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Variations of Corneal Hysteresis in Myopic Patients with Normal Pentacam Findings

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ABSTRACT

Background: hysteresis refers to the energy lost during the stress/strain cycle which is the result of viscous damping in the corneal tissue, is an indicator of corneal biomechanical properties. Refractive surgery currently uses corneal thickness as a basic qualification and planning parameter. However, corneal hysteresis may be more useful as a qualification factor for LASIK, a significant decrease in the IOP and biomechanical properties is found in eyes following LASIK surgery

Objective: this study aimed to reveal the variations of corneal hysteresis in patients with normal pentacam findings and to see if a correlation exists between corneal hysteresis, corneal resistance factor, mean keratometric reading, central corneal thickness and anterior chamber depth during the pre-operative assessment of myopic patients going for LASIK.

Patients and methods: in this study we did an analysis of corneal hysteresis in a group of myopic patients with normal pentacam findings undergoing evaluation for refractive surgery. In our study we included 50 eyes of 26 patients aged between 18 and 44.**Results:** this study included a mean keratometric reading of 44.108 D± 1.3243D, the mean central corneal thickness was 522.1um±38.416um, the mean anterior chamber depth was 3.2098mm±0.249mm the mean corneal hysteresis was 9.582 mmHg±1.4702 and the mean corneal resistance factor was 9.64 mmHg ±1.9838.**Conclusion:** our data suggested that patients should get their corneal hysteresis tested as a part of their routine investigation portfolio before undergoing refractive surgery as it may play a role in determining patients that are at higher risk of developing ectasia after surgery.

Keywords: corneal hysteresis, myopic patients , normal pentacam .

INTRODUCTION

Hysteresis refers to the energy lost during the stress/strain cycle. Viscous materials flow when an external shear stress is applied, but, unlike materials with elastic properties, they do not regain their original shape when the stress is removed. Collagen is viscoelastic and therefore exhibits hysteresis [1].Corneal Hysteresis (CH), which is the result of viscous damping in the corneal tissue, is an indicator of corneal biomechanical properties .The Ocular Response Analyzer (ORA; Reichert Inc., Depew, NY) is a novel instrument for measuring the adjusted intraocular pressure (IOP) of the eye. It is also one of the instruments capable of measuring the biomechanical properties of the cornea [2].

Corneal biomechanical properties influence intraocular pressure measurement, undergo alterations in corneal pathology and following corneal refractive surgery [2].

The pentacam is a rotating Scheimpflug imaging technology used to measure the anterior and posterior corneal surfaces, as well as other anterior segment structures [3].

The human cornea can be described by having 2 principal properties **[4]:**

1- A static resistance component (characterized by the corneal resistance factor), for which deformation is proportional to applied force.

2- A dynamic resistance component (characterized by corneal hysteresis), for which the relationship between deformation and applied force depends on time. In short, the tissue response in the presence of a force depends not only on the force magnitude but also on the velocity of the force application.

Factors affecting corneal biomechanics [4]

These can be classified into extra-corneal and intra-corneal factors.

Extra-corneal factors:

1. The atmospheric pressure which exerts a force on the external surface of the cornea.
2. Pressure exerted by the eyelids
3. Pressure exerted by the extra-ocular muscles (indirectly through their sclera insertions).
4. The IOP which exerts a force on the internal surface of the cornea.

Intra-corneal factors:

These are inherent factors to the own corneal structure, which has the elasticity, plasticity, deformability and viscosity necessary to support the pressures exerted by the extra-corneal factors.

These included:

1. Corneal thickness.
2. Collagen fibres.

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The ORA consists of: an infrared light emitter, a light intensity detector, a solenoid-driven air pump (one way valve) and a pressure transducer inside the plenum chamber (Air at positive pressure). When the measurement begins, the infrared light shines on the cornea and the intensity of the reflected light is monitored by the detector.

After a proper alignment with the apex of the cornea, the air pump delivers a collimated stream of air and the cornea begins to flatten. A central corneal flattening of approximately 3.0 mm in diameter is required to be achieved. Specifically, the intensity of the reflected light is maximal when this flattening state is reached during the increase and the decrease of the air pressure and therefore the pressure values associated to them can be easily recorded [(5)].

The two applanation changes take place within approximately 20 milliseconds, which is a time short enough to ensure that neither ocular pulse nor eye position changes during the measurement process. It should be considered that the maximum air pressure applied with this instrument is not constant and is dependent on P1, a value determined by both the true IOP and the structural resistance of each individual eye [(5)].Two independent pressure values were derived from the inward and outward applanation events, P1 and P2, and then provides:

1- The mean of the two measured pressures (P1 and P2) to give an IOP measurement correlated to IOP measured with GAT (IOPG).

2- The difference between the two pressures (P1 and P2) to give a measurement of CH, It is a numerical value denoting viscoelastic corneal tissue response to a dynamic deformation. A greater difference generates a higher CH, suggestive of a stiffer cornea. CH is influenced by the rate of force application and is likely linked to the stromal collagen nature and state of hydration.

