Results from the use of Corvis ST Device and femtosecond laser, and comparing the incidence of corneal edema

Dana Rezaei[a, 1*], Mehdi Rajabioun[a]
[a]Department of Medical Engineering, Tabriz, Iran
[1]E-mail address:D.Rezaei1227@gmail.com

Abstract

Corneal biomechanics examination using Corvis ST device and femtosecond laser corneal cleansing and also comparing the incidence of corneal edema between diabetic and non-diabetic people

Materials and methods: The Corvis ST uses a high-speed Scheimpflug camera that captures cross-sectional images of the cornea during the reshaping process. After a steady puff of air, the cornea moves inward and reaches its maximum deformation, and then returns to its previous position. In 31 consecutive minutes, consecutive imaging of the cornea and cross-sectional profiles of the posterior and anterior surfaces are performed during the application of external dynamic air pressure.

In the femtosecond method, the patient's head, eyes, or body remain immobile and the patient is placed behind the head only during surgery.

Discussion: Corvis ST is not reliable in measuring the highest concavity peak distance (HCPD). With the information obtained from this device, a distinction is made between the effects of intraocular pressure (IOP) and corneal biomechanics on corneal deformation. Among the biomechanical parameters, A1T and highest concavity (HCR) showed a good ability to detect keratoconus.

No significant differences were observed between men and women for any of the biomechanical parameters. Age was positively correlated with A1DA, A2DA, and the highest concavity deformation amplitude (HCDA). The cornea is more closely related to collagen fibers and becomes harder with age.

CVS-IOP error increased significantly with higher CCT

The use of femtosecond laser does not reduce the patient's vision we only have bad burns due to laser scattering, but its focus has increased compared to older methods such as traditional surgeries.

After phacoemulsification, patients with diabetes were 3.5 times more likely to develop severe corneal edema than non-diabetics.

Keywords: *Corneal; Corvis ST; Corneal biomechanics; Tonometry; Intraocular pressure; femtosecond*

Introduction

The cornea has viscous and elastic properties that can be evaluated by corneal biomechanical measurements [1]. Abnormal corneal biomechanics with several systemic and ocular conditions such as keratoconus, corneal dystrophy, corneal protrusion, and diabetes mellitus [2]. Obvious keratoconus is easily diagnosed by corneal topographies, but tracking its early stages and suspected patients is a major concern for refractive surgeons [3].

The biomechanical properties of normal eyes with keratoconus have been investigated in various studies using the Eye Reaction Analyzer (ORA: Reichert Eye Instruments, the first tool to measure the biomechanical properties of the cornea). Most of them showed that the biomechanical properties of ocular and normal keratoconus were significantly different [4]. Although knowledge of corneal biomechanics was important in the diagnosis, treatment, and evaluation of corneal degenerative conditions, it was impossible to accurately determine it in the body until the introduction of the Oral Reaction Analyzer (ORA) in 2005[5].

Recently, Corvis ST (Scheimpflug Corneal Visualization technology) has been introduced as a clinical tool for assessing the biomechanical properties of the cornea [3].

Evaluation of different corneal biomechanical parameters to identify the defining parameters can be an important step toward the early detection of marginal cases of keratoconus [3].

The Corvis ST is another non-contact tonometer that detects deformation of the posterior and anterior corneal surfaces under the dynamics of outside air pressure using a high-speed Scheimpflug camera [6]. This information made it possible to accurately determine the profile and curvature of the corneal thickness, both of which are important biomechanical parameters [6].

In this comparative study, two study groups were formed: the healthy group and the keratoconus group. The healthy control group consisted of refractive surgery volunteers [3]. A thorough ophthalmologic examination confirmed their eligibility for the study [3].

Ethical approval for the use of samples in the study was obtained by the Eye Bank following the Helsinki Declaration.

The diagnosis of keratoconus was made by a corneal specialist using microscopic signs and imaging of the cornea. In the keratoconus group, the first four steps of the topographic keratoconus (TKC) classification provided by Pentacam were included [7].

Each patient underwent a comprehensive ophthalmologic examination, which included a medical history examination, best-corrected vision, slit lamp and endoscopy, Pentacam tomography evaluation, and Corvis-ST measurements during the same visit [3]. All measurements were taken between 8 am and 1 pm. According to the literature, a measurement for the 10 biomechanical parameters measured in CST is not reliable. Therefore, to increase the accuracy of the results, two measurements were taken at an interval of 10-15 minutes, and the average of the results was obtained. The same operator performed all the topographies using a Pentacom, and the operator performed the CST examination with another experiment [3]. The method of measurement with the above tools is well described.

In this study, the following variables, measured by CST, were used to test the biomechanical condition of the corneas: applanation time 1 (A1T: first applanation time), applanation time 2 (A2T start time to the second applanation), highest Concavity time (HCT: time of highest corneal displacement); the Highest amplitude of concave deformation (HCDA: amplitude of highest corneal displacement), length of the first applanation (A1L length of first smoothed piece in the first applanation), length of the second applanation (A2L length of the smoothed piece in the second applanation), Applanation speeds 1 and 2 (A1V and A2V: corneal movement speed during two applanations); Highest concave radius (HCR: central concave curvature at highest concavity) [3] Statistical analyzes and maps were performed by MedCalc software [3].

