Original Article

Evaluating the Repeatability and Effect of Sex and Age on Corneal Biomechanical Parameters Measured Using Corvis ST Tonometer

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Abstract

Purpose: To evaluate the repeatability of biomechanical readings by Corvis ST (Wetzlar, Germany) in healthy eyes and its relation with age and sex.

Methods: Three consecutive measurements were performed on 100 eyes of 100 participants using the Corvis ST. Various parameters including first and second applanation length, first and second applanation velocity, first and second applanation time, peak distance, radius, deformation amplitude, corrected and non-corrected intraocular pressure (IOP), central corneal thickness (CCT), Corvis ST biomechanical index (CBI), and tomography and biomechanical index (TBI) were derived from the Corvis ST readings. Repeatability of each parameter and their correlation with age and sex were evaluated.

Results: The mean IOP, CCT, CBI and TBI were 15.47 ± 2.24 mm Hg, 541.24 ± 38.90 µm, 0.048 ± 0.13 and 0.138 ± 0.17 respectively. Intra class correlation coefficient (ICC) for CCT, second applanation velocity and deformation amplitude were 0.985, 0.809 and 0.825 respectively. ICC was less than 0.8 for all other parameters. The device-specific readings showed no significant relationship with age and sex.

Conclusion: The Corvis ST showed high repeatability in measuring CCT, second applanation velocity, and deformation amplitude parameters. No relation between Corvis ST readings and age or sex was observed.

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Introduction

Human cornea, with a mean diameter of 11.5 mm, mean central thickness of 0.5 to 0.6 mm and mean peripheral thickness of 0.6 to 0.8 mm has both viscous and elastic properties [1]. Such features enable shape re-formability of the cornea in the presence of external pressures [1]. Biomechanical characteristics of the cornea have high clinical importance. These characteristics are useful in monitoring corneal diseases and presurgical evaluations [1]. For example comparing the corneal hysteresis (CH) values of those with healthy corneas and patients suffering from a known corneal disease reveals a high level of difference in CH value [2].

Ocular response analyzer (Reichert Ophthalmic Instruments, Depew, New York) was introduced in 2005 and has been widely used in measuring and analyzing the biomechanical characteristics of the cornea [3]. CH and corneal resistance (CR) are the key factors measured by ocular response analyzer (ORA). These factors have been evaluated for healthy and unhealthy eyes in different studies. Although ORA can measure the CH and CR, this device cannot show the dynamic corneal changes in real time. The need for a real time measurement method along with a device capable of measuring other corneal biomechanical characteristics led to the invention of more advanced measuring instruments including a non-contact tonometer named corneal visualization Scheimpflug technology (Corvis ST, Oculus, Wetzlar, Germany) [4]. To measure corneal biomechanical characteristics, Corvis ST emits a pulse of air towards the cornea, while it captures and displays the physical changes in the cornea simultaneously, and the shape changing features of the cornea are saved [5]. The main difference between the Corvis ST and ORA is the presence of an ultra high-speed camera (Scheimpflug) with the shutter speed of 4330 frames/Sec [5].

The present study analyzed various parameters provided by Corvis ST in healthy eyes from an Iranian population to evaluate the repeatability of these parameters as well as their relation with patients' sex and age.

Methods

All procedures followed were in accordance with Declaration of Helsinki and participants signed an informed consent before entering the study. The study was approved by the ethics committee of Basir Eye Health Research Center, Tehran, Iran.

A total of 100 healthy eyes from 100 participants were evaluated in Vision Health Research Center, Tehran, Iran. One eye of each participant was chosen randomly to be included in the study. The exclusion criteria were any eye diseases (glaucoma, uveitis, corneal ectatic disorders, Fuchs' dystrophy, diabetic retinopathy), spherical refractive disorders, astigmatism more than 2 diopter, history of intraocular surgery, administration of topical eye drugs, corneal ulcer, and use of contact lenses .

Eye examinations

All participants went under a complete eye examination. Eye examinations included measurement of uncorrected visual acuity (UCVA), best corrected visual acuity (BCVA), manifest refraction, eye pressure using Goldmann applanation tonometry (Hagg Streit, Koenz, Switzerland Goldmann) and slit lamp exam. All examinations were performed between 9 am to 7 pm in one sitting by the same ophthalmologist, optometrist and trained operator.

Pentacam measurements

The Pentacam device uses a Scheimpflug camera to measure the corneal tomography [6,7]. The captured tomography image is generated by a 360 degree rotation of the camera around the optical axis of the eye [8]. While capturing the images, eye movements might blur the image [8]. This issue is corrected by the use of a secondary camera [8]. In this study, the Pentacam images were taken from each eye to acquire tomography biomechanical index (TBI) and only the measurements with ‘‘OK’’quality-specifications were considered. The TBI is a combined parameter based on corneal tomography and biomechanical assessments, which has been described in more detail previously [9].