3- IOPcc (Corneal-Compensated Intraocular Pressure): An intraocular pressure measurement that is less affected by corneal properties.

4- CRF (Corneal Resistance Factor): an indicator of the overall "resistance" of the cornea. CRF is derived from the formula P1 – kP2, where k is a constant, derived from the relationship between changes in P1 and P2, with change in IOP. CRF is more heavily weighted by corneal elasticity (static resistance).

5- The ORA also has a built in 20 MHz ultrasound pachymeter that measures CCT - Central corneal thickness [(5)].

In the normal healthy eye, the corneal hysteresis ranges between 9.3 ± 1.4 and 11.4 ± 1.5 mmHg and CRF between 9.2 ± 1.4 and 11.9 ± 1.5 mmHg.Therefore, there was a significant variability in CH and CRF among normal healthy individuals that can be influenced by the variability of IOP in the same population. In spite of this variability, CH and CRF have been suggested to be potentially useful for discriminating healthy eyes from those suffering a pathological condition, such as corneal ectasia or glaucoma. Some authors have reported significantly lower CH values in different types of glaucomatous eyes than in healthy eyes [(5)].This biomechanical alteration is especially useful for the early diagnosis of normal tension glaucoma and also for glaucoma risk assessment in combination with central corneal thickness [(6)].

Regarding corneal ectasia, several studies have demonstrated that CH and CRF are significantly reduced in keratoconic eyes compared with normal eyes [(7)].Refractive surgery currently uses corneal thickness as a basic qualification and planning parameter. However, corneal hysteresis may be more useful as a qualification factor for LASIK and related corneal refractive surgery procedures because different subjects with the same corneal thickness may display significantly different corneal mechanical properties [(2)]. A significant decrease in the IOP and biomechanical properties is found in eyes following LASIK surgery. In the study by Ortiz and associates, corneal hysteresis and corneal resistance factor decreased significantly, one month post LASIK.

The pentacam is a device manufactured by Oculus that obtains images of the anterior segment by a rotating Scheimpflug camera measurement. The camera is a digital CCD camera with synchronous pixel sampling [(3)].The light source consists of UV-free blue light emitting diode (LEDs) with a wavelength of 475 nm The system integrates two cameras One is located in the center for the purposes of detection of the size and orientation of the pupil and to control fixation, the second is mounted on rotating wheel to capture images from the anterior segment. It's a complete picture from anterior surface of the cornea to the posterior surface of the lens [(3)].This rotating process supplies pictures in three dimensions and also allows the center of the cornea to be measured precisely. The slit images are photographed on an angle form 0 to 180 degrees to avoid shadows from nose. Every picture is a complete image through the cornea at a specific angle, combination of such slit images creates a real 360 degrees image of the anterior segment [(3)].The software utilizes a ray tracing algorithm to construct and calculate the anterior segment. It acquires a total of 50 images in approximately two seconds extracting 2,760 true elevation points from these images which in turn generates 138.000 true elevation points for both the corneal front and back surfaces, from limbus to limbus.including the center of the cornea, a major advantage over keratometers and Placido-based corneal topographers [3].

The measurement process lasts less than two seconds and minute eye movements are captured and corrected simultaneou1y [3]. Scheimpflug photography provides images of the anterior eye segment with minimal distorsion. However.the distortion of the camera optics and of the cornea and lens itself distort the image. Therefore biometrical measurements in the anterior eye segment such as corneal curvature, changes of lens curvature during accommodation, depth of the anterior chamber and anterior chamber angle always have to be corrected by specific algorithms [3].

PATIENTS AND METHODS

In this study we did an analysis of corneal hysteresis in a group of myopic patients with normal pentacam findings underwent evaluation for refractive surgery. In our study we included 50 eyes of 26 patients aged between 18 and 44.

❖ **Inclusion criteria:**

1) Patients aged 18:45 years of age.
2) Myopic patients from (-2.00 D) to (-10.00 D) refraction.
3) Patients seeking LASIK.
4) Patients with normal pentacam findings

❖ **Exclusion criteria:**

1) Patients not fulfilling the inclusion criteria above.
2) Hyperopic patients.
3) High astigmatic patients
4) Patients giving history of any previous ocular surgery or trauma.
5) Patients giving history of any previous corneal diseases.
6) patients with high intra-ocular pressure IOP.

❖ **Patient evaluation**

All patients were submitted to:

- **Complete ophthalmic examination in the form of:**

1. Auto-refraction assessment.
2. Anterior segment examination by slit lamp examination.
3. Fundus examination using +20 D lens (funduscopy) and +90 D lens (bimicroscopy) after pupillary dilatation with tropicamide 1% eye drops.

- **All subjects were investigated as follows:**

*Corneal topography.
*ORA for assessment of corneal hysteresis.

- **Evaluation of topography:**

An anterior segment tomography was performed to all subjects included by an Oculus Pentacam (OCULUS Optikgeräte GmbH, Germany) . The following parameters were provided:

➢ Corneal tomography
➢ Keratometric readings
➢ Central corneal thickness
➢ Anterior chamber depth
➢ Keratoconus indices.

