. 2020;9(4):01-10. Available from: https://doi.org/10.1167/tvst.9.7.4.

[11] Alenezi B, Kazaili A, Akhtar R, Radhakrishnan H. Corneal biomechanical properties following corneal cross-linking: Does age have an effect? Exp Eye Res. 2022;214:108839. Available from: https://doi.org/10.1016/j.exer.2021.108839.

[12] Formisano N, Putten CVD, Grant R, Sahin G, Truckenmüller RK, Bouten CVC, et al. Mechanical properties of bioengineered corneal stroma. Advanced Health Mater. 2021;10(20):2100972. Available from: https://doi.org/10.1002/adhm.202100972.

[13] Esporcatte LP, Salomão MQ, Lopes BT, Sena N, Ferreira É, Filho JB, et al. Biomechanics in keratoconus diagnosis. Curr Eye Res. 2023;48(2):130-36.

[14] Leonard BC, Park S, Kim S, Young LJ, Jalilian I, Cosert K, et al. Mice deficient in TAZ (Wwtr1) demonstrate clinical features of late-onset fuchs' endothelial corneal dystrophy. Invest Ophthalmol Vis Sci. 2023;64(22):01-11. Available from: https://doi.org/10.1167/iovs.64.4.22.

[15] Chen YY, Wang TH, Huang JY, Su CC. Relationship of axial length and corneal biomechanical properties with susceptibility to unilateral normal-tension glaucoma. Graefe's Arch Clin Exp Ophthalmol. 2022;260(1):255-64. Available from: https://doi.org/10.1007/s00417-021-05346-2.

[16] Li DL, Liu MX, Yin ZJ, Li YZ, Ma R, Zheng YJ, et al. Refractive associations with corneal biomechanical properties among young adults: A population-based Corvis ST study. Graefe's Arch Clin Exp Ophthalmol. 2023;262(1):121-32. Available from: https://doi.org/10.1007/s00417-023-06164-4.

[17] De Bernardo M, Pagliarulo S, Rosa N. Unexpected ocular morphological changes after corneal refractive surgery: A review. Front Med. 2022;9:1014277. Available from: https://doi.org/10.3389/fmed.2022.1014277.

[18] Baptista PM, Ambrosio R, Oliveira L, Meneres P, Beirao JM. Corneal biomechanical assessment with ultra-high-speed Scheimpflug imaging during non-contact tonometry: A prospective review. Clin Ophthalmol. 2021;2021(15):1409-23. Available from: https://doi.org/10.2147/OPTH.S301179.

[19] Hatch KM, Ling JJ, Wiley WF, Cason J, Ciralsky JB, Nehls SM, et al. Diagnosis and management of post refractive surgery ectasia. J Cataract Refract Surg. 2022;48(4):487-99. Available from: https://doi.org/10.1097/j.jcrs.0000000000000808.

[20] Santos MJ, Francés FS, Quet OR, Lopez C, Bueso ES, Casa MM, et al. Dependence of corneal hysteresis on non-central corneal thickness in healthy subjects. J Fr Ophthalmol. 2023;46(8):866-72. Available from: https://doi.org/10.1016/j.jfo.2022.12.024.

[21] Kaur K, Gurnani B. Commentary: A novel way to assess corneal biomechanics in human eyes-The corneal stress-strain index. Indian J Ophthalmol. 2023;71(6):2427-28. Available from: https://doi.org/10.4103/IJO.IJO_300_23.

[22] Marinescu M, Dascalescu D, Constantin M, Coviltir V, Burcel M, Darabus D, et al. Corneal biomechanics–an emerging ocular property with a significant impact. Maedica J Clin Med. 2022;17(4):925-30. Available from: https://doi.org/10.26574/maedica.2022.17.4.925.

[23] Hwang HS, Park SK, Kim MS. The biomechanical properties of the cornea and anterior segment parameters. BMC Ophthalmol. 2013;13(49):01-06. Available from: https://www.biomedcentral.com/1471-2415/13/49.

[24] Çevik SG, Kıvanç SA, Akova-Budak B, Tok-Çevik M. Relationship among corneal biomechanics, anterior segment parameters, and geometric corneal parameters. J Ophthalmol. 2016;2016:8418613. Available from: https://doi.org/10.1155/2016/8418613.

[25] Montard R, Kopito R, Touzeau O, Allouch C, Lataief I, Borderie V, et al. Ocular response analyser: Feasibility study and correlation with normal eyes. J Fr Ophtalmol. 2007;30(10):978-84. Available from: https://doi.org/10.1016/s0181-5512(07)79273-2.

[26] Ramm L, Herber R, Lorenz G, Jasper CS, Pillunat LE, Pillunat KR. Evaluation of corneal biomechanical properties using the ocular response analyzer and the dynamic Scheimpflug-Analyzer Corvis ST in high pressure and normal pressure open-angle glaucoma patients. PLoS One. 2023;18(1):e0281017. Doi: 10.1371/journal.pone.0281017. PMID: 36701409.

[27] Lan G, Twa MD, Song C, Feng J, Huang Y, Xu J, et al. In vivo corneal elastography: A topical review of challenges and opportunities. Comput Struct Biotechnol J. 2023;21:2664-87. Available from: https://doi.org/10.1016/j.csbj.2023.04.009.

[28] Du Y, Zhang Y, Zhang YU, Li T, Wang J, Du Z. Analysis of potential impact factors of corneal biomechanics in myopia. BMC Ophthalmol. 2023;143(2023):01-07. Available from: https://doi.org/10.1186/s12886-023-02891-8.