Corvis ST Measurements

This device uses an ultra high-speed Scheimpflug camera (4330 frames/sec) and a LED light source with the wavelength of 455 nm to capture corneal deformation against a puff of air. After emitting the air puff, the cornea bends inward and flattens. This step is called first applanation. Then it keeps moving further into the maximum concavity. Lastly, it returns to its initial state and re-flattens (second applanation).Therefore, corneal changes are categorized into three phases, namely, first-applanation, highest concavity and the second applanation. Through this process parameters such as length, time and the speed of first and second applanation, the maximum range of corneal changes, and radius of the corneal curvature (in highest concavity stage) are measurable. Moreover, the CBI is measured and analyzed as well. CBI itself includes parameters such as deformation amplitude ratio at 1 and 2 mm, applanationa1 velocity and the standard deviation of deformation amplitude at highest concavity [10]. The slow motion video clip shows the physical response of the cornea to the emitted air puff in a time lap of 30 ms. Corvis ST also provides parameters such as central corneal thickness (CCT), internal eye pressure and other parameters related to corneal deformation [11]. It is noteworthy to mention that the intraocular pressure measured by the device can be converted to corrected pressure using different formulas such as Ehlers, Dresden and Shah, based on corneal pachymetry. In this study, Dresden formula was used to determine the adjusted pressure. Since the Pentacam device measurements were available for each eye, TBI was measured using “Tomographic Biomechanical Assessments Display” of the Corvis ST software.

Data analysis

Data analysis was performed using SPSS version 23 (Armonk, NY: IBM Corp.). Maximum, minimum, mean and standard deviation of each parameter was calculated. The correlation of the sex with each parameter was analyzed using independent sample t-test and Mann-Whitney U test. After categorizing the individuals into five different age groups (with the interval of 10 years), the variance in mean age was calculated using analysis of variance (ANOVA). In all analysis, values less than 0.05, were considered as statistically significant.

Results

In the present study, 53 % of the patients were female, and 47 % were male. The mean age of participants was 37.68 ± 12.09 years (range 12-63). The mean value of UCVA, sphere, cylinder and BCVA were 0.872 ± 0.212, - 0.006 ± 0.670, 47.10 ± 62.70, 1.0 ± 0.000 respectively.

The mean values as well as minimum and

maximum Corvis ST readings are presented in table 1. Different coefficients of repeatability indexes are analyzed and reported in table 2. Statistical analysis showed that second applanation velocity, deformation amplitude and CCT had the highest level of repeatability with the intra class correlation coefficient (ICC) of 0.809, 0.825 and 0.985, respectively. IOP and TBI showed a relatively high repeatability with the ICC values of 0.763 and, 0.764 respectively. The remaining parameters did not show a high level of repeatability.

Age classification was 12 to 22 years, 23 to 33 years, 34 to 44 years, 45 to 55 years, and 56 to 66 years. The results of independent sample t-test and Mann-Whitney U test for parametric and non-parametric variables indicated that there were no statistically significant relation between sex (Table 3) and age with corneal biomechanical parameters calculated using Corvis ST.

Discussion

The correct measurement of the corneal biomechanics helps in diagnosis and successful treatment of corneal diseases such as keratoconus and ectasia [12]. We found that the repeatability of corneal biometric parameters measurement using Corvis ST is relatively high when measuring CCT, deformation amplitude and second applanation velocity. The ICCs for these parameters were 0.985, 0.825, 0.809 respectively. In a report from Newzealand, the CCT was the only parameter with acceptable repeatability [13]. In another study among Chinese population a high level

Table 1: The mean, minimum and maximum values of the measured corneal biomechanical parameters using Corvis ST

Parameter	Minimum	Maximum	Mean	Std. Deviation
A1 length	1.61	1.90	1.81	0.04938
A1 velocity	0.08	0.18	0.146	0.01959
A2 length	0.86	2.34	1.75	0.32759
A2 velocity	- 0.77	- 0.23	- 0.41	0.09835
Peak Distance	2.12	5.54	3.35	0.94501
Radius	6.02	9.86	7.84	0.73053
Deformation Amplitude	0.85	1.33	1.02	0.08739
IOP* non corrected	9.75	23.50	15.12	2.53025
IOP corrected	11.20	22.60	15.47	2.24237
CCT	443.00	643.50	541.24	38.89967
A1 time	6.54	8.24	7.174	0.3141
HC time	15.83	17.21	16.54	0.33462
A2 time	11.86	21.98	21.19	0.98041
CBI	0.00	0.78	0.048	0.13159
TBI	0.00	0.66	0.138	0.16907

IOP: Intraocular Pressure; CCT: Central Corneal Thickness; HC: Highest Concavity;
CBI: Corvis Biomechanical Index; TBI: Tomography and Biomechanical Index; A1: First; A2: Second

Table 2: Repeatability analyzes of the measured corneal biomechanical parameters using Corvis ST