Subjects with the following conditions were excluded from the study: 1- Modified vision (CDVA) more than 0.1 in both eyes, 2- Spherical equivalent in each eye less than 6- Diapoter or cylindrical degree less than +2 3- Intraocular asymmetry SE 1 diopter 4- mmHg, 5- Evidence of abnormality in the appearance of the inner part of the eye or the bottom of the eye, 6- Internal disease of the eye except cataract, 7- History of wearing contact lenses in the last two months, 8 History of eye surgery or laser interventions. 9- Systemic diseases such as diabetes, cardiovascular disease, or systemic hypertension. People who were unable to complete all examinations were excluded [2].

IOP, CCT, and all corneal biomechanical measurements were obtained in all subjects with CST. The CST is a non-contact tonometer equipped with a high-speed Scheimpflug camera that captures 140 images in 31 minutes focused on an 8mm horizontal cornea with a resolution. After a steady puff of air, the cornea moves inward and reaches its maximum deformation, and then returns to its previous position. There are three distinct stages during the corneal deformation process.

First applanation (A1); highest concavity (HC), second applanation (A2). Along with IOP and CCT, corneal biomechanical parameters during each condition were obtained with the latest software through corneal dynamics analysis.

To eliminate changes within the evaluator, the same technician who was unaware of the study design performed all examinations. Only individuals with sufficient quality images (quality index was OK) were analyzed [2].

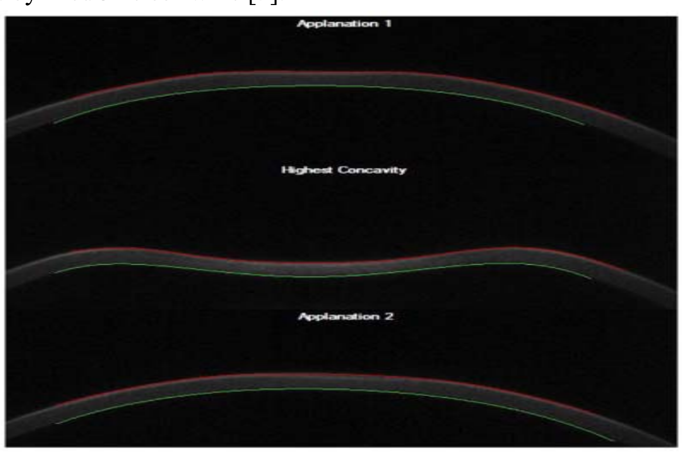

Figure 1 a- Corneal reaction to an air jet and corneal biomechanical parameters

Central corneal thickness (CCT) was measured using a DGH 55 Pachmate thickness gauge. After removing the extraocular tissue, a G14 needle was inserted through the posterior pole and glued around the entry point to prevent leakage and used to remove the vitreous. The inside of the butter was washed several times with phosphate brine to allow the liquid to move gently through the needle and syringe attached to it. Then 10% dextran solution was injected into the eye before placing it in the test instrument to prevent swelling during the test. During these steps, the eye was kept moist with a layer of a viscous tear to prevent dryness using over-clearing[6].in Figure 1.

The needle, inserted through the posterior pole, is connected to a 4 mm diameter tube that was connected to a syringe pump and was controlled using custom LabVIEW software. The pressure applied was monitored using a syringe pump inside the sphere using an FDW pressure transducer fixed at the same horizontal level as the center of the eye to avoid head pressure differences. The pressure transducer reading was assumed to represent the true IOP operating in the eyeball, and since the contents of the inner sphere, including the vitreous and glass lenses, were removed, the IOP showed pressure on the surface of the cornea and the inner surface of the sclera enters [6].

Statistical analysis was performed on IBM SPSS 24. The three Corvis ST readings were averaged for bIOP and CVS-IOP and compared with the actual IOP measured with a pressure transducer. After norm analysis, one-way ANOVA and Bonferroni analysis were used to compare the mean difference after Pearson correlations to evaluate the relationship between bIOP and CVS-IOP with CCT and IOPt. Values of p less than 0.05 were considered statistically significant [6].

Femtosecond laser technology can be used in cataract surgery to perform capsulotomy, lens fractures, and corneal incisions. Compared to traditional cataract surgery, femtoscope laser-assisted cataract surgery (FLACS) can show potential benefits such as increased intraocular lens focus and reduced lens replacement power [8, 9]. However, the potential for increasing the usefulness and safety of conventional techniques has not been fully elucidated. Although FLACS is a safe procedure, there are complications such as loss of suction, rupture of the anterior capsule, rupture of the contralateral capsule, abandoned nucleus, or loss of vitreous. Patterns of partial lens segmentation are applied to the patient's cornea after FLACS, despite the absence of any complications from surgery [10, 11].

On the first day after surgery, the left eye had a BCVA of 20.60 and an IOP of 18 mm Hg. Examination of the left eye socket showed a faint irregular light on the corneal tissue (Figure 1B). This circular pattern consists of discrete radial sections that are similar to the inside of a femtosecond laser mold during lens segmentation (Figure 1C). There was swelling of the left cornea. The patient had no additional disabilities or discomforts [9].

Two weeks after surgery, BCVA was 30.30 OS. The laser pattern faded significantly and the corneal inflammation disappeared. At 8 weeks after surgery, corneal resection was not apparent and BCVA was 20/25 OS. The patient was satisfied with the final result after surgery [9].