- **Evaluation of corneal hysteresis:**

All patients were scanned for corneal hysteresis and corneal resistance factor using a Reichert **Ocular Response Analyzer® G3.**

❖ ***Statistical analysis***

Data were coded and entered using the statistical package SPSS version 24. Data was summarized using mean, standard deviation, median, minimum and maximum for quantitative variables and frequencies (number of cases) and relative frequencies (percentages) for categorical variables. Correlations between quantitative variables were done using Pearson correlation coefficient. P-values less than 0.05 were considered as statistically significant [9].

The study was approved by the Ethics Board of Al-Azhar University.

RESULTS

The patient's ages ranged from 18 to 44 years old with a mean value of 27.923 ± 7.3426 years old. This study included 8 male patients (30.7%) and 18 female patients (69.3%). The study included eyes with refractive power showing mean sphere power of -4.93D ± 2.3984D and mean cylinder power of -1.13D ± 0.5327D **(Table 1)**

Table 1: showing refractive power of patients

	Minimum	Maximum	Mean	Std. Deviation
Refraction (Sphere)	-2.00	-9.75	-4.93	2.398469
Refraction (Cylinder)	0	-1.75	-1.13	0.532706

This study included a mean keratometric reading of 44.108 D± 1.3243D, the mean central corneal thickness was 522.1um±38.416um, the mean anterior chamber depth was 3.2098mm±0.249mm the mean corneal hysteresis was 9.582 mmHg±1.4702 and the mean corneal resistance factor was 9.64 mmHg ±1.9838 **(Table 2).**

Table 2: showing Km, CCT, CH, CRF of patients

	Minimum	Maximum	Mean	Std. Deviation
Km	41.1	46.9	44.108	1.3243
CCT	455	602	522.1	38.416
ACD	2.62	3.78	3.2098	0.249
CH	7.2	12.7	9.582	1.4702
CRF	5.4	14	9.64	1.9838

There was a significant positive correlation between corneal hysteresis and central corneal thickness where p-value was <0.05

There was a significant positive correlation between corneal resistance factor and central corneal thickness where p-value was <0.05

There was a significant negative correlation between corneal hysteresis and anterior chamber depth where p-value was <0.05

There was a significant negative correlation between corneal resistance factor and anterior chamber depth where p-value was <0.05

There was no significant correlation between corneal hysteresis and mean keratometric reading where p-value was >0.05

There was no significant correlation between corneal resistance factor and mean keratometric reading where p-value was >0.05.

DISCUSSION

Our study showed that the standard screening criteria, based on corneal topography and CCT had important limitations regarding sensitivity and specificity and that new technologies such as corneal hysteresis and waveform analysis are needed and have already shown the potential for improving the sensitivity and specificity for detecting ectasia risk especially the new set of 36 new waveform-derived parameters. These parameters are basically related to specific waveform characteristics, such as the width, peak, area, height of the peaks (signal during applanation moments) and general morphology of the waveforms. Our results agreed with a study done by **Ambrosio *et al*** [(10)] they studied the evaluation of corneal shape and biomechanics before LASIK.

Our results also agreed with a study done by **Zhang *et al*** [(11)] who studied the relationship between corneal biomechanics and corneal shape in normal myopic eyes; their study included 480 normal myopic eyes (240 healthy volunteers), with ages ranged from 18 to 44 years (mean, std 23.84 ± 5.08 years) and mean spherical equivalent (MSE) ranged from -14.00 to -1.13 D (mean, std –5.68 ± 2.17 D). Corneal hysteresis (CH) and corneal resistance factor (CRF) were measured using the Ocular Response Analyser (ORA; Reichert Ophthalmic Instruments, Depew, New York, USA) in both eyes. Pentacam (Oculus GmbH, Wetzlar, Germany, and software version 1.17r27) were used to obtain corneal central elevation and corneal asphericity (Q value within 6 mm diameters) of both anterior and posterior surfaces, corneal central thickness (CCT), corneal volume (CV).This study showed that there was a homogeneous relationship displayed between corneal biomechanical parameters (CH and CRF) and corneal morphological features.

Our results also agreed with another study done by **Refai *et al*** [(12)] for correlation between apical protrusion in the Scheimflug imaging and corneal hysteresis and corneal resistance factor by ocular response analyzer among refractive non-keratoconic Egyptian patients and they showed strong positive correlation between both corneal hysteresis and corneal resistance factor and the central corneal thickness and mean K reading being important for biomechanical corneal stability.

The findings of this study came to the same conclusion we did. We both support using both machines preoperatively to decrease the risk of post-Lasik ectasia.

CONCLUSION AND RECOMMENDATIONS

We discovered that there was a statistically significant positive relationship between corneal hysteresis and central corneal thickness.

This result suggested that patients with low central corneal thickness have to undergo corneal hysteresis analysis to select which of them are of more risk of developing post-LASIK ectasia.

We could thus recommend that patients should get their corneal hysteresis tested as a part of their routine investigation portfolio before undergoing refractive surgery as it may play a role in determining patients that were at higher risk of developing ectasia after surgery.

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