Parameter	ICC	95 % CI for ICC	95 % Lower CI for Cranach's alpha	SD	Coefficient of Repeatability
A1 length	0.360	0.177 to 0.519	0.301	0.067	0.134
A1 velocity	0.575	0.427 to 0.692	0.598	0.020	0.04
A2 length	0.345	0.160 to 0.506	0.276	0.456	0.931
A2 velocity	0.809	0.729 to 0.868	0.844	0.069	0.138
Peak Dist	0.121	- 0.976 to 0.310	- 0.164	1.667	3.335
Radius	0.000	- 0.196 to 0.195	- 0.487	0.776	1.552
Deformation Amplitude	0.825	0.750 to 0.879	0.857	0.059	0.118
IOP* non corrected	0.800	0.717 to 0.861	0.835	1.759	3.515
IOP corrected	0.763	0.667 to 0.834	0.800	1.725	3.451
CCT	0.985	0.977 to 0.990	0.989	6.785	13.570
A1 time	0.001	- 0.195 to 0.196	- 0.484	0.207	0.415
HC time	0.355	0.171 to 0.514	0.292	0.459	0.919
A2 time	0.059	- 0.138 to 0.251	- 0.321	0.260	0.521
CBI	0.582	0.425 to 0.705	0.596	0.134	0.269
TBI	0.764	0.661 to 0.839	0.796	0.123	0.219

IOP: Intraocular Pressure; CCT: Central Corneal Thickness; HC: Highest Concavity;
CBI: Corvis Biomechanical Index; TBI: Tomography and Biomechanical Index

Table 3: The correlation between sex and the corneal biomechanical parameters measured using Corvis ST

Parameter	Sex	Minimum	Maximum	Mean ± SD	P Value
A1 length	Male	1.62	1.88	1.809 ± 0.0496	0.122
	Female	1.60	1.90	1.824 ± 0.0486	
A1 velocity	Male	0.08	0.17	0.1467 ± 0.0192	0.788
	Female	0.08	0.18	0.1459 ± 0.0200	
A2 length	Male	0.86	2.34	1.747 ± 0.3476	0.982
	Female	0.86	2.20	1.755 ± 0.3120	
A2 velocity	Male	- 0.77	- 0.24	- 0.4207 ± 0.1130	0.652
	Female	- 0.57	- 0.22	- 0.411 ± 0.0841	
Peak Distance	Male	2.14	5.54	3.275 ± 1.026	0.270
	Female	2.12	5.12	3.431 ± 0.8690	
Radius	Male	6.02	9.75	7.7753 ± 0.7784	0.685
	Female	6.08	9.86	7.900 ± 0.687	
Deformation Amplitude	Male	0.85	1.33	1.035 ± 0.0961	0.428
	Female	0.86	1.17	1.021 ± 0.0791	
IOP non corrected	Male	9.75	23.50	14.936 ± 2.855	0.384
	Female	11.50	21.50	15.297 ± 2.216	
IOP corrected	Male	11.20	22.60	15.448 ± 2.325	0.926
	Female	11.85	22.55	15.489 ± 2.188	
CCT	Male	443.00	622.50	537.06 ± 37.549	0.314
	Female	475.00	643.50	544.94 ± 40.047	
A1 time	Male	6.54	8.24	7.1586 ± 0.3528	0.623
	Female	6.74	7.96	7.1884 ± 0.2781	
HC time	Male	15.82	17.21	16.528 ± 0.349	0.659
	Female	15.94	17.19	16.558 ± 0.323	
A2 time	Male	11.86	21.98	21.112 ± 1.408	0.546
	Female	20.76	21.72	21.270 ± 0.252	
CBI	Male	0.00	0.78	0.0559 ± 0.153	0.628
	Female	0.00	0.48	0.0426 ± 0.111	
TBI	Male	0.00	0.55	0.1396 ± 0.171	0.961
	Female	0.00	0.66	0.1370 ± 0.168	

of repeatability was observed for IOP, CCT and A1 velocity [14]. Nemeth al., [15] observed that the highest repeatability belongs to CCT and IOP.

The relationship between corneal biomechanical parameters with sex and age of participants has been evaluated in different studies. We found no statistically significant relation between these parameters measured by Corvis ST with sex and age. Strobbe et al., [16] examined a total of 400 Italian individuals divided into five different age categories and found that CH decreases as the age increases [16]. Moreover, male participants showed higher CH and CRF levels [16]. In another study conducted on 350 eyes of 350 healthy Egyptian individuals, the influence of sex on CRF, CH and IOP measured using ORA was analyzed and a significant difference between male and female participants for CH and CRF was found [17]. Valbon et al., [18] reported no difference in Corvis ST readings between Brazilian male and female participants. Asaoka et al., [19] in a study conducted on 94 healthy eyes found a significant relation between peak distance and sex of the individuals [19]. They also reported a relation between A1 time, A2 time, A1 length, deformation amplitude and A2 velocity with the age of healthy participants [19].

A shortcoming of the present study was the relatively low number of participants which might be the reason for not finding probable correlations between age and sex with Corvis ST readings. Future studies with higher sample size are recommended to further evaluate these probable relations.

Conclusion

The Corvis ST showed high repeatability in measuring CCT, second applanation velocity, and deformation amplitude parameters. No relation between Corvis ST readings and age or sex was observed.

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Footnotes and Financial Disclosures

Conflict of interest:

The authors have no conflict of interest with the subject matter of the present study.