Despite the precise safety features associated with Lens AR and other systems, femtosecond laser incineration has been reported in a variety of contexts. For example, improper laser combustion is associated with changes in the surface of the anterior capsule that may occur during the capsulotomy, although this burn is located in the anterior capsule. In addition, the presence of micro-pitting bubbles in front of the laser target may be due to laser scattering. During FLACS, the anterior capsule may initially increase the formation of anterior gas bubbles in the lens, which could potentially lead to laser scattering during lens segmentation. It is not clear if this is a factor in the current case, in which case the position of the small gas bubbles may be difficult to understand during treatment [12, 13].

The previous 2 cases of corneal ETCHING were understood using a precision catalyst laser system. The potential for unintentional laser delivery to the cornea may not be limited to a particular brand of femtosecond technology. Although there is no error in notifying the Lens AR system of automatic termination during this case, the possibility of system malfunction due to laser malfunction cannot be ruled out [9].

The complexity of FLACS stated here does not appear to reduce the patient's visual acuity. However, corneal ETCHING transcends the center of the visual axis. The effects of this corneal ETCH are not generally expressed and thus the potential for visual complications is not known [9].

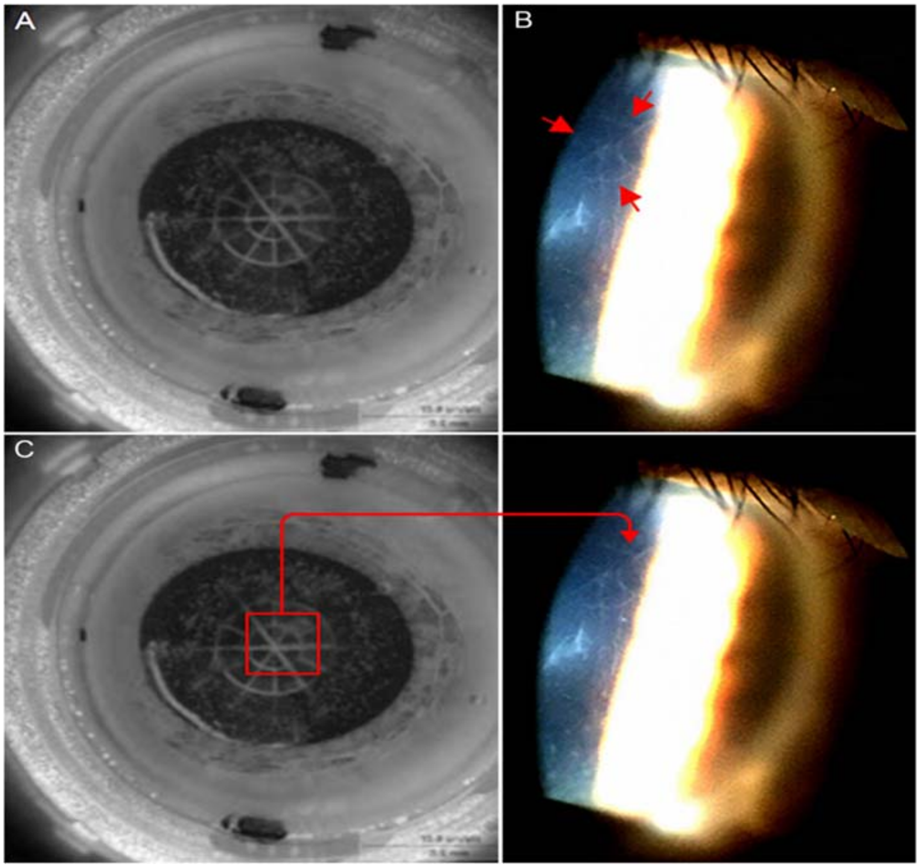

Figure1 b. The femtosecond laser pattern is transferred to the cornea. A- Image of lens segmentation pattern used by Lens AR femtosecond laser system during patient's cataract surgery. This shape consists of a combination of 2 concentric cylindrical cuts and 6 cross plates to move the cylinders, creating a radial pattern of circular sections. B- Picture of the patient's left eye slit one day after surgery and 20 hours after surgery. Poor removal (with red marks) is evident in the corneal tissue, which is similar to the inner cylinder section and the radial sections of the laser pattern. Rupture is also evident. C- Show a diagram showing the potential mechanism by which de-escalation is transmitted to the cornea. The internal cylinder section and radial incisions (left by the red box) should involve the patient's cornea. (Red curve mark on the right).

Patients in the control and study groups were evaluated for corneal edema three times after surgery after surgery: days 1, 7-3, 10-14 days after surgery. Ultrasound energy consumed during phacoemulsification was also a parameter considered and possible correlations with pre-existing cataract severity and subsequent incidence of corneal edema were investigated [14].

Several studies attempt to link the absolute number of endothelial cells to the progression of corneal edema after phacoemulsification. However, there are reports that the cornea is supported by a small number of endothelial cells; It is transparent; On the other hand, corneal edema may develop after surgery despite a sufficient number of endothelial cells. As a result, the number of cells becomes quite an important factor; but the most significant factor remains to be the quality of endothelial cells, even if they are small in number [15].