[29] Sbordone S, Ragucci A, Iaccarino G, Scognamiglio G, Leone A, Gironi C, et al. Comparison of IOP obtained in different kind of eyes with contact and no contact tonometers. Oman J Ophthalmol. 2022;15(3):315-20. Available from: https://doi.org/10.4103/ojo.ojo_147_21.

[30] Wang B, Yang L, Cheng J, Wang J, Mei Y. In-vivo high-speed biomechanical imaging of the cornea using Corvis ST and digital image correlation. Comput Biol Med. 2023;153:106540.

[31] Da Silva F, Linhares JM, Lira M. The influence of the tear film on the intraocular pressure and the corneal biomechanical properties analysed with the ocular response analyser. J Optom. 2024;17(2):100488.

[32] López-Muñoz A, López-Castaño I, Torres-Parejo Ú, García-Romera MC. A corneal biomechanical study measured with a Scheimpflug Dynamic Analyser in soft contact lens wearers. Life. 2023;13(12):2313.

[33] Lee R, Chang RT, Wong IYH, Lai JSM, Lee JWY, Singh K. Assessment of corneal biomechanical parameters in myopes and emmetropes using the Corvis ST. Clin Exp Optom. 2021;99(2):157-62. Available from: https://doi.org/10.1111/cxo.12341.

[34] Vinciguerra R, Elsheikh A, Roberts CJ, Ambrosio R, Kang DSY, Lopes BT, et al. Influence of pachymetry and intraocular pressure on dynamic corneal response parameters in healthy patients. J Refract Surg. 2016;32(8):550-61. Available from: https://doi.org/10.3928/1081597X-20160524-01.

[35] Matsuura M, Murata H, Fujino Y, Yanagisawa M, Yoshitaka N, Nakakura S, et al. Repeatability of the novel intraocular pressure measurement from Corvis ST. Trans Vis Sci Technol. 2019;8(3):48. Available from: https://doi.org/10.1167/tvst.8.3.48.

[36] Wang W, He M, He H, Zhang C, Jin H, Zhong X. Corneal biomechanical metrics of healthy Chinese adults using CorvisST. Contact Lens Anterior Eye. 2017;40(2):97-03. Available from: https://doi.org/10.1016/j.clae.2016.12.003.

[37] Sashia BN, Bach PI, Anders I, Jesper H. Repeatability, reproducibility, and age dependency of dynamic Scheimpflug-based pneumotonometer and its correlation with a dynamic bidirectional pneumotonometry device. Cornea. 2015;34(1):71-77. Available from: https://doi.org/10.1097/ICO.0000000000000293.

[38] Chu Z, Ren Q, Chen M, Cheng L, Cheng H, Cui W, et al. The relationship between axial length/corneal radius of curvature ratio and stress–strain index in myopic eyeballs: Using Corvis ST tonometry. Front Bioeng Biotechnol. 2022;10:939129. Available from: https://doi.org/10.3389/fbioe.2022.939129.

[39] Wallace HB, Misra SL, Li SS, Mckelvie J. Biomechanical changes in the cornea following cataract surgery: A prospective assessment with the Corneal Visualisation Scheimpflug Technology. Clin Exp Ophthalmol. 2019;47(4):461-68. Available from: https://doi.org/10.1111/ceo.13451.

[40] Kenia VP, Kenia RV, Pirdankar OH. Age-related variation in corneal biomechanical parameters in healthy Indians. Indian J Ophthalmol. 2020;68(12):2921-29. Available from: https://doi.org/10.4103/ijo.IJO_2127_19.

[41] Salouti R, Bagheri M, Shamsi A, Zamani M, Ghoreyshi M, Nowroozzadeh MH. Corneal parameters in healthy subjects assessed by Corvis ST. J Ophthalmic Vis Res. 2020;15(1):24-31. Available from: https://doi.org/10.18502/jovr.v15i1.5936.

[42] Valbon BF, Ambrósio Jr R, Fontes BM, Luz A, Roberts CJ, Alves MR. Ocular biomechanical metrics by CorVis ST in healthy Brazilian patients. J Refract Surg. 2014;30(7):468-73. Available from: https://doi.org/10.3928/1081597X-20140521-01.

[43] Valbon BF, Fontes BM, Alves MR. Effects of age on corneal deformation by non-contact tonometry integrated with an ultra-high-speed (UHS) Scheimpflug camera. Arquivosbrasileiros de Oftalmologia. 2013;76(4):229-32. Available from: https://doi.org/10.1590/S0004-27492013000400008.

[44] He M, Ding H, He H, Zhang C, Liu L, Zhong X. Corneal biomechanical properties in healthy children measured by corneal visualization scheimpflug technology. BMC Ophthalmol. 2017;70(2017):01-07. Available from: https://doi.org/10.1186/s12886-017-0463-x.

[45] Del Buey MA, Lavilla L, Ascaso FJ, Lanchares E, Huerva V, Cristóbal JA. Assessment of corneal biomechanical properties and intraocular pressure in myopic Spanish healthy population. J Ophthalmol. 2014;2014:905129. Available from: https://doi.org/10.1155/2014/905129.

[46] Al-Arfaj K, Yassin SA, Al-Dairi W, Al-Dairi W, Al-Shamlan F, Al-Jindan M. Corneal biomechanics in normal Saudi individuals. Saudi J Ophthalmol. 2016;30(3):180-84. Available from: https://doi.org/10.1016/j.sjopt.2016.05.001.

[47] Leite MT, Alencar LM, Gore C, Weinreb RN, Sample PA, Zangwill LM, et al. Comparison of corneal biomechanical properties between healthy blacks and whites using the ocular response analyser. Am J Ophthalmol. 2010;150(2):163-68. Available from: https://doi.org/10.1016/j.ajo.2010.02.024.

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