One of the most common comorbidities among people with cataracts is diabetes mellitus [16]. We know that high blood sugar levels affect the cells of the eye in many cases [17], and in particular, there have been reports of a link between diabetes and corneal endothelial function [14].

The protocol of this study was based on the principles of the Helsinki Declaration and ensured that patients remained anonymous and gained their trust [14].

Exclusion criteria were: 1) People with a history of iris inflammation, dense cataracts, corneal disease or degeneration (mainly corneal focal dystrophy), and diabetic macular edema were not included in the study 2) Endothelial pump to oxygen metabolism, which Is dependent on glucose and carbohydrates; Therefore, special attention should be paid to identifying the factors that can independently affect the endothelial pump; Like severe lung disease [18]. 3) Another notable factor is the activity of the ATPase complex [18]. Drugs such as dactinomycin, ovabine, and oligomycin are potential inhibitors of the activity of this complex, and patients who have taken these drugs; were excluded from the study [14].

Preoperative evaluation included eye slit monitoring and retinal examination, correction of visual acuity and intraocular pressure (IOP), and classification of nuclear cataracts according to the classification system. LOCS III classification was classified as NC1 to NC5 (NO1 to NO5); While NC6 cases were assigned to extracapsular extraction of cataracts. Biometrics were performed on all patients by an ultrasound scan to calculate the power of the intraocular lens. All patients were advised to use tobramycin/dexamethasone eye drops four times daily for 2 days before surgery [14].

There is no universally accepted pattern for follow-up after cataract surgery. In the United Kingdom, according to the Royal College of Ophthalmologists, even a day visit after surgery is not mandatory [14].

Anterior chamber activity and lens loading location were also documented. The postoperative drug treatment algorithm includes the standard use of steroid drops every 4 hours for the first week and four times a day until the fourth week. It is recommended to take antibiotic drops 4 times a day for the first two weeks. Some cataract treatment centers recommend the use of hypertonic saline solutions such as 5% sodium chloride solution or ointment. We tend to use these solutions in cases of persistent corneal edema and they are not used directly after surgery [14].

As expected; The results of the study showed that the energy required for ultrasound is strongly dependent on the severity of the cataract (nuclear density); However, energy expenditure is not the only determinant of the severity of corneal edema; Especially in the study group where patients with mild edema were more likely than those with eventually severe edema to develop. They needed more ultrasound energy (in the two subgroups of mild and severe edema in the diabetic group, the CDE was 23.3 versus 12.34, respectively). This observation may be explained by the hypothesis that the most important factor is the anterior condition of endothelial cells, some of which enable them to tolerate elevated CDE levels [14].

Another factor to consider is the time it takes to restore corneal transparency after surgery. In the control group, 64 patients had severe corneal edema on the first day after surgery, and only 15 of them showed persistent severe edema after a temporary visit (3-7 days after surgery). On the other hand, in the study group, 38% of patients had severe edema and this number decreased to 19% after the second visit. This finding confirms the same results obtained from previous studies on the slower recovery of corneal endothelial cells in diabetic patients [14].

This study has certain limitations. First, we did not determine the number of endothelial cells in each eye. However, special attention should be paid to patients who have similar demographic characteristics (equal age) but without significant corneal pathology; As a result, we hypothesized that endothelial cell stocks were the same among participants.in Table 1. Another limitation is that corneal edema was not diagnosed in a modern regional hospital in Greece due to a lack of resources (human and financial) [14], But through examination with a slit lamp according to a standard protocol that ensures a satisfactory assessment of corneal edema; was identified [14].

Given that many patients had limited access to the hospital (they had to drive 2-3 hours to reach the hospital); the present study was initially designed as a clinically sensitive project to determine the optimal plan for postoperative follow-up. According to the results of this study, only 15 patients (out of 242 patients) needed a follow-up period two weeks after surgery. Our findings helped our ward minimize the number of appointments for patients without clinical complications and diabetes; while the condition of most diabetic patients was assessed on the first day and 2 weeks after surgery; because after this time we can better assess the ability of the diabetic endothelium to restore corneal transparency [14].

In conclusion, the results of our study showed that the behavior of corneal endothelium after cataract surgery is different in patients with diabetes mellitus. Therefore, follow-up of diabetic patients should be considered and special care should be taken during surgery to minimize damage to endothelial cells due to ultrasound load or mechanical manipulation. The cataract service center must change the patterns before and after surgery to suit specific needs. In any case, diabetic patients in the population are at increased risk of complications during or after surgery, and therefore special attention should be paid to them [14].

Results

The mean differences in the biomechanical parameters test showed that A1T, A1L, and HCR were significantly lower and A1V, A2T, A2V, HCDA, and HCPD were significantly higher in the keratoconus group [3].

The mean HCPD in stage 1 was significantly different from stage 2 and the normal group, but this does not mean a significant difference between stage 2 and normal individuals. An explanation for this illogical result could be that the instrument is not reliable in measuring HCPD [3].

Among the biomechanical parameters, A1T and HCR showed a good ability to detect keratoconus [3].

Table 1- Parameters provided by CST

Parameters	Abbreviation	Explanation

IOP(mmHg) Pachy(μ m)	IOP CCT	Intraocular pressure based on A1 CCT by optical pachymetry
The first applanation (A1) A1 time (ms) A1 length (mm) A1 velocity (m/s) A1 DA (mm)	 A1t A1L A1V A1DA	 Time from start to A1 Length at A1 Velocity of the corneal apex at A1 Sagittal deformation amplitude of apex at A1
The highest concavity (HC) HC time (ms) HC DA (mm) HC radius (mm) Peak distance	 HCT HCDA HCR PD	 Time to reach the maximum deformation Sagittal deformation amplitude of apex at HC Central radius of curvature at HC Distance between both non-deformed peaks
The second applanation (A2) A2 time (ms) A2 length (mm) A2 velocity (m/s) A2 DA (mm)	 A2T A2LL A2V A2DA	 Time from start to A2 Length at A2 Velocity of the corneal apex at A2 Deformation amplitude at A2

Table 2 - Mean values of biomechanical parameters provided by CST

Parameter	Total	Male	Female	P-value
A1T, ms	7.26±0.26	7.26±0.28	7.25±0.24	0.782
A1L, mm	1.72±0.05	1.72±0.05	1.71±0.05	0.173
A1V, m/s	0.14±0.01	0.14±0.01	0.14±0.01	0.448
A1DA, mm	0.12±0.01	0.12±0.01	0.12±0.01	0.957
A2T, ms	21.97±0.48	21.94±0.48	22.00±0.47	0.370
A2L, mm	1.65±0.28	1.68±0.27	1.62±0.30	0.235
A2V, m/s	-0.34±0.07	-0.34±0.07	-0.34±0.08	0.672
A2DA, mm	0.39±0.09	0.39±0.09	0.40±0.09	0.318
HCT, ms	16.81±0.48	16.82±0.47	16.80±0.50	0.863
PD, mm	2.72±0.98	2.80±1.05	2.64±0.89	0.304
HCR, mm	6.67±0.97	6.60±1.13	6.76±0.71	0.295
HCDA, mm	1.06±0.10	1.05±0.10	1.07±0.10	0.249

Table 2 shows the mean values of corneal biomechanical parameters of the whole sample in both sexes. No significant differences were observed between men and women in biomechanical parameters.

Table 3- Corneal biomechanical parameters divided by age group

parameters	$18-29\ years$		$30-49\ years$		$50-69\ years$		$\geq 70\ years$		P- value
	$Mean$	SD	$Mean$	SD	$Mean$	SD	$Mean$	SD	
A1T, ms	7.33	0.27	7.33	0.24	7.15	0.21	7.14	0.27	<0.001

A1L, mm	1.72	0.04	1.71	0.07	1.71	0.05	1.72	0.05	0.348
A1V, m/s	0.14	0.01	0.15	0.01	0.15	0.01	0.14	0.01	0.007
A1DA, mm	0.11	0.01	0.12	0.01	0.12	0.01	0.13	0.01	<0.001
A2T, ms	21.83	0.54	21.99	0.38	22.13	0.36	22.02	0.53	0.027
A2L, mm	1.63	0.32	1.61	0.27	1.72	0.27	1.67	0.25	0.427
A2V, m/s	-0.35	0.08	-0.33	0.07	-0.34	0.06	-0.33	0.09	0.437
A2DA, mm	0.34	0.1	0.39	0.07	0.42	0.06	0.47	0.07	<0.001
HCT, ms	16.78	0.46	16.81	0.46	16.78	0.54	16.91	0.51	0.654
PD, mm	2.62	0.85	2.76	1.01	2.65	0.93	2.97	1.23	0.453
HCR, mm	6.46	1.1	6.88	1.02	6.8	0.64	6.64	0.86	0.157
HCDA, mm	1.02	0.09	1.04	0.09	1.1	0.08	1.15	0.11	<0.001

Table 3 presents the mean values of each biomechanical parameter for all subgroups by age. With age, a significant increase was observed in A1V, A1DA, A2T, A2DA, and HCDA. A1T decreased significantly with age. There were no significant differences between age subgroups in A1L, A2L, A2V, HCT, PD, or HCR.

Figure 2 shows the result of cluster analysis with the Pearson coefficient. CST parameters were divided into 5 sub-clusters in which IOP, A1T, and A2V were in one sub-cluster. A1T was the shortest distance from the IOP class, followed by A2V. The shortest distance from the CCT category was observed for HCR, A1DA, A1L, and A2L. The farthest parameters from IOP or CCT were HCT, A2DA, and PD parameters, which show that these parameters were less affected by IOP and CCT.

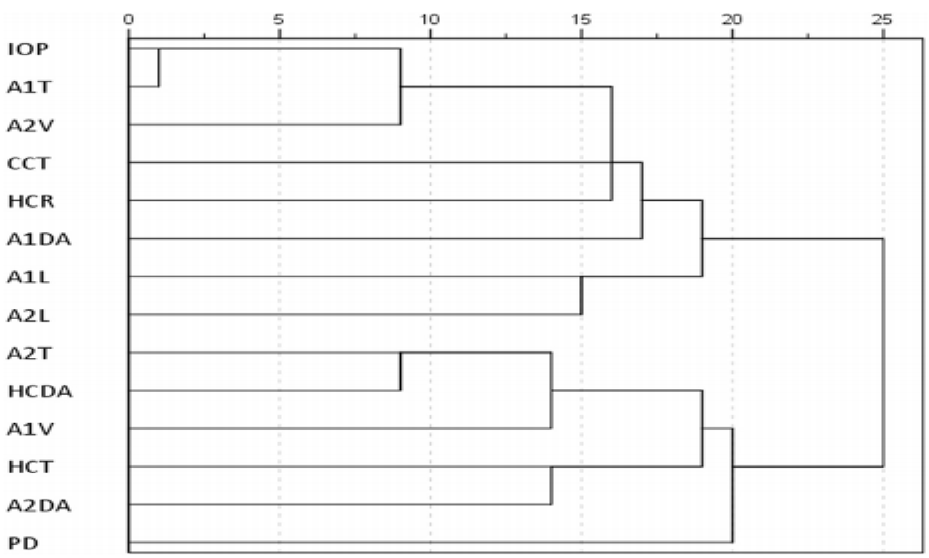

Figure 2. Batch analysis for parameters measured by CST based on Pearson correlation coefficient

Relationships between individual factors and corneal biomechanics

In univariate linear analysis, 10 of the 12 parameters were correlated with IOP, 8 of the 12 parameters were associated with CCT, 5 of the 12 parameters were significantly correlated with age, and 3 of the 12 parameters were significantly associated with SE. None of the CST parameters were sex-related. After adjusting for other factors, multivariate regression analyzes showed that age had a positive relationship with A1DA, A2DA, and HCDA. IOP had a positive relationship with A1T, A2V, and HCDA and a negative relationship with A1V, A2T, HCT, PD, and HCDA. CCT was negatively correlated with A1L, A1DA, A2L, A2V, or HCR. After IOP control, age, bias, and CCT, SE had no relationship with biomechanical parameters [2].

No correlations were identified for bIOP errors with IOPt in percentage (p = 0.756) or values (p = 0.617). In addition, CVS-IOP error increased significantly with higher CCT as opposed to bIOP error which was smaller and correlated with CCT [6].

Increasing knowledge of corneal biomechanical standards is important for several reasons: 1- To achieve accurate measurement and correction of IOP, especially in people with corneal diseases and refractive surgery, 2- To gain a better understanding of the pathogenicity of corneal destructive diseases like keratoconus, 3- To screen people suspected of having keratoconus before refractive surgery [1, 19].

Early detection of keratoconus is critical for refractive surgery programs, but the defining characteristics of its primary and marginal forms remain a clinical challenge. Corneal biomechanical changes have been suggested as a factor in the formation of keratoconus and may be detectable before clinical signs and keratoconus[3] tomography appears [3]. The ability to measure the biomechanical properties of the cornea can improve our understanding of corneal biomechanics under normal and pathological conditions [3].

Currently, two of the available clinical equipment that makes it possible to measure the biomechanical properties of the cornea are ORA and CST. Several studies have evaluated the biomechanical properties of the cornea by the ORA, but no high-sensitivity, high-specificity points have been identified for its parameters to distinguish between keratoconus and a healthy cornea. Evaluating other corneal biomechanical parameters to find more distinct power than ORA parameters for overt keratoconus can be another step in tracing primary or peripheral cases [3].

CST, a newly introduced tool, is not widely used in clinics. A limited number of studies have tested the ability of its measured parameters to distinguish between normal and keratoconus eyes [3].

Previous studies have shown similar results for HCT between the two groups. They also showed that HCPD and A1L were significantly different between the two groups. This part of their study was consistent with our results. But in other parts of the present study, when we performed ROC curve analyses to evaluate the distinguishing power of the parameters, or when we evaluated the differences in the parameters between the keratoconus and normal subgroups, we were able to distinguish less between the two parameters. We observed. Significant differences between the two study groups in most CST parameters could be an indicator of biomechanical defects and decreased ability in ocular keratoconus [3].

In a previous study, researchers reported a good AUC for HCDA, which was close to the result we obtained for this parameter. But the sensitivity they reported for this parameter was higher than the present study [3]

Table 4- Values of Scheimpflug corneal visualization technology (Corvis ST) technology for 70% and higher specificity for separating normal and keratoconus corneas in two centrally controlled corneal thickness subtypes

Variable	Cut-off point	Sensitivity	specificity
A1T (ms)	≤7	90	90
A2T (ms)	>21.23	80	70
A2V (m/s)	≤-0.37	75	75
HCDA (mm)	>0.96	70	70
HCR (mm)	≤6.8	75	70

Although the AUC of all 5 parameters decreased compared to the previous results, they were still above 0.7

Although the thinner cornea was an influential factor in the results obtained in keratoconus, the viscoelastic properties of the cornea are a more decisive factor in the biomechanical response we obtain. This result is confirmed by previous studies that reported significant differences in the biomechanical properties of normal and keratoconus eyes after compensating for the difference between CCT or selecting keratoconus eyes with normal CCT as experimental [20, 21]. Our study showed that A1T with AUC ROC higher than 0.9 and sensitivity and specificity of about 90% in both tests (with random groups and CCT matching subgroups) has the best differentiating value among CST parameters and Reducing it can be a good indicator of keratoconus [3].

In addition to CCT, IOP is mentioned as a confusing factor in corneal biomechanical response and should be considered as a parameter in interpreting corneal deformation patterns measured in the body [22, 23].in Table 4.

Its reliability must be evaluated before it can be widely accepted and used in clinical applications. This study revealed that IOP, CCT, HCDA, and A1V were the most repeatable parameters while A1L, A2L, and PD had poor reliability. These findings were consistent with previous CST studies [23, 24].

Evidence has shown that corneal biomechanics was associated with IOP and CCT. This study showed that IOP and CCT had an independent effect on most CST parameters. The IOP was reported to be the strongest predictor of HCDA [2].

This study developed a previous study and found that IOP was positively correlated with A1T and A2V and negatively correlated with A2T, A1V, and DA, indicating that higher IOP required a higher threshold of air pressure to move the cornea and therefore Longer time and lower initial speed were required [2].

Age-related changes in corneal structure have been confirmed in many studies. The cornea has been reported to be more closely related to collagen fibers and to become harder with age. Interestingly, this causes a positive correlation between age and HCDA, not the expected negative correlation. But these findings were consistent with previous CST studies that showed higher HCDA in the elderly than in the young [2].

Relationships between corneal biomechanics and sex, SE, and AL were discussed in previous studies. Lim et al reported that both CH and CRF were not correlated with SE or AL in Singaporean children [25]. Sang et al. Revealed that CH had a significant relationship with SE in Chinese children [2]. But Chang et al. showed that CH had a significant relationship with SE but not CRF. The results of the effect of gender on corneal biomechanics were not consistent [26].

Strobe et al. Reported significant gender differences in CH and CRF. Men showed higher values [2]. Conversely, Elam et al. Showed higher CH and CRF in women than men [27]. Using CST, Walban et al. Found no gender differences between 11 biomechanical parameters in Brazilian patients. This study found no correlation between corneal biomechanics and SE or sex after adjustment for other factors [2].

The strength of this study is the relatively large sample size, homogeneous Chinese origin, and the use of the latest CST software with additional parameters. But this study has its limitations. First, daily corneal biomechanical changes were not considered[28]. But previous studies reported that CH and CRF were constant and did not change significantly between day and night. Second, many potentially unrelated factors were not identified, such as post-corneal keratometry and corneal curvature.

But CCT has a stronger relationship with corneal biomechanics than corneal curvature. Therefore, these factors may have some effect on the results. Third, linear regression relationships were performed between the parameters generated by the tool. it is imperative to check regression against independent parameters, but the IOP determined by the applanation method was not obtained due to social factors in China. Finally, ORA parameters were not obtained simultaneously, although direct comparisons between the two tools were impossible due to the completely different algorithms used. Further future studies on ORA and CST are needed in different populations [2].

It has long been known that the stiffness of the cornea, which is affected by the thickness of the tissue and the biomechanics of the material, also affects the resistance to deformation under the applied force and therefore can cause changes in the measurement of IOP. The difficulty of separating the effects of IOP and tissue biomechanics on IOP measurement has been the subject of numerous research studies and has so far been entirely possible [6].

The Corvis ST aims to address this challenge with a relatively new non-contact tonometer. This method obtains cross-sectional profiles of the posterior and anterior surfaces recorded during the application of external dynamic air pressure. This information, together with thickness measurements in the central corneal region, was used in early studies to distinguish between the effects of IOP and corneal biomechanics on corneal deformation, thus providing IOP estimates for less dependence on biomechanical parameters including CCT and Age is designed [6].

The lack of comparison of Biop with GAT, DCT, and IOP can be considered a limitation of the present study [6]. Another limitation of this study is the difficulty in obtaining human donor eyes with a wider age range, which makes it possible to consider the effects of age and consequently tissue stiffness on both modified and unmodified IOP estimates [6].

In addition, although specimens were tested shortly after death and kept hydrated during transport, preparation, and testing, they may experience changes in the mechanical properties of their living state, which in turn can particularly Affect unmodified CVS-IOP measurements. This was particularly evident in the S4 model, where the growth of more than 60 microns in the CCT in the final stage of the test was probably due to inflation. Another limitation was the lack of access to donated keratoconus eyes, which means that the effect of geometry and biomechanical abnormalities were not studied [6].

The femtosecond laser does not reduce the patient's vision. We only have bad burns due to laser scattering, but its focus has increased compared to older methods such as traditional surgeries.

After phacoemulsification, patients with diabetes were 3.5 times more likely to develop severe corneal edema than non-diabetics. In the control group, 64 patients had severe corneal edema on the first day after surgery [6].

Acknowledgments
None.
Conflict of interest
None.

Financial Support
None.

Ethics Statement
All Permissions to conducting this research has been approved.

References

1. Piñero, D.P. and N. Alcón, *In vivo characterization of corneal biomechanics.* Journal of Cataract & Refractive Surgery, 2014. **40**(6): p. 870-887.
2. Wang, W., et al., *Corneal biomechanical metrics of healthy Chinese adults using Corvis ST.* Contact Lens and Anterior Eye, 2017. **40**(2): p. 97-103.
3. Elham, R., et al., *Keratoconus diagnosis using Corvis ST measured biomechanical parameters.* Journal of current ophthalmology, 2017. **29**(3): p. 175-181.
4. Shah, S., et al., *Assessment of the Biomechanical Properties of the Cornea with the Ocular Response Analyzer in Normal and Keratoconic Eyes.* Investigative Ophthalmology & Visual Science, 2007. **48**(7): p. 3026-3031.
5. Luce, D.A., *Determining in vivo biomechanical properties of the cornea with an ocular response analyzer.* Journal of Cataract & Refractive Surgery, 2005. **31**(1): p. 156-162.
6. Eliasy, A., et al., *Ex-vivo experimental validation of biomechanically-corrected intraocular pressure measurements on human eyes using the Corvis ST.* Exp Eye Res, 2018. **175**: p. 98-102.
7. Rabinowitz, Y.S., *Keratoconus.* Survey of Ophthalmology, 1998. **42**(4): p. 297-319.
8. Kránitz, K., et al., *Femtosecond laser capsulotomy and manual continuous curvilinear capsulorhexis parameters and their effects on intraocular lens centration.* J Refract Surg, 2011. **27**(8): p. 558-63.
9. Garcia, G.A., et al., *Corneal etching in femtosecond laser-assisted cataract surgery.* Canadian Journal of Ophthalmology, 2017. **52**(1): p. e15-e18.
10. Bali, S.J., et al., *Early experience with the femtosecond laser for cataract surgery.* Ophthalmology, 2012. **119**(5): p. 891-9.
11. Abell, R.G., et al., *Femtosecond laser-assisted cataract surgery versus standard phacoemulsification cataract surgery: outcomes and safety in more than 4000 cases at a single center.* J Cataract Refract Surg, 2015. **41**(1): p. 47-52.
12. Abell, R.G., et al., *Anterior capsulotomy integrity after femtosecond laser-assisted cataract surgery.* Ophthalmology, 2014. **121**(1): p. 17-24.
13. Palanker, D.V., et al., *Femtosecond laser-assisted cataract surgery with integrated optical coherence tomography.* Sci Transl Med, 2010. **2**(58): p. 58ra85.
14. Tsaousis, K.T., et al., *Corneal edema after phacoemulsification in the early postoperative period: A qualitative comparative case-control study between diabetics and non-diabetics.* Ann Med Surg (Lond), 2016. **5**: p. 67-71.
15. Hillenaar, T., H. van Cleynenbreugel, and L. Remeijer, *How Normal Is the Transparent Cornea? Effects of Aging on Corneal Morphology.* Ophthalmology, 2012. **119**(2): p. 241-248.
16. Richter, G.M., et al., *Risk Factors for Cortical, Nuclear, Posterior Subcapsular, and Mixed Lens Opacities: The Los Angeles Latino Eye Study.* Ophthalmology, 2012. **119**(3): p. 547-554.
17. De Clerck, E.E.B., et al., *New ophthalmologic imaging techniques for detection and monitoring of neurodegenerative changes in diabetes: a systematic review.* The Lancet Diabetes & Endocrinology, 2015. **3**(8): p. 653-663.
18. Waring, G.O., et al., *The Corneal Endothelium: Normal and Pathologic Structure and Function.* Ophthalmology, 1982. **89**(6): p. 531-590.
19. Roberts, C.J., *Concepts, and misconceptions in corneal biomechanics.* Journal of Cataract & Refractive Surgery, 2014. **40**(6): p. 862-869.
20. Fontes, B.M., et al., *Ocular Response Analyzer Measurements in Keratoconus with Normal Central Corneal Thickness Compared with Matched Normal Control Eyes.* Journal of Refractive Surgery, 2011. **27**(3): p. 209-215.
21. Schweitzer, C., et al., *Screening of Forme Fruste Keratoconus with the Ocular Response Analyzer.* Investigative Ophthalmology & Visual Science, 2010. **51**(5): p. 2403-2410.
22. Kling, S. and S. Marcos, *Contributing Factors to Corneal Deformation in Air Puff Measurements.* Investigative Ophthalmology & Visual Science, 2013. **54**(7): p. 5078-5085.
23. Huseynova, T., et al., *Corneal Biomechanics as a Function of Intraocular Pressure and Pachymetry by Dynamic Infrared Signal and Scheimpflug Imaging Analysis in Normal Eyes.* American Journal of Ophthalmology, 2014. **157**(4): p. 885-893.
24. Lanza, M., et al., *Evaluation of corneal deformation analyzed with a Scheimpflug based device.* Contact Lens and Anterior Eye, 2015. **38**(2): p. 89-93.
25. Lim, L., et al., *Cornea Biomechanical Characteristics and Their Correlates with Refractive Error in Singaporean Children.* Investigative Ophthalmology & Visual Science, 2008. **49**(9): p. 3852-3857.
26. Chang, P.-Y., S.-W. Chang, and J.-Y. Wang, *Assessment of corneal biomechanical properties and intraocular pressure with the Ocular Response Analyzer in childhood myopia.* British Journal of Ophthalmology, 2010. **94**(7): p. 877-881.
27. Allam, R.S.H.M. and N.M.M.M. Khalil, *Evaluation of Sex Differences in Corneal Hysteresis.* European Journal of Ophthalmology, 2015. **25**(5): p. 391-395.
28. Laiquzzaman, M., et al., *Diurnal variation of ocular hysteresis in normal subjects: relevance in a clinical context.* Clinical & Experimental Ophthalmology, 2006. **34**(2): p. 114-118.